SOURCES AND SUMMARIES OF WATER-QUALITY INFORMATION FOR THE RAPID CREEK BASIN, WESTERN SOUTH DAKOTA

By J. S. Zogorski, E. M. Zogorski, and T. E. McKallip

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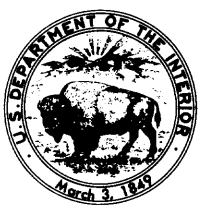

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MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

Subdistrict Chief
U.S. Geological Survey
Rm. 237, 515 9th St.
Rapid City, SD 57701

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ABSTRACT

This report provides a compilation of water-quality information for the Rapid Creek basin in western South Dakota. Two types of information are included. First, past and current water-quality monitoring data collected by the South Dakota Department of Water and Natural Resources, U.S. Forest Service, U.S. Geological Survey, and others are described. Second, a summary is included for all past water-quality reports, publications, and theses that could be located during this study. A total of 62 documents were abstracted and include journal articles, abstracts, Federal agency reports and publications, university and State agency reports, local agency reports, and graduate theses. The report should be valuable to water-resource managers, regulators, and others contemplating water-quality research, monitoring, and regulatory programs in the Rapid Creek basin.

INTRODUCTION

Maintaining and enhancing the quality of the water resources of the United States remains a national priority. Major legislation to prevent water pollution and to protect the quality of the Nation's surface and ground waters has been passed by the Congress since 1970. Such legislation includes, but is not limited to, the National Environmental Policy Act, the Clean Water Act, the Safe Drinking Water Act, the Resource Conservation and Recovery Act, the Toxics Substances Control Act, and the Comprehensive Environmental Response, Compensation and Liability Act. From these environmental acts, numerous governmental programs have been established to address both point and nonpoint sources of pollution. In general, many water experts believe the quality of the Nation's surface waters--streams, rivers, lakes, and estuaries--has improved, primarily as a result of regulatory programs initiated by State and Federal agencies to reduce pollution from municipal and industrial, point-source discharges. Today, nonpoint-source pollution is the major cause of degradation in the surface waters of the United States. This form of pollution is the causative factor of water-quality degradation in 76 percent of lakes, 65 percent of rivers and streams, and 45 percent of estuaries (U.S. Environmental Protection Agency, 1987). Future enhancement of the quality of the Nation's water resources must consider abatement of nonpoint sources of water pollution from various activities such as agriculture, construction, urbanization, silviculture, resource extraction, and land disposal of wastewater sludges and solid waste.

The U.S. Environmental Protection Agency (EPA) has taken a major step towards establishing the framework to implement the National Nonpoint Source (NPS) Program, which has the goal of reducing nonpoint-source pollution nationwide (U.S. Environmental Protection Agency, 1989). Also, the U.S. Geological Survey has begun the pilot phase of the National Water-Quality Assessment (NAWQA) Program to test and refine water-quality assessment concepts and approaches, and to evaluate the potential use of a fully

implemented program (Hirsch and others, 1988). When fully implemented, NAWQA will provide a consistent description of water quality for the Nation's waters and changes thereto, which may result due to the implementation of EPA's NPS program and other national pollution-abatement programs. Comprehensive national programs like NPS and NAWQA are essential for maintaining and improving the quality of the Nation's waters and for evaluating the effectiveness of water-pollution abatement programs.

Background

In October 1987, the South Dakota District, U.S. Geological Survey, began the Rapid Creek Water-Quality Investigation, a 4-year cooperative study with the Civil Engineering Department, South Dakota School of Mines and Technology, to enhance knowledge about the water quality of surface and ground waters in the Rapid Creek basin. The general location of the basin in western South Dakota is shown in figure 1. Surface drainage in the basin is well defined; however, the boundaries for ground-water drainage are largely unknown. For the purpose of this report, the term "Rapid Creek basin" is used to describe the drainage area outlined in figure 1, which is admittedly a simplification for the basin's ground-water boundaries.

The hydrology and quality of water in this basin is highly complex, due in part to its size, diverse land and recreational use, climate, geology, karst hydrology, and ground-water/surface-water interactions. Increased development pressures are occurring in the basin due to the renewed interest in surface mining for gold and the expansion of irrigation, housing projects, and recreational activities, especially boating, fishing, and snowmobiling. Many of these activities are occurring on or near the recharge zones of regionally important aquifers, such as the Minnelusa and Madison Formations. Concern has been expressed by local authorities and citizens that continued development within the Rapid Creek basin may significantly degrade both the quantity and quality of surface water (streams and lakes) and ground water (wells and springs). Much of this concern focuses on nonpoint-source pollution since Federal and State programs have already addressed point-source pollution.

The overall objective of the Rapid Creek Water-Quality Investigation is to provide a comprehensive understanding and documentation of the water quality, both surface and ground water, of the Rapid Creek basin. Particular emphasis will be placed on those water resources within the Rapid Creek basin that are known or suspected to have degraded water quality, due to nonpoint-source pollution. Examples include: (1) Deerfield and Pactola Reservoirs and eutrophication therein; (2) Canyon Lake and recent taste and odor concerns; (3) Rapid Creek alluvial aquifer in Rapid City and gasoline and fecal contamination thereof; (4) urban runoff in Rapid City and heavy-metal transport to Rapid Creek; (5) Minnelusa and Madison aquifers and possible contamination from onsite sewage disposal by residential communities; and (6) occurrence of radon, radium, and other natural radioactive isotopes in ground waters.

The major outcome of this investigation will be a comprehensive, basin-wide, water-quality assessment of surface and ground waters of the Rapid Creek basin. In addition, more detailed water-quality studies will be conducted at sites where known or suspected contamination is occurring due to nonpoint-source pollution.

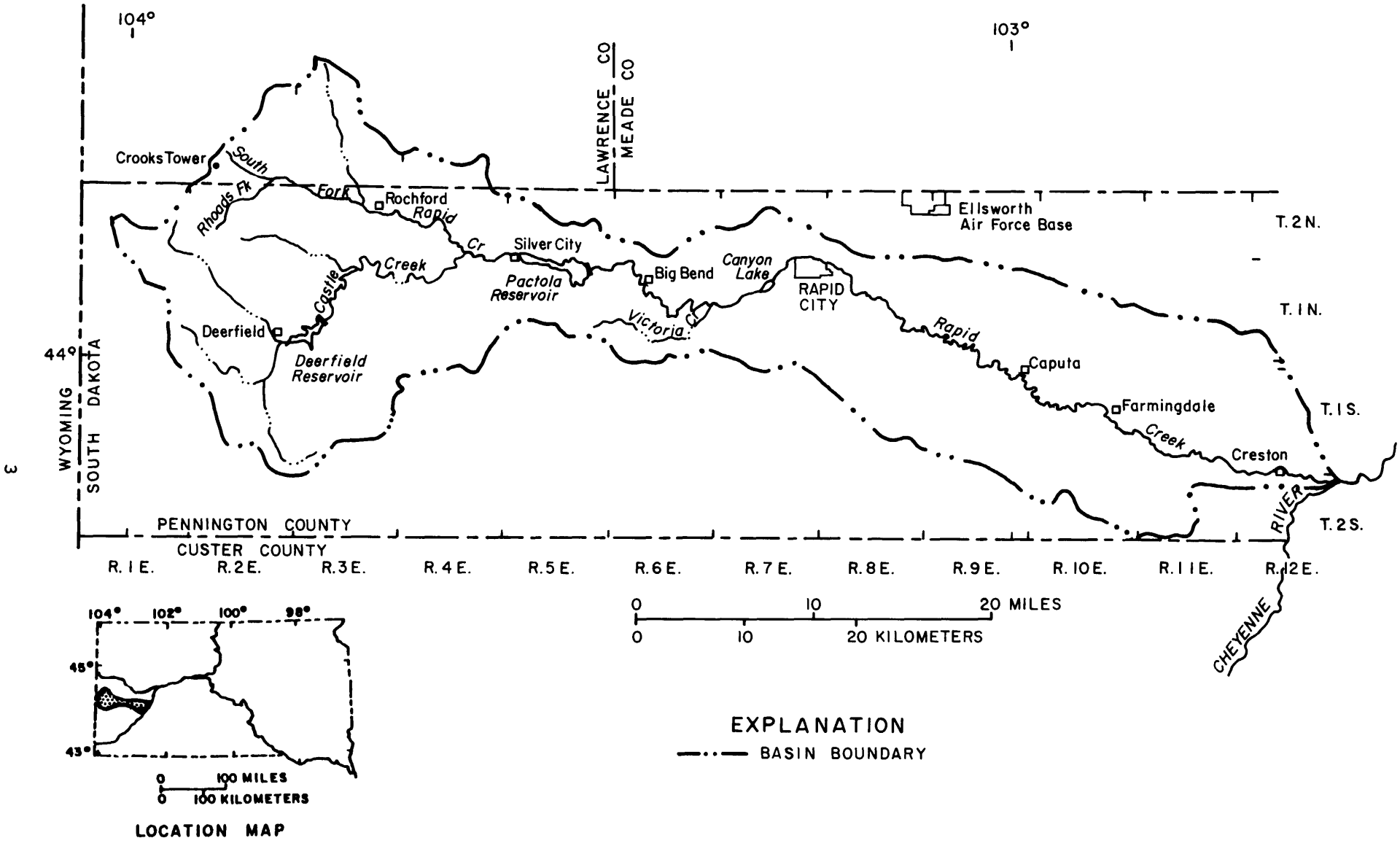

Figure 1.--Location of Rapid Creek basin in western South Dakota.

Purpose and Scope

The purpose of this report is to: (1) Describe past and current water-quality monitoring data collected in the Rapid Creek basin by local, State, and Federal agencies; and (2) summarize, via an annotated listing, past water-quality investigations and related research.

The report should be of value to water-resource managers, regulators, and others contemplating the initiation of additional water-quality monitoring or research in the Rapid Creek basin. It provides a description of the source, type, and location of past water-quality monitoring data and a brief description of water-quality studies which have been conducted and reported previously.

A second report from the Rapid Creek Water-Quality Investigation will review past water-quality data and present a general assessment of water-quality concerns in the Rapid Creek basin. A third report will quantify the magnitude of nitrogen and phosphorous loadings along the Rapid Creek main stem from Pactola Dam to Farmingdale. A fourth report will assess the transport of herbicides, indicator bacteria, and other contaminants to the Rapid Creek alluvial aquifer.

SOURCES AND DESCRIPTION OF WATER-QUALITY MONITORING DATA

A number of local, State, and Federal agencies have collected and/or continue to collect water-quality data in the Rapid Creek basin. These include: (1) The South Dakota Department of Water and Natural Resources; (2) the U.S. Forest Service; (3) the U.S. Geological Survey; (4) the Black Hills Conservancy Sub-District; (5) the South Dakota Department of Game, Fish and Parks; and (6) the City of Rapid City. A description of each agency's monitoring program with a duration of five years or more follows, whereas a brief explanation is given in the "Other" section for agencies with monitoring programs of a shorter duration or for monitoring programs of municipal drinking water and wastewater.

South Dakota Department of Water and Natural Resources

The South Dakota Department of Water and Natural Resources currently operates six water-quality sampling stations in the Rapid Creek basin. Five of these stations are located on the main stem of Rapid Creek and one is located on Castle Creek. A seventh sampling station, Rapid Creek below Pactola Dam near Silver City, was discontinued in 1975. Information about the location of each sampling station and the period during which water-quality data have been collected is listed in table 1. Water samples have been collected monthly for most but not all of the period of record. Water-quality parameters tested varied somewhat from station to station and throughout the period of record. Most water samples were analyzed for the following parameters: water temperature, conductivity, dissolved oxygen, pH, alkalinity, total dissolved solids, total suspended solids, fecal coliform bacteria, calcium, magnesium, sodium, and ammonia. Some of the stations also have information for all major cations and major anions, iron, manganese, fecal streptococcus bacteria, and various nutrient analyses for both nitrogen and phosphorus. Water-quality data collected by the Department of Water and Natural Resources are maintained in STORET, an EPA data storage and retrieval system.

Table 1.--Information on water-quality sampling stations operated by the South Dakota Department of Water and Natural Resources in the Rapid Creek basin

Station name and location	Station identification number	Latitude	Longitude	Period of record
Castle Creek near Mystic	SD-WQM-46	44°04'37"	103°38'25"	September 1970-September 1989
Rapid Creek near Rochford	SD-WQM-47	44°06'53"	103°41'38"	September 1970-September 1989
Rapid Creek below Pactola Dam, near Silver City	SD-WQM-18	44°04'36"	103°28'54"	May 1968-July 1975
Rapid Creek west Rapid City	SD-WQM-69	44°02'42"	103°19'04"	August 1975-September 1989
Rapid Creek above wastewater treament plant discharge, Rapid City	SD-WQM-110	44°01'24"	103°08'23"	November 1982-September 1989
Rapid Creek below wastewater treatment plant discharge, Rapid City	SD-WQM-92	44°01'20"	103°04'40"	May 1979-September 1989
Rapid Creek near Farmingdale	SD-WQM-19	43°56'30"	102°51'15"	June 1967-September 1989

U.S. Forest Service

The U.S. Forest Service maintains a surface-water-quality sampling program in the Black Hills. From 1968 to 1987, a total of 24 stations were located in the Rapid Creek basin upstream of Rapid City. Of these 24 sampling stations, three were located on lakes (Pactola and Deerfield Reservoirs), five were located on the Rapid Creek main stem, and sixteen sites were located on upland tributaries. The monitoring program was consolidated in 1983 to include five headwater sampling stations (460550, 460551, 460598, 460599, and 460602) located at or above Silver City (Lee Leffort and Halaine Peck, personal commun., 1989). Information on the location and period of record for the sampling stations is presented in table 2.

Grab samples were collected on a varying frequency, typically 4 to 10 samples per station per year. Most water samples are analyzed for pH, dissolved oxygen, water temperature, turbidity, conductivity, alkalinity, suspended solids, total solids, dissolved solids, ammonia, nitrite and nitrate, orthophosphate, total phosphate, dissolved chloride, fecal coliform bacteria, and fecal streptococcus bacteria. Some water samples (at a few sampling stations) also are analyzed for major cations and major anions, major metals, and heavy metals. Water-quality data collected by the U.S. Forest Service prior to 1983 are maintained in STORET. Data from 1983 to present (1989) are available only at the U.S. Forest Service office in Custer.

Table 2.--Information on water-quality sampling stations operated by the U.S. Forest Service in the Rapid Creek basin

Station name and location	Station identification number	Latitude	Longitude	Period of record
Thompson Ranch Draw	460592	44°05'16"	103°55'37"	April 1976-August 1982
Spring on Upper Castle Creek	460593	44°04'38"	103°54'31"	April 1976-August 1982
Castle Creek below Hughes Draw	460594	44°02'24"	103°51'42"	April 1976-August 1982
Silver Creek above Castle Creek	460595	44°01'50"	103°52'30"	September 1973-October 1980
South Fork Castle Creek below Heeley Creek	460596	43°59'13"	103°49'52"	May 1976-October 1981
Deerfield Reservoir at cove boat launch	460572	44°00'49"	103°48'43"	September 1969-June 1982
Castle Creek at Castle Peak Campground	460597	44°05'22"	103°43'31"	April 1976-August 1982
Castle Creek at FDR 181, at Hoodoo Campground	460598	44°03'38"	103°40'10"	June 1971-September 1989
Buskala Creek at FDR 206	460600	44°12'25"	103°48'37"	September 1974-August 1978
Tillson Creek at FDR 259, at (mouth) North Rapid Creek	460601	44°10'40"	103°45'21"	September 1975-August 1982
North (Fork) Rapid Creek (at mouth) South Rapid Creek	460602	44°07'53"	103°44'08"	April 1976-September 1989
South Fork Rapid Creek at Black Fox Campground	460550	44°08'21"	103°50'42"	October 1968-September 1989
Silver Creek above Rapid Creek	460603	44°07'24"	103°41'53"	September 1975-November 1980
Slate Creek at FDR 243 above dam	460599	44°02'02"	103°37'56"	May 1976-September 1989

Table 2.--Information on water-quality sampling stations operated by the U.S. Forest Service in the Rapid Creek basin--Continued

Station name and location	Station identification number	Latitude	Longitude	Period of record
Rapid Creek at Silver City Bridge	460551	44°05'07"	103°33'47"	October 1968-September 1989
Nugget Creek above East Nugget Creek	460604	44°04'03"	103°34'04"	May 1975-July 1978
Pactola Reservoir at Custer Gulch	460565	44°03'51"	103°29'50"	July 1976-September 1982
Pactola Reservoir at boat launch	460566	44°05'01"	103°30'03"	September 1969-June 1982
Rapid Creek below Pactola Dam	460552	44°04'28"	103°29'06"	October 1968-June 1973
Deer Creek at Deer Creek Campground	460553	44°06'00"	103°30'19"	October 1968-June 1973
Rapid Creek at Johnson Siding	460554	44°05'05"	103°26'24"	October 1968-September 1975
Rapid Creek above Prairie Creek	460555	44°02'15"	103°23'22"	October 1968-June 1973
Prairie Creek at McGee Siding	460557	44°02'15"	103°23'22"	October 1968-June 1973
Rapid Creek below Prairie Creek	460556	44°02'15"	103°23'21"	October 1968-June 1982

U.S. Geological Survey

The Water Resources Division, U.S. Geological Survey, has collected water-quality information in the Rapid Creek basin since 1949. Water-quality data-collection efforts are grouped into three categories as follows: (1) Comprehensive water-quality data collected at surface-water-quality monitoring stations; (2) miscellaneous field analyses done in conjunction with routine visits to gaging stations; and (3) comprehensive water-quality data collected at ground-water access sites. These three data-collection programs are further described below.

The U.S. Geological Survey publishes water-quality records for the Rapid Creek basin annually in the publication series "U.S.G.S. Water Resources Data--South Dakota." These data also are maintained in a computer storage and retrieval system called WATSTORE, and information retrievals are provided upon request.

Surface-Water-Quality Monitoring Stations

Water-quality information has been collected at a number of locations in the Rapid Creek basin, however, a majority of these data are for three sampling stations. These include Castle Creek above Deerfield Reservoir, Rapid Creek below Pactola Dam, and Rapid Creek near Farmingdale. The location and period of water-quality records at these sampling stations are described in table 3.

Castle Creek above Deerfield Reservoir has been sampled extensively by the U.S. Geological Survey. Water-quality data collection commenced in the 1964 water year and has continued to date (1989). This sampling station was designated by the U.S. Geological Survey as a bench-mark station in 1967 and as a radiochemical station in 1968; these designations remain today. The groups of constituents analyzed have varied through the period of record and include: physical and chemical properties, major cations and major anions, trace elements, major metals, nutrients, general organic substances, pesticides, radiochemicals, suspended sediment, and indicator bacteria. Daily water-temperature records and particle-size analyses for suspended sediment and bed sediment also have been collected at this sampling station. A summary of the period of record and sampling frequency for various water-quality-constituent groups analyzed for Castle Creek above Deerfield Reservoir is given in table 4.

Water-quality data were collected at Rapid Creek below Pactola Dam during the 1969-80 water years. Grab samples were collected approximately once per month for the entire period of record, whereas composited samples also were analyzed for the 1969-73 water years. Constituent groups analyzed included physical and chemical properties, major cations and major anions, and nutrients. Boron analyses also were run for the 1969-79 water years, and iron and manganese were analyzed during the 1969-1971 water years. Once-daily water temperature and specific conductance were measured for the period of record. Particle-size analyses of bed materials were completed in July 1977.

Water-quality data were collected at Rapid Creek near Farmingdale for water years 1950, 1953, 1956-58, and 1969-80. Grab samples were collected for the period 1969-80. Composited samples also were analyzed during the 1969-73 water years, and all samples collected prior to the 1969 water year were "composited by discharge." Constituent groups analyzed included physical and chemical properties, major cations and major anions, and nutrients. Analyses for boron, iron, and manganese were completed for many of the water samples. Once-daily water temperature and specific conductance were determined for nearly the entire period of record (table 3).

Miscellaneous Measurements at Gaging Stations

Since about 1976, the U.S. Geological Survey has routinely made field water-quality determinations while servicing streamflow gaging stations. These measurements include air temperature, water temperature, and specific conductance. Typically, 6 to 12 sets of measurements per year are available for each gaging station. Table 5 presents a compilation of gaging stations in the Rapid Creek basin where these field determination have been made.

Table 3.--Information on three water-quality sampling stations operated by the U.S. Geological Survey in the Rapid Creek basin

Information	Station name and location		
	Castle Creek above Deerfield Reservoir near Hill City	Rapid Creek below Pactola Dam	[1]Rapid Creek near Farmingdale
Station number	06409000	06411500	06421500
Latitude	44°00'49"	44°04'36"	43°56'31"
Longitude	103°49'48"	103°28'54"	102°51'12"
Period of record			
Water-quality analyses	September 1964 to September 1989	October 1968 to September 1980	December 1949; February 1953 to September 1953; October 1955 to September 1958; October 1968 to September 1980
Daily water temperature	May, 1964 to September 1984	October 1968 to September 1980	October 1955 to September 1958; October 1968 to September 1980
Daily specific conductance	--	October 1968 to September 1980	October 1952 to September 1953; October 1955 to September 1958; October 1968 to September 1980

[1]Prior to the 1969 water year, water-quality samples were collected approximately 1.6 miles upstream of the current location of this sampling station.

Table 4.--Summary of water-quality data available for Castle Creek above Deerfield Reservoir

	Constituent group	Period of record (water years)	Frequency of sampling	Remarks
1.	Physical and chemical properties	1964-89	Quarterly 1965-67 and 1984-89; monthly 1968-83	--
2.	Major cations-major anions	1964-82, 1984-89	Quarterly 1965-67 and 1984-89; monthly 1968-83	--
3.	Trace elements	1964-82, 1984-89	Typically 1-2 samples per year	--
4.	Major metals	1964-82, 1984-89	Typically 1-2 samples per year	--
5.	Nutrients	1964-89	Quarterly 1965-67 and 1984-89; monthly 1968-83	Constituents analyzed per sample have varied
6.	Organic substances (general)	1968-69, 1971-74	Typically monthly	Total organic carbon and biochemical oxygen demand
7.	Pesticides	1968-82	Typically 1-2 samples per year	Constituents analyzed per sample have varied
8.	Radiochemicals	1968-71, 1974-85	Typically 1-2 samples per year	Constituents analyzed per sample have varied
9.	Suspended sediment	1967-68, 1970-76, 1978-83, 1985-89	Typically monthly, but less frequent for some years	--
10.	Particle-size analyses	1967-68, 1977	One sample per year	Suspended sediment and bed sediment
11.	Indicator bacteria	1968-89	Typically monthly 1968-83; quarterly 1984-89	Constituents analyzed per sample have varied
12.	Water temperature	1964-75, 1977-80, 1983-84	Daily maximum and daily minimum values	--

Table 5.--Information on U.S. Geological Survey gaging stations in the Rapid Creek basin where miscellaneous field water-quality measurements have been made

Station name and location	Station identification number	Latitude	Longitude	Period of record (water years)
Rhoads Fork near Rochford	06408700	44°08'12"	103°51'29"	1982-89
Rapid Creek near Rochford	06408860	44°06'17"	103°38'35"	1989
Castle Creek above Deerfield Reservoir	06409000	44°00'49"	103°49'48"	1965-89
Castle Creek below Deerfield Dam	06410000	44°01'45"	103°46'53"	1976-89
Rapid Creek above Pactola Reservoir, at Silver City	06410500	44°05'05"	103°34'48"	1976-89
Rapid Creek below Pactola Dam	06411500	44°04'36"	103°28'54"	1968-89
Rapid Creek above Victoria Creek, near Rapid City	06412200	44°02'48"	103°21'06"	1989
Rapid Creek above Canyon Lake, near Rapid City	06412500	44°03'04"	103°18'47"	1976-89
Cleghorn Springs main channel at Fish Hatchery, at Rapid City	06412600	44°03'32"	103°17'54"	1988-89
Cleghorn Springs south channel at Fish Hatchery, at Rapid City	06412700	44°03'31"	103°17'56"	1988-89
Cleghorn Springs north channel at Fish Hatchery, at Rapid City	06412800	44°03'32"	103°17'50"	1988-89
Rapid Creek below Cleghorn Springs, at Rapid City	06412900	44°03'33"	103°17'49"	1988-89
Rapid Creek below Park Ave Drive, at Rapid City	06413200	44°03'33"	103°17'02"	1988-89

Table 5.--Information on U.S. Geological Survey gaging stations in the Rapid Creek basin where miscellaneous field water-quality measurements have been made--Continued

Station name and location	Station identification number	Latitude	Longitude	Period of record (water years)
Leedy Ditch at headgate below Canyon Lake Dam, at Rapid City	06413300	44°03'27"	103°17'12"	1988-89
Leedy Ditch at mouth, at Rapid City	06413550	44°03'49"	103°16'22"	1987-89
Rapid Creek above Jackson Blvd, at Rapid City	06413570	44°03'55"	103°16'21"	1987-89
Lime Creek at mouth, at Rapid City	06413650	44°04'27"	103°15'53"	1982, 1987-89
Storybook Ditch at headgate, at Rapid City	06413660	44°04'04'	103°16'15"	1988-89
Storybook Ditch at mouth, at Rapid City	06413670	44°04'29"	103°15'44"	1988-89
Rapid Creek above water treatment plant, at Rapid City	06413700	44°04'04"	103°15'34"	1980-82, 1988-89
Deadwood Avenue drain at mouth, at Rapid City	06413800	44°04'58"	103°15'34"	1982, 1987-89
Rapid Creek at Rapid City	06414000	44°05'09"	103°14'31"	1976-89
Rapid Creek at East Main Street, at Rapid City	06414700	44°04'45"	103°12'12"	1980-82
Hawthorne Ditch at Rapid City	06415500	44°04'29"	103°11'30"	1981-82
Rapid Creek below Hawthorne Ditch, at Rapid City	06416000	44°04'00"	103°10'25"	1980-82
Rapid Creek below sewage treatment plant, near Rapid City	06418900	44°01'24"	103°05'43"	1982-89
Rapid Creek near Farmingdale	06421500	43°56'31"	102°51'12"	1950, 1953, 1956-58, 1969-89

Ground-Water Access Sites

The U.S. Geological Survey maintains a computerized data base of various information (latitude, longitude, well depth, water-quality analyses, etc.) for 672 ground-water access sites in the Rapid Creek basin. Water-quality data have been collected at 154 of these sites through the sampling of wells, springs, and cave seepage. Typically, only one water-quality sample has been collected at each access site, although approximately 45 sites have had multiple water samples tested. The constituent groups tested have varied and are characterized in table 6. A majority of the completed analyses were for physical and chemical properties, major cations and major anions, nutrients, and radiochemicals. Other analyses which have been completed include trace elements, iron, manganese, stable isotopes, pesticides, organic carbon, arsenic, selenium, and indicator bacteria. The ground-water quality data are maintained in WATSTORE.

Other

A number of agencies have collected ambient water-quality data in the Rapid Creek basin for a shorter duration than the programs just described. Typically, the water-quality data collected are for specific projects with a duration of sampling less than three years. In addition, the City of Rapid City routinely tests the quality of the City's drinking water and wastewater effluent, and these analyses also are described in this section.

The Black Hills Conservancy Sub-District, now the West Dakota Water Development District, conducted a limited water-quality investigation during the summer of 1971. Grab samples were collected twice at three stations including Castle Creek above and below Deerfield Reservoir, and Rapid Creek south of Farmingdale. Constituent groups analyzed included physical and chemical properties, major cations and major anions, nutrients, indicator bacteria, major metals, and trace elements. The results of these water-quality analyses have been reported (Black Hills Conservancy Sub-District, 1973).

The South Dakota Department of Game, Fish and Parks conducted a spatially intense water-quality sampling program during 1962-63 in the Rapid Creek basin including 36 sites on Rapid Creek and its tributaries, two sites at Cleghorn Springs Fish Hatchery, and one site at Pactola Reservoir. Typically, a single grab sample was collected at each sampling site and analyzed for physical and chemical properties, major cations and major anions, major metals, nutrients, and cyanide. The results of these analyses have been published (Stewart and Thilenius, 1964).

The City of Rapid City conducts routine water-quality testing of treated water from its various water sources including: (1) Two Minnelusa wells; (2) three alluvial galleries; and (3) Rapid Creek at the Water Treatment Plant. The City also conducts various analyses on the effluent from the Rapid City Wastewater Treatment Plant. These latter water-quality analyses are reported monthly to the South Dakota Department of Water and Natural Resources as part of the plant's National Pollutant Discharge Elimination System permit.

Table 6.--Types of water-quality analyses performed by the U.S. Geological Survey on water samples from wells, springs, and cave seepage in the Rapid Creek basin

[X indicates that a least one consituent in the group was analysed. PHYS-CHEM, physical and chemical properties; MC-MA, major cations and anions; NUTR, nutrient analyses - various nitrogen and phosphorous species; TR-ELEM, trace elements; RAD, radiochemical analyses; FE-MN; iron and/or manganese analyses; ST-ISO, standard isotopes - hydrogen and oxygen isotopes; ORG, organic carbon analyses; PEST, organo phosphate pesticide analyses; AS-SE, arsenic and/or selenium analyses; IN-BACT, indicator bacteria]

	Number of wells	PHYS-CHEM	MC-MA	NUTR	TR-ELEM	RAD	FE-MN	ST-ISO	ORG	PEST	AS-SE	IN-BACT
	53	X	X	X		X						
	36	X	X									
	12	X	X	X			X					
	11	X	X	X								
	7	X	X			X	X		X			
	6	X										
	5							X				
	3	X	X	X						X		
	2	X	X	X	X		X		X		X	X
	2	X	X	X	X	X	X	X	X	X	X	X
	2	X	X	X	X	X	X		X		X	
	2	X	X	X				X		X		
	2	X	X				X					
	2	X	X				X					
	2	X	X			X						
	1	X	X	X			X					
	1	X	X			X	X					
	1	X	X	X	X	X	X	X	X	X	X	
	1	X		X				X				
	1	X									X	
	1	X		X				X				
	1			X				X				
Total	154	148	139	92	7	68	32	13	14	8	8	4

The U.S. Geological Survey has collected water-quality information in conjunction with special projects at a number of locations in the Rapid Creek basin. A compilation of this information for 12 sampling stations, including period of record, approximate number of water samples tested, and the constituent group tested, is presented in table 7. Constituent groups analyzed at most stations included: physical and chemical properties, major cations and major anions, nutrients including various analyses for nitrogen and phosphorus, indicator bacteria, and trace elements. The five stations with the largest number of samples analyzed (table 7) were part of the Rapid City National Urban Runoff Program study conducted in 1980-82. Water-quality data collected in this program have been reported (Goddard and others, 1989).

Water-quality data are currently being collected in the Rapid Creek basin by the U.S. Geological Survey for three special investigations including: (1) The Rapid Creek Water-Quality Investigation;(2) the Rapid City Merit Fund study; and (3) a special project for West Dakota Water Development District. Information about these three investigations can be obtained from the South Dakota District office.

Table 7.--Information on additional water-quality-sampling stations operated by the U.S. Geological Survey in the Rapid Creek basin

Station name and location	Station identification number	Period of record (water years)	Number of water samples analyzed	Constituent groups analyzed[1]
Castle Creek below Deerfield Dam	06410000	1949, 1953, 1987-89	11	PHYS-CHEM, MC-MA, NUTR, TR-ELEM, IN-BAC, RAD, Fe
Rapid Creek near Pactola	--	1953	29	PHYS-CHEM, MC-MA, NUTR, B
Rapid Creek at Big Bend below Deer Creek	--	1953	2	PHYS-CHEM, MC-MA, NUTR, IN-BAC, TR-ELEM, Fe
Rapid Creek above Canyon Lake, near Rapid City	06412500	1953, 1980-82	48	PHYS-CHEM, MC-MA, NUTR, ORG, B, Fe
Rapid Creek above Water Treatment Plant, in Rapid City	06413700	1980-82	59	PHYS-CHEM, MC-MA, NUTR, TR-ELEM, IN-BAC
Deadwood Avenue Drain at mouth, at Rapid City	06413800	1982	5	PHYS-CHEM, MC-MA, NUTR, TR-ELEM, IN-BAC
Rapid Creek at Rapid City	06414000	1950, 1953, 1977, 1980-82	70	PHYS-CHEM, MC-MA, NUTR, TR-ELEM, IN-BAC, ORG, Fe, PS-BED

Table 7.--Information on additional water-quality-sampling stations operated by the U.S. Geological Survey in the Rapid Creek basin--Continued

Station name and location	Station identification number	Period of record (water years)	Number of water samples analyzed	Constituent groups analyzed[1]
Rapid Creek at East Main Street, at Rapid City	06414700	1980-82	67	PHYS-CHEM, MC-MA, NUTR, TR-ELEM, IN-BAC
Rapid Creek below Sewage Treatment Plant	06418900	1971, 1982	2	PHYS-CHEM, MC-MA, NUTR, TR-ELEM
Rapid Creek below Little Giant Ditch	--	1950, 1953	3	PHYS-CHEM, MC-MA, NUTR, B, Fe
Rapid Creek at Caputa	--	1950, 1953	3	PHYS-CHEM, MC-MA, NUTR, B, Fe
Rapid Creek below Hawthorne Ditch	06416000	1949, 1953, 1980-82	98	PHYS-CHEM, MC-MA, NUTR, TR-ELEM, IND-BACT, PS-SS, ORG, B

[1]Constituents:
PHYS-CHEM = Physical and chemical properties
MC-MA = Major cations and major anions
NUTR = Nutrient analyses - various nitrogen and phosphorous species
IN-BAC = Indicator bacteria
RAD = Radiochemical analyses
ORG = Detailed analyses for various trace organic compounds
PS-BED = Particle-size analyses of bed materials
PS-SS = Particle-size analyses of suspended sediment
B = Boron
Fe = Iron

SUMMARIES OF WATER-QUALITY REPORTS, PUBLICATIONS, AND THESES

This section contains summaries of 62 documents containing information on: (1) Water quality of surface and ground waters in the Rapid Creek basin; (2) water-quality management and regulatory programs; (3) point and nonpoint sources of pollution; or (4) factors affecting water quality in the basin. The results of some investigations have been reported in several documents and in this report only the earliest document has been abstracted. An exception is for the South Dakota Department of Water and Natural Resources, which has a number of reports issued under two publication series: (1) Chemical data for public water systems; and (2) section 305(b) water-quality assessments. Only the most recent edition of these reports is abstracted herein.

Journal Articles and Abstracts

Gries, J.P.

1971. Hydrogen ion concentration in surface and underground waters, Black Hills South Dakota: Proceedings of the South Dakota Academy of Science, v. 50, p. 57-60.

The significance of mine waters on the acidity of two small streams in the Black Hills, Hop Creek and Squaw Creek, is described. The pH values and the concentrations of iron and arsenic for these waters are discussed relative to the areas' geology and mining history.

Harms, L.L.

1978. (Vidal, P.H., and McDermott, T.E.). Phosphorus interactions with stream-bed sediments: Journal of the Environmental Engineering Division, American Society of Civil Engineers, p. 271-288.

This journal article presents the results of research completed by P. Vidal and T. McDermott, listed separately herein in the "Graduate Theses" section.

Pirner, S.M.

1978. (and Harms, L.L.). Rapid City combats the effects of urban runoff on surface water: Water and Sewage Works, February 1978, v. 125, no. 2, p. 48-53.

Various aspects of urban storm-water runoff from the Meade Street and South Canyon watersheds in Rapid City, South Dakota, are reported including: (1) Range and mean concentration of specific conductance, chemical oxygen demand, suspended solids, volatile suspended solids, total phosphorus, and soluble phosphorus; (2) correlation between the concentrations of the above water-quality parameters and pollutant mass loadings and runoff volume; and (3) a comparison of mass loadings from urban runoff versus point-source loadings from the Rapid City Wastewater Treatment Plant. The importance of removing suspended sediment and organic material from storm-water runoff is discussed. (See "Graduate Theses" section (Pirner, 1976) for additional details.)

Rahn, P.H.

1976. (Back, William, Hanshaw, B.B., and Rightmire, C.T.). Flow pattern and chemical character of water in the Pahasapa aquifer near the Black Hills, South Dakota and Wyoming: Geol. Soc. Am. Abstracts, v. 8, p. 1056-1057.

The major cation and major anion chemistry of the Madison aquifer is described, including information on the prevalent chemical components and how the concentration of these constituents change with distance from the Black Hills. These chemical data, along with isotopic data, were used to substantiate the regional flow pattern and areas of recharge of the Madison aquifer, as deduced from potentiometric surfaces. The temperature of water in the recharge areas and downgradient of these areas is described.

Rice, L.R.

1970. (and Luza, K.V.). Factors controlling stream pollution related to bog iron ore mining in the North-Central Black Hills, South Dakota: Geol. Soc. Am. Abstracts, v. 2, no. 5, p. 346.

The water quality of Rapid and Castle Creeks flowing through bog-iron deposits derived from ferruginous gravel conglomerate and pyrite-pyrrhotite schist is described including typical concentrations for dissolved oxygen, pH, ferrous iron, and ferric iron. Mining methods to control stream contamination resulting from the mining of bog iron are described. (See "Graduate Theses" section (Luza, 1969) for additional details.)

Federal Agency Reports

U.S. Environmental Protection Agency

Hern, S.C.

1978. (Lambow, V.W., Morris, F.A., Morris, M.K., Taylor, W.D., and Williams, L.R.). Distribution of phytoplankton in South Dakota lakes: Office of Res. and Dev., Las Vegas, Nevada, U.S. EPA pub. EPA-600/3-7-069, 84 p.

The species and abundance of phytoplankton in 31 lakes sampled throughout South Dakota in 1974 are described. A phytoplankton list for the State is included. Two of these lakes are in the Rapid Creek basin including Deerfield and Pactola Reservoirs. For each lake, a list of phytoplankton species is presented with concentrations of individual species counted on three separate sampling dates. A number of pollution indices were calculated for each lake including: (1) Nygaard Trophic State Indices; (2) Palmer's Organic Pollution Indices; and (3) species diversity and abundance.

U.S. Environmental Protection Agency.

1971. Report on pollution affecting water quality of the Cheyenne River system in western South Dakota: U.S. Environmental Protection Agency, Division of Field Investigations, Denver, Colorado, 99 p.

The occurrence and effects of mercury and other toxic materials throughout the Cheyenne River basin during 1970-71 are described. A majority of the reported chemical analyses are for the Gold Run Creek-Wildwood Creek-Cheyenne River-Cheyenne Arm of Lake Oahe system; however, data are reported for three sampling sites in the Rapid Creek basin. Information reported includes mercury analyses of water samples and fish flesh, and a determination of the number and species of benthic invertebrates.

U.S. Federal Water Pollution Control Administration.

1951. Sanitary survey Rapid Creek, vicinity of Rapid City, South Dakota: U.S. Federal Water Pollution Control Administration, Kansas City, Missouri, 14 p.

The water quality of Rapid Creek from approximately 1 mile upstream of Canyon Lake to 7 miles below the Rapid City Wastewater Treatment Plant was determined via stream surveys completed in January 1951. Water samples were collected at 15 sampling sites along the Rapid Creek main stem and analyzed for water temperature, pH, turbidity, dissolved oxygen, biochemical oxygen demand, and coliform bacteria. Sources of pollution discharging to Rapid Creek are described. Also, the population equivalence of pollution discharged to Rapid City's sewer system from industrial wastewaters was estimated.

U.S. Geological Survey

Goddard, K.E.

1983. (Lockner, T. K., Harms, L. L., and Smith, M. H.). Urban-runoff control in Rapid City, South Dakota--Description and collation of data obtained during the investigation of precipitation runoff and its effects on Rapid Creek in Rapid City, South Dakota: (unpublished), U.S. Geological Survey Open-File Report 87-45, Appendix A, 246 p.

The rationale behind the data-collection program and the methodologies used to collect data for the Rapid City National Urban Runoff Program investigation are described. Water-quality and other hydrologic data were collected during this 1980-82 investigation and are tabulated in this report.

Koch, N.C.

1987. (Lawrence, S.J., Goodman, J., and Pirner, S.M.). South Dakota ground-water quality: U.S. Geological Survey Open-File Report 87-0752, 8 p.

Water quality of South Dakota's major ground-water aquifers are described as to their content of total dissolved solids, hardness, nitrate plus nitrite, selenium, and fluoride. Also, the effects of various land uses on ground-water quality are described. Land uses included are flowing wells, petroleum products and agricultural chemicals, wastewater disposal systems, feedlots, mining, and oil and gas activities. South Dakota's ground-water quality management programs are described.

Peter, K.D.

1985. Availability and quality of water from the bedrock aquifers in the Rapid City Area, South Dakota: U.S. Geological Survey Water-Resources Investigations Report 85-4022, 34 p.

The availability of additional water withdrawals from the Madison, Minnelusa, and Inyan Kara aquifers is described. Also included for these three aquifers is a discussion of water quality relative to primary and secondary drinking-water standards. Water-quality data are tabulated for the following parameters: arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, radium-226, selenium, silver, chloride, copper, iron, dissolved solids, manganese, pH, sulfate, zinc, hardness, and uranium.

Smith, R.A.

1983. (and Alexander, R.B.). Evidence for acid-precipitation-induced trends in stream chemistry at hydrologic bench-mark stations: U.S. Geological Survey Circular 910, 12 p.

The temporal trend in stream chemistry at the U.S. Geological Survey's bench-mark stations across the United States is described. These sampling sites consist predominately of small, undeveloped headwater basins. U.S. Geological Survey station 06409000 Castle Creek above Deerfield Reservoir near Hill City, South Dakota, was included. The trends of several water-quality parameters are reported including: pH, sulfate, alkalinity, and ratio of total alkalinity to total major cations.

U.S. Geological Survey.

1975. Mineral and water resources of South Dakota: Report to the Chairman, Committee on Interior and Insular Affairs, U.S. Senate, 313 p.

The chemical and sanitary quality, and fluvial sediment characteristics of major streams in South Dakota are described. Water-quality parameters discussed include: suspended sediment, sediment load, dissolved nitrogen and phosphorus, biochemical oxygen demand, dissolved oxygen, coliform bacteria, color, selenium, fluoride, iron, manganese, total dissolved solids, major cations, and major anions. Generalized maps for concentrations of suspended sediment, total dissolved solids, and prevalent chemical components are presented for the State's major streams.

Other

U.S. Department of the Interior and U.S. Department of Agriculture.

1967. Black Hills area resources study: 225 p.

A general description of the water quality of the major streams and aquifers in the Black Hills of South Dakota is presented. Total dissolved solids, hardness, water type, and sediment transport are described. Pollution of streams by mining, municipal and industrial discharges, and by natural processes is discussed. Also included are the needs for additional water and water-quality management for agriculture, recreation, fish and wildlife propagation, and municipal and industrial purposes. Water is one of several natural resources discussed.

Department of Civil Engineering, South Dakota
School of Mines and Technology

Harms, L.L.

1979. (and Foster, J. D.). Agriculturally related water-quality problems in Rapid Creek: (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 58 p.

The water quality of Rapid Creek and Lone Tree Irrigation Ditch was investigated during the period of February to September 1978, to determine the effect of the Rapid City Wastewater Treatment Plant effluent on receiving waters. Several grab samples were collected at each of four sites on Rapid Creek and two sites on Lone Tree Irrigation Ditch. Water samples were analyzed for the following parameters: water temperature, pH, specific conductance, ammonia-nitrogen, nitrate-nitrogen, boron, orthophosphate, total phosphorus, suspended solids, volatile suspended solids, total dissolved solids, calcium, hardness, alkalinity, chloride, iron, sodium, and potassium.

1983. (Smith, M.H., and Goddard, K.E.). Urban-runoff control in Rapid City, South Dakota: (unpublished), Final Report, Department of Civil Engineering, South Dakota School of Mines and Technology, and U.S. Geological Survey, Rapid City, South Dakota, 153 p.

The water quality of urban runoff was investigated at five sites on the Rapid Creek main stem and one drainage channel in Rapid City, South Dakota, during the period 1980-82. This study was part of EPA's National Urban Runoff Program. A total of 33 runoff events were monitored and discrete or composited samples were analyzed for a variety of water-quality parameters including: alkalinity, biochemical oxygen demand, turbidity, pH, conductance, fecal coliform bacteria, suspended solids, volatile suspended solids, total solids, total Kjeldahl nitrogen, total and soluble phosphorus, ammonia, nitrate, sulfate, chloride, potassium, sodium, calcium, magnesium, and lead. Runoff loads, regression analyses, and a discussion of violation of water-quality standards are presented.

1984. Inventory of non-community public water systems in South Dakota: (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 21 p.

This investigation was conducted to ascertain the compliance of non-community public water systems in South Dakota with provisions of the Safe Drinking Water Act. A total of 153 water systems were inventoried, mostly in western South Dakota. Each water source was analyzed for turbidity, nitrate, total coliform bacteria and if disinfected, chlorine residual.

Hovey, W.H.

1981. Effects of septic tank leach fields on water quality in Rapid Valley, South Dakota: (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 25 p.

This is the final project report, submitted to the Sixth District Council of Local Governments, on ground-water pollution in the Green Valley Estates subdivision. The details of the study are described in "Graduate Theses" section (Bad Moccasin, 1986).

Department of Geology and Geological Engineering, South Dakota School of Mines and Technology

Gries, J. P.

1974. The geochemistry of certain mine and spring waters, western South Dakota: (unpublished), Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 32 p.

The water quality and flow of drainage waters from 14 inactive or abandoned mines in the northern Black Hills were determined during the period September 1973 to September 1974. Between three to eight samplings were made at each site. The following water-quality parameters are reported: water temperature, pH, specific conductance, and total iron. The suitability of drainage water from the mines for various uses is described.

South Dakota Department of Water and Natural Resources

Koth, R.M.

1983. Biological sampling related to the Rapid City, South Dakota, urban-runoff program: Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 51 p.

Biological investigations conducted along the main stem of Rapid Creek in Rapid City, South Dakota, by the South Dakota Department of Water and Natural Resources in 1980-82 are described. The taxa composition and numbers of macroinvertebrates and periphyton were determined at six locations along the creek, whereas the level of trace metals (Cu, Zn, Cr, Cd, Ni, and Pb) in the flesh of white suckers, mountain suckers, and brown trout were determined at three locations along Rapid Creek. The spatial distribution of macroinvertebrates, periphyton, and heavy metals in fish flesh is reported, as well as the differences in the findings for non-urban versus urban sampling stations.

Matthew, F.L.

1969. Report on pollution and water supply problems in the Rapid Creek Drainage--Hisega to Pactola Dam: South Dakota Department of Health, Pierre, South Dakota, 13 p.

The results of an investigation of water pollution along the Rapid Creek main stem from Pactola Dam to Hisega, South Dakota, are described. Water samples were collected on August 24-25, 1969, at six sites along Rapid Creek and one site on Deer Creek and analyzed for the following parameters: water temperature, dissolved oxygen, pH, specific conductance, total solids, suspended solids, turbidity, chloride, nitrate, orthophosphate, biochemical oxygen demand, fecal streptococcus bacteria, and fecal coliform bacteria. Pollution sources and pollution problems along this segment of Rapid Creek are described.

Meyer, M.R.

1981. Preliminary appraisal of existing and potential ground-water quality problems in the Rapid Creek alluvial aquifer between the east edge of Rapid City and Farmingdale, Pennington County: Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 37 p.

The hydrogeology, water uses, and existing and potential ground-water quality problems of the Rapid Creek alluvial aquifer east of Rapid City are described. Water-quality data previously reported by Coker (1980) and additional data collected by the South Dakota Department of Water and Natural Resources for this study are included. The latter consisted of grab samples collected between December 9-11, 1980, from 11 private, shallow wells located adjacent to Rapid Creek and from Rapid Creek itself at four locations between the Rapid City Wastewater Treatment Plant and Farmingdale. Analyses completed by the Department of Water and Natural Resources included: total dissolved solids, chloride, sulfate, sodium, nitrate, fluoride, and fecal coliform bacteria. Recommendations and suggestions to protect the quality of ground water in the Rapid Creek alluvial aquifer are described.

1983. Water and natural resources in South Dakota: A bibliography of unpublished and published information--with special emphasis on ground water, water quality, and geology, v. 1, unpublished information (review of agencies) and published information by subject: Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota (total pages not available).

This is the first volume of a two-volume set. It contains a bibliography of unpublished information on South Dakota's water and natural resources which is available from Federal and State agencies, and from South Dakota's universities. Each agencies' function and ground-water projects are described. Volume 1 also contains a subject index with numerous citations.

1983. Water and natural resources in South Dakota: A bibliography of unpublished and published information--with special emphasis on ground water, water quality, and geology, v. 2, published information by county, geology, and river basin: Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota (total pages not available).

Volume 2 is a compilation of published information on South Dakota's water and natural resources. The bibliography is organized by county, geology, and river basin.

1984. Evaluation of the ground-water resources of western South Dakota--Task 5: Water quality suitability by aquifer for drinking, irrigation, livestock watering and industrial use: Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 200 p.

A variety of information related to ground water in western South Dakota is summarized including: (1) Statistics for 62 water-quality parameters for each of 17 aquifers; (2) diagrams showing the irrigation suitability for water from these same aquifers; and (3) a bibliography of ground-water related publications for western South Dakota arranged alphabetically by author.

1986. A summary of groundwater monitoring in South Dakota for water-quality protection: Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 47 p.

Existing ground-water monitoring programs conducted by the U.S. Geological Survey, South Dakota Geological Survey, South Dakota Department of Water and Natural Resources, and others to assess water quality are described. Also included are the elements of South Dakota's ground-water quality monitoring program. Recommendations for future monitoring including ground-water quality goals, objectives, and priorities are described.

1986. A summary of ground-water pollution problems in South Dakota: Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 18 p.

A brief summary of ground-water pollution problems within South Dakota is described. The following topics are included: (1) Petroleum and chemical leaks and spills; (2) poor domestic well construction and location practices; (3) feedlots, barnyards, and stockyards; (4) domestic septic systems; (5) municipal-wastewater treatment and disposal; (6) landfills and dumps; (7) hazardous materials; (8) nonpoint agricultural sources; (9) inter-aquifer leakage; (10) oil and gas activities; (11) mining activities; (12) urban related activities; and (13) miscellaneous sources.

Repsys, A.J.

no date. Black Hills stream condition inventory and habitat classification project--water quality: (unpublished), Office of Water Quality, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 25 p.

Water-quality information collected from field surveys of several streams in the Black Hills of South Dakota are listed and discussed in this agency report. These same water-quality data were later discussed in the report by Lechner and others (1988). Ambient water-quality data are compared to South Dakota's water-quality standards for various beneficial uses. The effects of reservoirs, bog-iron deposits, and wastewater-treatment plants on stream quality are described.

Stewart, W.C.

1989. (and Houtcooper, W.C., and Delange, K.). Canyon Lake and Rapid Creek - Diagnostic feasibility study: Water Resources Management Division, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 32 p.

This study was conducted to investigate the taste and odor problem in Canyon Lake during the spring and summer of 1987. Grab water samples were collected at nine sampling stations on many occasions during December 1987 to November 1988. These sites included: (1) Five sites on Rapid Creek main stem from Pactola Dam to outlet of Canyon Lake; (2) two sites at Cleghorn Springs Fish Hatchery; and (3) two sites in Canyon Lake. Water samples were analyzed for the following parameters: water temperature; field and lab pH; dissolved oxygen; specific conductivity; total alkalinity; sulfate; fecal coliform bacteria; total, suspended, and dissolved solids; un-ionized and total ammonia; ortho- and total phosphate; nitrite and nitrate nitrogen, and total Kjeldahl nitrogen. Also, a sediment survey was completed in June 1989 and elutriate samples (of Canyon Lake sediments) were tested for 24 inorganic and organic parameters. Various alternatives for the restoration of Canyon Lake and five specific Department of Water and Natural Resources recommendations are described.

South Dakota Department of Environmental Protection.

1974. Comprehensive water-quality management for the State of South Dakota--303(e) Basin plan for the Cheyenne River Basin: South Dakota Department of Environmental Protection, Pierre, South Dakota, 135 p.

A compilation of various information for the Black Hills portion of the Cheyenne River basin is contained including, but not limited to: (1) Inventory of municipal, industrial, and agricultural point-source discharges; (2) wasteload allocation and permit strategy; (3) municipal-wastewater construction projects and compliance; (4) nonpoint-source pollution; and (5) classification and ranking of stream segments. The report also includes a discussion of water quality and degradation due to agriculture, mining, timbering, municipal discharges, and rural development. Water quality of surface waters in the Rapid Creek basin is included in this latter discussion.

South Dakota Department of Water and Natural Resources.

1984. Public water-system data: Office of Drinking Water, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 447 p.

This report contains a compilation of water-system data, including water-quality characteristics for municipalities, housing developments, trailer courts, rural-water systems, State facilities, and Indian reservations in South Dakota. A wide variety of water-quality characteristics are reported including radionuclides, inorganic chemicals, and sanitary parameters. Analyses are reported for Rapid Creek and Rapid City's alluvial and ground-water sources.

1988. The 1988 South Dakota report to Congress--305(b) water-quality assessment: South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 187 p.

An assessment of South Dakota's surface and ground waters relative to designated water uses is presented. Also included is a description of South Dakota's pollution-control programs and special water-quality concerns. Five stream segments in the Rapid Creek basin were assessed including: Castle Creek from headwaters to Deerfield Reservoir; Castle Creek from Deerfield Reservoir to mouth of Rapid Creek; North Fork Rapid Creek from headwaters to Pactola Reservoir; Rapid Creek from Pactola Reservoir to below Rapid City; and Rapid Creek below Rapid City to mouth of Cheyenne River. The cause of impaired water use and the cause of contamination are described for each stream reach. This report is known as the "305(b) report" and has been prepared every other year since 1975 by the South Dakota Department of Water and Natural Resources to comply with provisions of the Clean Water Act.

1988. The South Dakota section 319 nonpoint source assessment report: Office of Water Resources Management, South Dakota Department of Water and Natural Resources, Pierre, South Dakota, 107 p.

An assessment of nonpoint-source pollution for South Dakota's rivers and lakes, including the extent to which water quality supports designated water uses, is described. The reasons for stream segments not fully supporting their water use is categorized. A separate discussion of the State's 14 major river basins is reported, including the Cheyenne River basin in western South Dakota.

South Dakota State Department of Health.

1964. Water-pollution investigation of Rapid Creek--December 1963--Pactola Reservoir to Cheyenne River: South Dakota State Department of Health, Division of Sanitary Engineering, Pierre, South Dakota, 61 p.

The results of an investigation on water pollution along the Rapid Creek main stem, from Pactola Dam to Creston, South Dakota, near the confluence with the Cheyenne River, and in the Rapid Creek alluvial aquifer east of Rapid City are described. Technical information reported includes: (1) Water-quality data collected December 3-12, 1963, for 17 sampling stations along Rapid Creek; (2) fish and benthos data for December 10-12, 1963, at 16 sites along Rapid Creek; and (3) water-quality data for 22 private, shallow wells east of Rapid City. Information also is given about the Rapid City Wastewater Treatment Plant and its effluent quality. Water-quality analyses reported for Rapid Creek include: pH, water temperature, dissolved oxygen, biochemical oxygen demand, ABS detergent, nitrate, total coliform bacteria, and fecal coliform bacteria. Fish and benthos data reported include: occurrence of fish species, density of macroinvertebrates, and percent volatile solids of streambed sediments. A summary of bacteria, ABS detergent, and nitrate in shallow, alluvial wells also is reported.

South Dakota Department of Game, Fish and Parks

Lyons, J.R.

1966. Iron mining and aquatic resources in the Black Hills: (unpublished), South Dakota Department of Game, Fish and Parks, Rapid City, South Dakota, 18 p.

This speech was made by John R. Lyons to the Board of Directors of the Black Hills Conservancy Sub-District on March 29, 1966. It concerns iron resources in the Black Hills and the impact of surface mining on aquatic resources, especially fishery production. The significance of the iron content of water to various beneficial uses is described. The economic values of fisheries versus mined iron deposits are compared. Water-quality analyses for four sampling stations in the Rapid Creek basin are tabulated. Three sites were located on South Fork Rapid Creek and one site was on Hop Creek. Constituent groups analyzed include physical and chemical properties, major cations and major anions, nutrients, and major metals.

Stewart, R.K.

1964. (and Thilenius, C.A.). Stream and lake inventory and classification in the Black Hills of South Dakota, 1964: Department of Game, Fish and Parks, Rapid City, South Dakota, 102 p.

Streams and lakes of the Black Hills were inventoried and classified as to their water quality and pollution and, if degraded, the causative factor(s) was reported. Both the main stem of Rapid Creek, from the headwaters to the confluence with the Cheyenne River, and many of Rapid Creek's tributaries were assessed. During 1962-63, water samples were collected for water-quality analyses at a large number of sites including 36 sampling stations on Rapid Creek and its tributaries, two sites at Cleghorn Springs Fish Hatchery, and one site at Pactola Reservoir. Water-quality data are tabulated and include: pH, specific conductance, total dissolved solids, suspended solids, turbidity, alkalinity, major cations, major anions, total iron, dissolved total phosphate, ammonia, nitrite, nitrate, organic nitrogen and cyanide. Replicate water-quality sampling was completed at a few sites, however, a single water-quality sample was collected at most sites.

Local Agency Reports

Black Hills Conservancy Sub-District

Black Hills Conservancy Sub-District.

1973. Comprehensive water quality management plan for the Black Hills Region--Water quality management data for the Cheyenne River Basin: Black Hills Conservancy Sub-District, Rapid City, South Dakota, Publication no. 7, 331 p.

The first portion of this report presents a regional-scale description of land resources, surface-water resources, pollution problems, and pollution-control needs in the Cheyenne River basin. The remainder of the report presents a variety of detailed information for specific portions of the basin, including a section on the Rapid Creek basin. Water-quality data are tabulated from a variety of agencies including U.S. Forest Service, U.S. Geological Survey, Black Hills Conservancy Sub-District, and South Dakota Department of Health. Information is reported on general water quality, pesticides, nutrients, inorganic chemicals, and indicator bacteria.

1973. Comprehensive water quality management plan for the Black Hills Region--Lake management data: Black Hills Conservancy Sub-District, Rapid City, South Dakota, Publication no. 7, Appendix A, 222 p.

This appendix contains information on 29 lakes and reservoirs in western South Dakota. The following information is given for each lake: general information, watershed characteristics, beneficial water uses, sediment studies, water-quality studies, pollution problems, influence of pollution problems on beneficial uses, pollution sources, management recommendations, sediment maps, and water-quality data. Information for Pactola and Deerfield Reservoirs is included.

1973. Comprehensive water quality management plan for the Black Hills Region--Bog iron pollution: Black Hills Conservancy Sub-District, Rapid City, South Dakota, Publication no. 7, Appendix E, 11 p.

The potential effect of bog-iron mining on water quality in the headwaters of the Rapid Creek basin is described. The location, size, and mining history of 15 bog-iron deposits are tabulated. No water-quality data were collected for this investigation and conclusions were based on the analysis of past water-quality data. Regulations and methodologies to control bog-iron pollution are discussed. A comparison is made of the economic value of water resources versus the mining of bog iron.

Black Hills Council of Local Governments

Harms, L.L.

1983. Urban runoff control in Rapid City, South Dakota: Executive Summary, Black Hills Council of Local Governments, Rapid City, South Dakota, 21 p.

This executive summary combines the research findings by the South Dakota School of Mines and Technology (Harms and others, 1983) and the U.S. Geological Survey (Goddard and others, 1989), for the Rapid City National Urban Runoff Program. Conclusions and recommendation from this study are presented.

Sixth District Council of Local Governments

Sixth District Council of Local Governments.

1978. Water quality management plan: Final report, Sixth District Council of Local Governments, Rapid City, South Dakota, 196 p.

This report is the water-quality management plan for western South Dakota, as required by the Water Pollution Control Act amendments of 1972. Information on water quality for the area's streams, lakes, and ground water is presented. Point and nonpoint sources of pollution and related control strategies and institutional mechanisms are described. Water-quality data are presented for Canyon Lake, Deerfield Reservoir, Pactola Reservoir, Rapid Creek near Rochford, and Rapid Creek near Farmingdale. A general discussion of the areas' ground-water quality is included.

West Dakota Water Development District

Harms, L.L.

1986. The potential water quality for the proposed Rapid Creek reservoir and interstate water system: (unpublished), West Dakota Water Development District, Rapid City, South Dakota, 6 p.

This report discusses water quality expected in a proposed, multipurpose reservoir at the confluence of Rapid Creek and the Cheyenne River. The sediment and nutrient loads of Rapid Creek are described and related to eutrophication of the reservoir. Carlson's Trophic Status Index was calculated from an estimated concentration of phosphorus entering the reservoir. Alterations to the Rapid City Wastewater Treatment Plant to reduce phosphorous loadings in Rapid Creek are discussed.

Graduate Theses

Bad Moccasin, D.B.

1986. Effects of septic tank effluent on ground water quality, Green Valley Estates, Pennington County, South Dakota: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 34 p.

The effects of septic tank-soil absorption systems on the water quality of Rapid Creek and the Rapid Creek alluvial aquifer are described. Well water from 33 landowners in Green Valley Estates was collected during the summer of 1981 and analyzed for nitrate, chloride, specific conductance, total coliform bacteria, and fecal coliform bacteria. In addition, several water samples were collected during 1981 and 1982 at various sampling sites on Rapid Creek in Rapid Valley, and tested for the same parameters. The extent and significance of ground-water contamination are discussed.

Bauman, S.J.

1980. An inventory of eutrophic lakes in the southern Black Hills of South Dakota: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 113 p.

The quality of water in 13 lakes in the Black Hills of South Dakota was determined and used to ascertain their eutrophic status. Water samples were collected at three sites in each lake and sampling was completed during the months of June and August 1979. The following parameters were determined: water temperature, dissolved oxygen, specific conductance, turbidity, Secchi depth, pH, total phosphorus, chlorophyl a, and the species and genera of phytoplankton. The trophic state of each lake was determined by Carlson's Trophic Status Index.

Behal, R.

1988. Occurrence of selenium in the Inyan Kara Aquifer system in Meade, Pennington, and Custer Counties, South Dakota: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 77 p.

The occurrence and major factors responsible for the concentration of selenium in the Inyan Kara aquifer, western South Dakota, are described. Water samples were collected from 48 wells, some of which are located in the Rapid Creek basin. Each water sample was analyzed for the following parameters: water temperature, specific conductance, pH, redox potential, alkalinity, total organic carbon, sulfate, and selenium. The statistical significance of the nearness of wells to lineaments on selenium, total organic carbon, alkalinity, and water temperature is discussed relative to the origin of water in the Inyan Kara aquifer.

Bergeron, B.P.

1986. Gasoline contamination of the alluvial aquifer in east-central Rapid City, South Dakota: M.S. Thesis (unpublished), Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 55 p.

The contamination of the Rapid Creek alluvial aquifer in Rapid City, South Dakota, by a leaking, underground gasoline storage tank was investigated. A two-dimensional, finite-difference, solute-transport computer model was used to estimate the movement of free gasoline and dissolved gasoline. Water samples were collected from the aquifer and gas chromatographic analyses were completed to confirm the presence of gasoline, benzene, and toluene. The gasoline leak was found in October 1983, and was located approximately 150 feet southwest of City Hall.

Brown, K.S.

1988. Concentration and mass loading of nutrients in Rapid Creek, Rapid City, South Dakota.: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 120 p.

This investigation evaluated water quality along Rapid Creek and its tributaries in Rapid City during the spring and summer of 1987. Three separate stream surveys were completed and the following water-quality measurements were made at 17 sampling stations: pH, water temperature, dissolved oxygen, organic nitrogen, ammonia nitrogen, nitrite and nitrate nitrogen, and orthophosphate. Estimates of mass loadings of nitrogen and phosphorus from point-source discharges to Rapid Creek and from tributary inflow were made. The significance of Canyon Lake as a nutrient sink is described.

Carda, D.D.

1975. A study of the radium content of the ground waters in western South Dakota with emphasis on the Madison (Paha Sapa) Limestone: Ph.D. Thesis (unpublished), Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 58 p.

The occurrence and possible cause of radioactivity in various waters in western South Dakota were investigated. A total of 28 wells, three springs and two creeks were sampled for their radium-226 content. A total of three sites were located in the Rapid Creek basin in Rapid City including Rapid Creek, Cleghorn Springs, and "Ben French" well. The geology and hydrology of the Madison aquifer were evaluated to help explain the existence of radium and high water temperature in the Philip, Midland, and Bar-N well waters, the only sites where radium was detected.

Coker, D.

1981. Shallow ground-water resources of a portion of Rapid Valley, Pennington County, South Dakota: M.S. Thesis (unpublished), Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 96 p.

The hydrogeology and water quality of the Rapid Creek alluvial aquifer were investigated. Forty-five wells and one spring were sampled in summer 1979 and analyzed for the following parameters: total coliform bacteria, fecal coliform bacteria, hardness, nitrate-nitrogen, orthophosphate, total iron, silica, pH, specific conductance, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride. The suitability of this ground-water aquifer for various beneficial uses is discussed.

Gabe, G. R.

1982. Quality changes in urban stormwater runoff detained in a flood mitigation dam in Rapid City, South Dakota: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 74 p.

The quality of storm-water (urban) runoff flowing into and out of a flood-mitigation dam located in Rapid City was investigated. Grab samples were collected from five storm events between July to October 1980. The following water-quality parameters were examined: suspended solids, volatile suspended solids, turbidity, specific conductance, chloride, biochemical oxygen demand, chemical oxygen demand, fecal coliform bacteria, sulfate, pH, ammonia nitrogen, nitrate nitrogen, total phosphorus, and dissolved phosphorus. The effect of the dam on water quality is described.

Jordan, B.

1938. Fluorides in South Dakota water supplies: M.A. Thesis (unpublished), Department of Chemistry, University of South Dakota, Vermillion, South Dakota, 37 p.

The chemical characteristics of numerous springs, wells, and impounded waters are tabulated including information for total solids, silica, sulfate, chloride, fluoride, calcium, magnesium, hardness, iron, manganese, and alkalinity. Two sampling stations were located in the Rapid Creek basin and are described in the text only as "Rapid City (spring)" and "Rapid City

Sanatorium." A location map is included as an appendix, however. Information also is included about the correlation between fluoride content and the type of water (hard, soft, artesian, etc.), and between the concentrations of fluoride and other chemical constituents. A brief discussion is included about the high fluoride-ion content in drinking water and the existence of mottled teeth.

Luza, K.V.

1969. Origin, distribution, and development of bog iron in the Rochford District, North-Central Black Hills, South Dakota: M.S. Thesis (unpublished), Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 159 p.

As part of this investigation, monthly water samples were collected in 1968-69 upstream, within, and downstream of the outcrop of several bog-iron deposits in the headwaters of Rapid Creek near Rochford. The sampling stations were located along Bloody Gulch, Iron Hills Gulch, Hop Creek Swilly Gulch, and Solomon Gulch. The following water-quality parameters were determined: water temperature, total iron, soluble iron, suspended iron, pH, and Eh value. The importance of the solution's pH value on the transport of iron is described.

Magee, G.L.

1981. Water quality effects of urban stormwater runoff on a portion of Rapid Creek: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 212 p.

The quality of urban, storm-water runoff, and dry weather runoff was determined for five sampling stations on Rapid Creek and one site on Meade-Hawthorne drain, Rapid City, during the period May 1980 to June 1981. A total of sixteen storm events and six baseline assessments were completed, and water samples were tested for pH, specific conductance, fecal coliform bacteria, chemical oxygen demand, ammonia nitrogen, suspended solids, volatile suspended solids, total Kjeldahl nitrogen, and total phosphorus. Correlation coefficients for the interdependency of water-quality constituents are reported. Pollutant loadings during storm events were compared to baseline loads.

McDermott, T.E.

1977. Sorption and release of phosphorus by streambed sediments: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 129 p.

The significance of streambed sediments to increased phosphorous concentrations in storm-water runoff was investigated along a 21-mile reach of Rapid Creek from May to August 1976. The reach of Rapid Creek investigated included runoff from Black Hills National Forest, urbanized Rapid City, and agricultural rangeland. Core samples of streambed sediments were collected at various sites before and after periods of high flow and analyzed for total and organic phosphorous content. Water samples were collected at four sites at peak water levels during high flow conditions and analyzed for total phosphate, dissolved phosphate, and dissolved orthophosphate. A comparison was made of streambed sediments versus nonpoint-source runoff as the causative factor for high phosphorous levels in storm-water runoff.

Nowak, C.L.

1982. Analysis of urban runoff from the Meade Street Drainage Basin: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 98 p.

The quality of storm-water (urban) runoff from the Meade Street drainage basin, Rapid City, was investigated from June 1980 to July 1981. The study was part of EPA's National Urban Runoff Program. A total of nineteen runoff events were sampled and analyzed for a variety of water-quality parameters including: suspended solids, volatile suspended solids, biochemical oxygen demand, chemical oxygen demand, nitrate nitrogen, total phosphorus, specific conductance, and fecal coliform bacteria. Mass loadings of water-quality constituents and correlations between various water-quality parameters are described.

Pirner, S.M.

1976. Quantification of pollutants from an urban watershed in Rapid City, South Dakota: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 160 p.

The quality of storm-water (urban) runoff from the Meade Street drainage basin, Rapid City, South Dakota, was studied from May to September 1975. A total of fifteen runoff events were sampled of which eight were sampled completely throughout the hydrograph. The following water-quality parameters were determined: chemical oxygen demand, suspended solids, volatile suspended solids, total phosphorus, soluble phosphorus, and specific conductance. Correlation coefficients between total runoff volume occurring from storm events and pollutant loads are reported. A comparison of the loading from urban runoff versus point-source discharges is presented.

Rice, L.R.

1970. The treatment of iron and acid stream contamination in the Black Hills of South Dakota: M.S. Thesis (unpublished), Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 212 p.

As a part of a detailed investigation of bog-iron deposits located near Rochford, water samples were collected in fall 1969 from nine streams including: Rhoads Fork, Maitland Draw, Long Draw, Hop Creek, Castle Creek, Bittersweet Creek, Iron Hills Creek, Cottrill Draw, and a portion of Rapid Creek main stem. Dissolved oxygen, ferric and ferrous iron, and sulfate were determined. These data are discussed relative to the transport and precipitation of iron. Also, a method of water treatment to remove iron and to neutralize the acidity of contaminated water is described.

Vidal, P.H.

1977. Sorption and release of point-source phosphorus by streambed sediments: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 134 p.

The phosphorous content of streambed sediments and water in Rapid Creek downstream from the effluent of the Rapid City Wastewater Treatment Plant was investigated from April to September 1976. The objectives of the research were: (1) To determine if point-source phosphorous loadings from the wastewater plant accumulate in streambed sediments; and (2) to investigate the resuspension of phosphorus during high flows, thereby causing increased phosphorous concentrations in the water phase. Water samples were collected at sampling stations below the wastewater discharge during occasions of both normal and high streamflow. The following analyses were completed: total phosphorus, dissolved phosphorus, and dissolved orthophosphate. Streambed sediments were collected before and after high flows and analyzed for total, inorganic, and organic phosphorus.

Williams, J.M.

1988. The origin and occurrence of dissolved nitrogen and oxygen gas in natural waters of the Black Hills Area, South Dakota: M.S. Thesis (unpublished), Department of Civil Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, 85 p.

The concentration and percent saturation of dissolved nitrogen and oxygen in 26 natural waters in the Black Hills of South Dakota were determined from February to May 1987. Both surface waters and ground waters were sampled on a monthly basis, except for Cleghorn Springs, Jackson Springs, and Rapid Creek at Cleghorn Springs Fish Hatchery which were sampled biweekly. Ammonia nitrogen, nitrite and nitrate nitrogen, and ambient water temperature were determined at each sampling station. The extent and cause of nitrogen supersaturation are described.

Other

Bell, Galyardt & Associates, Inc.

1981. Water quality parameter update for 208 areawide water quality management planning program: (unpublished), Bell, Galyardt & Associates, Inc., Rapid City, South Dakota, 95 p.

A summary and assessment of the water-quality data collected over a period of several years for the Black Hills National Forest by the U.S. Forest Service are described. Information is reported for nine watersheds, two of which (Castle Creek and Rapid Creek) are within the Rapid Creek basin. A total of 20 sampling stations are listed for the Rapid Creek watershed. Water-quality parameters include: orthophosphate, total phosphate, suspended solids, dissolved solids, nitrite and nitrate, chloride, fecal coliform bacteria, fecal streptococcus bacteria, iron, pH, dissolved oxygen, water temperature, and turbidity.

Lechner, M.

1984. (Modde, T.C., Repsys, A.J., and Hanson, R.A.). Black Hills stream inventory and classification: (unpublished), Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University, Stillwater, Oklahoma; Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah; and South Dakota Department of Water and Natural Resources, Office of Water Quality, Pierre, South Dakota, 43 p.

Water quality, macroinvertebrate, and other data were collected at 56 locations along streams in the Black Hills in summers of 1984-86 for stream and riparian classification. In addition, 28 other stream locations were sampled to investigate the effects of reservoirs, bog-iron deposits, and wastewater-treatment facilities on macroinvertebrate community structure and water quality. Water-quality parameters analyzed include: pH, water temperature, turbidity, dissolved orthophosphate, nitrate, total alkalinity, sulfate, conductivity, and dissolved oxygen.

Union Carbide Corporation.

1980. Hydrogeochemical and stream sediment reconnaissance basic data for Rapid City NTMS Quadrangle, South Dakota: Nuclear Division, Union Carbide Corporation, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, 39 p.

This investigation was completed as part of the National Uranium Resource Evaluation Program, administered by the Department of Energy. A total of 417 ground water and 477 streambed sediments were sampled May to October 1979, and tested for uranium and 38 uranium-related parameters including: specific conductance, major cations, major anions, heavy metals, minor elements, and other inorganic constituents. Statistical and areal distribution of these parameters are displayed and observations are made relative to the potential for uranium mineralization. A partial listing of water-quality data for ground water and streambed sediments is included as an appendix.

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Coker, D.K., 1980, Shallow ground-water resources of a portion of Rapid Valley, Pennington County, South Dakota: Rapid City, South Dakota, South Dakota School of Mines and Technology, unpublished M.S. thesis, 96 p.

Goddard, K.E., Lockner, T.K., Harms, L.L., and Smith, M.H., 1989, Summary of data pertaining to land use, rainfall, dryfall, stream discharge, and storm runoff collected as part of a study of the effects of urban runoff on Rapid Creek, Rapid City area, South Dakota: U.S. Geological Survey Open-File Report 87-45, 194 p.

Harms, L.L., Smith, M.H., and Goddard, K.E., 1983, Urban-runoff control in Rapid City, South Dakota: Rapid City, South Dakota, Unpublished final report, South Dakota School of Mines and Technology and U.S. Geological Survey, 153 p.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a national water-quality assessment program: U.S. Geological Survey Circular 1021, 42 p.

Stewart, R.K., and Thilenius, C.A., 1964, Stream and lake inventory and classification in the Black Hills of South Dakota, 1964: South Dakota Department of Game, Fish and Parks, Rapid City, South Dakota, 102 p.

U.S. Environmental Protection Agency, 1987, National water-quality inventory--1986 report to Congress: Office of Water, U.S. Environmental Protection Agency, Washington, D. C., EPA-440/4-87-008, 141 p.

U.S. Environmental Protection Agency, 1989, 1988 NPS report to Congress: Office of Water, U.S. Environmental Protection Agency, Washington, D.C., 71 p.

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