

U.S. Department of the Interior
U.S. Geological Survey

Water-Quality Characteristics in the Black Hills Area, South Dakota

By Joyce E. Williamson and Janet M. Carter

Water-Resources Investigations Report 01-4194

Prepared in cooperation with the
South Dakota Department of Environment and Natural Resources
and the West Dakota Water Development District

U.S. Department of the Interior

Gale A. Norton, Secretary

U.S. Geological Survey

Charles G. Groat, Director

The use of firm, trade, and brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Rapid City, South Dakota: 2001

For additional information write to:

**District Chief
U.S. Geological Survey
1608 Mt. View Road
Rapid City, SD 57702**

Copies of this report can be purchased from:

**U.S. Geological Survey
Information Services
Building 810
Box 25286, Federal Center
Denver, CO 80225-0286**

CONTENTS

Abstract.....	1
Introduction	2
Purpose and Scope.....	3
Description of Study Area.....	3
Physiography and Climate.....	3
Geologic Setting.....	5
Hydrologic Setting.....	9
Major Aquifers	9
Minor Aquifers	11
Previous Investigations.....	12
Acknowledgments	13
Water-Quality Characteristics.....	13
Sampling Sites and Methods	13
Water-Quality Criteria	17
Water-Quality Characteristics of Selected Aquifers.....	25
Physical Properties	25
Common Ions	42
Precambrian Aquifers.....	42
Deadwood Aquifer	42
Madison Aquifer.....	65
Minnelusa Aquifer.....	65
Minnekahta Aquifer.....	67
Inyan Kara Aquifer.....	67
Minor Aquifers	68
Nutrients	69
Trace Elements	75
Precambrian Aquifers.....	75
Deadwood Aquifer	90
Madison Aquifer.....	90
Minnelusa Aquifer.....	90
Minnekahta Aquifer.....	90
Inyan Kara Aquifer.....	90
Minor Aquifers	92
Radionuclides	92
Deadwood Aquifer	102
Madison Aquifer.....	102
Minnelusa Aquifer.....	106
Inyan Kara Aquifer.....	106
Minor Aquifers	106
Summary for Aquifers in Relation to Water Use.....	106
Water-Quality Characteristics of Selected Surface-Water Sites	107
Physical Properties	108
Group Comparisons.....	108
Additional Comparisons	118
Common Ions	121
Group Comparisons.....	121
Additional Comparisons	132

CONTENTS—Continued

Water-Quality Characteristics—Continued

Water-Quality Characteristics of Selected Surface-Water Sites—Continued

Nutrients.....	137
Group Comparisons	137
Additional Comparisons	142
Trace Elements.....	144
Group Comparisons	144
Additional Comparisons	154
Radionuclides.....	154
Summary for Surface-Water Groups in Relation to Water Use	164
Summary	165
References.....	168
Supplemental Information.....	173

FIGURES

1. Map showing area of investigation for the Black Hills Hydrology Study.....	4
2. Stratigraphic section for the Black Hills.....	6
3. Map showing distribution of hydrogeologic units in the Black Hills area	7
4. Geologic cross section A-A'	8
5. Schematic showing simplified hydrogeologic setting of the Black Hills area	10
6. Map showing location of ground-water sampling sites	14
7. Map showing location of selected surface-water sampling sites by group.....	15
7a. Map showing location of selected surface-water sampling sites in the Rapid Creek Basin.....	16
8. Graphs showing relations between water hardness and freshwater aquatic-life standards for acute and chronic toxicity of selected trace elements	24
9. Boxplots of physical properties for selected aquifers	29
10. Graphs showing selected relations between physical properties and well depth for selected aquifers	32
11-15. Map showing distribution of:	
11. Water temperature in the Madison aquifer.....	36
12. Specific conductance in the Madison aquifer	38
13. Specific conductance in the Minnelusa aquifer.....	39
14. Specific conductance in the Inyan Kara aquifer.....	40
15. Hardness in the Inyan Kara aquifer.....	41
16. Boxplots of concentrations of selected common ions for selected aquifers	48
17. Trilinear diagrams showing proportional concentrations of major ions in selected aquifers	54
18. South Dakota irrigation-water classification diagram	57
19. Graphs showing relations between sulfate and specific conductance in the Madison, Minnelusa, and Inyan Kara aquifers	58
20. Graphs showing selected relations between common ions and well depth for selected aquifers.....	59
21. Map showing distribution of sulfate concentrations in the Minnelusa aquifer.....	66
22. Boxplots of concentrations of selected nutrients for selected aquifers.....	73
23. Boxplots of concentrations of selected trace elements for selected aquifers.....	83
24. Graphs showing selected relations between trace elements and well depth for selected aquifers.....	91
25. Boxplots of concentrations of selected radionuclides for selected aquifers	98
26. Graphs showing selected relations between radionuclides and well depth for selected aquifers	103
27. Map showing distribution of radon concentrations in the Deadwood aquifer.....	105
28. Boxplots of concentrations of selected properties by surface-water group	109
29. Duration hydrographs of daily mean flow for selected headwater, crystalline, artesian, and exterior surface-water group sites.....	112
30. Graphs showing relations between discharge and specific conductance for selected sampling sites by surface-water group.....	116
31. Graph showing relations between temperature and dissolved oxygen for selected surface-water groups.....	117

FIGURES—Continued

32. Boxplots of specific conductance and hardness for selected surface-water sites in Rapid Creek Basin.....	119
33. Graph showing downstream progression of pH for selected streams influenced by acid mine drainage.....	120
34. Boxplots of concentrations of selected ions by surface-water group.....	124
35. Graph showing relation between specific conductance and dissolved solids by surface-water group.....	128
36. Trilinear diagrams showing proportional concentrations of major ions by surface-water group	129
37. Stiff diagrams for surface-water groups and selected sites.....	130
38. Map showing spatial distribution of median calcium concentrations in surface water	133
39. Map showing spatial distribution of median sulfate concentrations in surface water	134
40. Graph showing relation between specific conductance and calcium, sodium, and sulfate concentrations in surface water	135
41. Boxplots of selected ions for selected surface-water sites in Rapid Creek Basin.....	136
42. Graph showing changes in selected ions at Bear Butte Creek near Deadwood, 1988-97	137
43. Boxplots of concentrations of selected nutrients by surface-water group	138
44. Graph showing nitrite plus nitrate concentrations in Annie Creek near Lead, 1988-97.....	141
45. Graph showing nitrite plus nitrate concentrations at Horse Creek near Vale and Horse Creek above Vale.....	142
46. Boxplots of selected nutrients for selected surface-water sites in Rapid Creek Basin	143
47. Boxplots of concentrations of selected trace elements by surface-water group	148
48. Map showing spatial distribution of maximum arsenic concentrations in surface water	155
49. Map showing spatial distribution of median manganese concentrations in surface water	156
50. Map showing spatial distribution of maximum selenium concentrations in surface water.....	157
51. Graph showing comparison of dissolved copper concentrations to hardness-dependent chronic and acute aquatic-life criteria for Bear Butte Creek near Deadwood	158
52. Boxplots of concentrations of selected radionuclides by surface-water group.....	160
53. Map showing spatial distribution of median gross beta as cesium-137 concentrations in surface water.....	162
54. Map showing spatial distribution of median uranium concentrations in surface water.....	163

TABLES

1. Water-quality criteria, standards, or recommended limits and general significance for selected properties or constituents	18
2. Surface-water-quality standards for selected physical properties and constituents.....	22
3. Summary of physical properties in ground water.....	26
4. Summary of concentrations of common ions in ground water.....	43
5. Relation between specific conductance and dissolved solids for selected aquifers	56
6. Summary of concentrations of nutrients in ground water	70
7. Summary of concentrations of trace elements in ground water	76
8. Summary of concentrations of radionuclides in ground water.....	93
9. Summary of physical properties in surface water by group	114
10. Summary of concentrations of common ions in surface water by group	122
11. Relation between specific conductance and dissolved solids for selected surface-water groups.....	132
12. Summary of concentrations of nutrients in surface water by group.....	140
13. Summary of concentrations of trace elements in surface water by group.....	145
14. Summary of concentrations for radionuclides in surface water by group	159
15. Ground-water sampling sites summarized in this report	175
16. Surface-water sampling sites summarized in this report	193

CONVERSION FACTORS AND VERTICAL DATUM

	Multiply	By	To obtain
	cubic foot per second	0.02832	cubic meter per second
	foot	0.3048	meter
	inch	2.54	centimeter
	inch	25.4	millimeter
	mile	1.609	kilometer

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) by the following equations:

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C}) + 32$$

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

Chemical concentrations: Chemical concentrations of substances in water are given in metric units of milligrams per liter (mg/L) and micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as mass (milligrams) of solute per unit volume (liter) of water. Micrograms per liter is a unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. Micrograms per liter are equivalent to milligrams per liter divided by 1,000.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Water year: Water year is the 12-month period, October 1 through September 30, and is designated by the calendar year in which it ends. Thus, the water year ending September 30, 1992, is called the "1992 water year."

OTHER ABBREVIATIONS, SYMBOLS, AND ACRONYMS USED:

mg/L	milligrams per liter
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25 degrees Celsius
pCi/L	picocuries per liter
TU	tritium units
<	less than

DENR	South Dakota Department of Environment and Natural Resources
MCL	Maximum Contaminant Level
NURE	National Uranium Resource Evaluation
NWIS	U.S. Geological Survey National Water Information System
NWQL	U.S. Geological Survey National Water Quality Laboratory
SMCL	Secondary Maximum Contaminant Level
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey