Firesteel Creek/Lake Mitchell Water Quality Study Area Report

Prepared by the
South Dakota Department of Water and Natural Resources
Water Quality Management Section

September 1985

The preparation of this report was financed through a Section 208 Water Quality Management Planning Grant from the U.S. Environmental Protection Agency

Firesteel Creek/Lake Mitchell WQSA Summary

The Firesteel Creek/Lake Mitchell Water Quality Study Area encompasses some 230,000 acres in Jerauld, Aurora, and Davison Counties. Major population centers within the study area include the municipalities of Mitchell (population 13,425) and Wessington Springs (population 1,300). Lake Mitchell is an artificial impoundment on lower Firesteel Creek in northeastern Davison County. The dam is situated about 3 miles above the confluence of Firesteel Creek with the James River which receives the reservoir outflow. Lake Mitchell has a surface area of 671 acres, a maximum depth of 29 feet and a mean depth of about 12 feet.

Lake Mitchell is classified under the South Dakota State Water Quality Standards for the beneficial uses of domestic water supply, warm water permanent fish life propagation, immersion recreation, limited contact recreation, wildlife propagation and stock watering. Aquatic weeds are not particularly abundant; but the reservoir supports large populations of algae. Common fish species in Lake Mitchell are walleye, northern pike, crappie, and bullhead. No fish kills have been documented to date.

Land use in the watershed is predominantly agricultural. Approximately 41% is estimated to be cropland and 59% rangeland or pasture. SCS estimated that 58% of the watershed was adequately treated in 1981.

At least half of the reservoir shoreline has been developed with lakeside residences, beaches, and public access areas. The present number of lakeside dwellings has not been determined.

Lake Mitchell has extensive public use as a recreational area and there is local interest in the reservoir as evidenced by the existence of the Lake Mitchell Improvement Association.

To determine water quality characteristics and identify water quality problems within the Firesteel Creek watershed samples were taken at 12 sites. Three (3) were in-lake sites and 9 were established on Firesteel Creek. Samples were collected after rainfall events and during snowmelt runoff.

In-lake sampling indicated Lake Mitchell to be hypereutrophic with regard to total phosphorus concentrations and eutrophic as indicated by organic nitrogen concentrations. The principal problem at Lake Mitchell appears to be extensive nutrient loading from the Firesteel Creek watershed. The annual phosphorus and nitrogen loads to Lake Mitchell for 1982 were 0.50 and 2.65 g/m^2/year, respectively. For lakes with mean depths of 5 meters or less, phosphorus and nitrogen loads greater than 0.13 and 2.0 g/m^2/year, respectively, are considered dangerous (Vollenweider, 1968).

Excessive fecal coliform levels (>1,000/100 ml) were found in 30% of Firesteel Creek samples but in only 7% of in-lake samples. Generally, fecal coliforms were not a serious problem in Lake Mitchell.

Watershed erosion, primarily from cropland, provided 6,411 tons and shoreline erosion contributed 1,060 tons of sediment to Lake Mitchell. Total sediment yield amounted to about 6.81 acre-feet per year or .08% of reservoir water capacity. Non-point sources of pollution from the watershed are probably inadequate crop cover on agricultural land, lack of fertilizer management practices, and over grazing on streamside land. Secondary sources of nutrients as well as primary sources of excessive fecal coliform levels to the reservoir

are watershed livestock operations without pollution controls and possible failing individual septic tank systems around the reservoir periphery.

Recommendations

Nutrient loading to Lake Mitchell from the watershed may be reduced by utilizing BMP's on the land including implementation of fertilizer management practices, and conservation tillage to reduce erosion. Proper grazing use and feedlot waste management systems will help in the reduction of nutrients, particularly phosphorus, and possible bacterial contamination to the reservoir. Vegetative sediment barrier strips can be seeded to protect overgrazed and eroding streamside land and further reduce sediment and nutrient input into the tributaries. A septic tank survey should be conducted around Lake Mitchell to identify any problem areas and technical assistance should be provided to control existing problems. Lake bank and streambank stabilization is recommended in areas that are rapidly eroding.

After the above measures are implemented, a selective dredging program and chemical phosphorus flocculation are recommended, if proven feasible, to improve water quality and the overall recreational potential of the reservoir.

B10304AR.wq

I. Firesteel Creek/Lake Mitchell Watershed Description

A. General Description

The Firesteel Creek/Lake Mitchell WQSA is about 58 miles long and averages about 10 miles wide encompassing some 230,000 acres primarily in Jerauld, Aurora, and Davison Counties (Figure 1). A small portion of the watershed also extends into Sanborn County. Major population centers within the study area include the municipalities of Mitchell and Wessington Springs.

Lake Mitchell is an artificial impoundment on lower Firesteel Creek about 3 miles above its confluence with the James River which receives the reservoir outflow. The reservoir has a surface area of 671 acres, a maximum depth of 29 feet and a mean depth of about 12 feet. Shoreline length is approximately 10 miles. The bottom varies from accumulated silt and muck in the reservoir basin to sand and gravel in near shore areas. Less than 5% of the shoreline is covered with cattails and bullrushes. Emergent and submerged aquatic vegetation is common but not particularly abundant. No information is available regarding the occurrence of blue-green algal blooms in Lake Mitchell but a lake survey conducted by the South Dakota Department of Water and Natural Resources (DWNR) in 1979 noted reduced water clarity and high algal densities in the reservoir which is suggestive of eutrophic conditions (Koth, 1981). Common fish species in Lake Mitchell are walleye, northern pike, crappie, and bullhead. No fish kills have been documented to date.

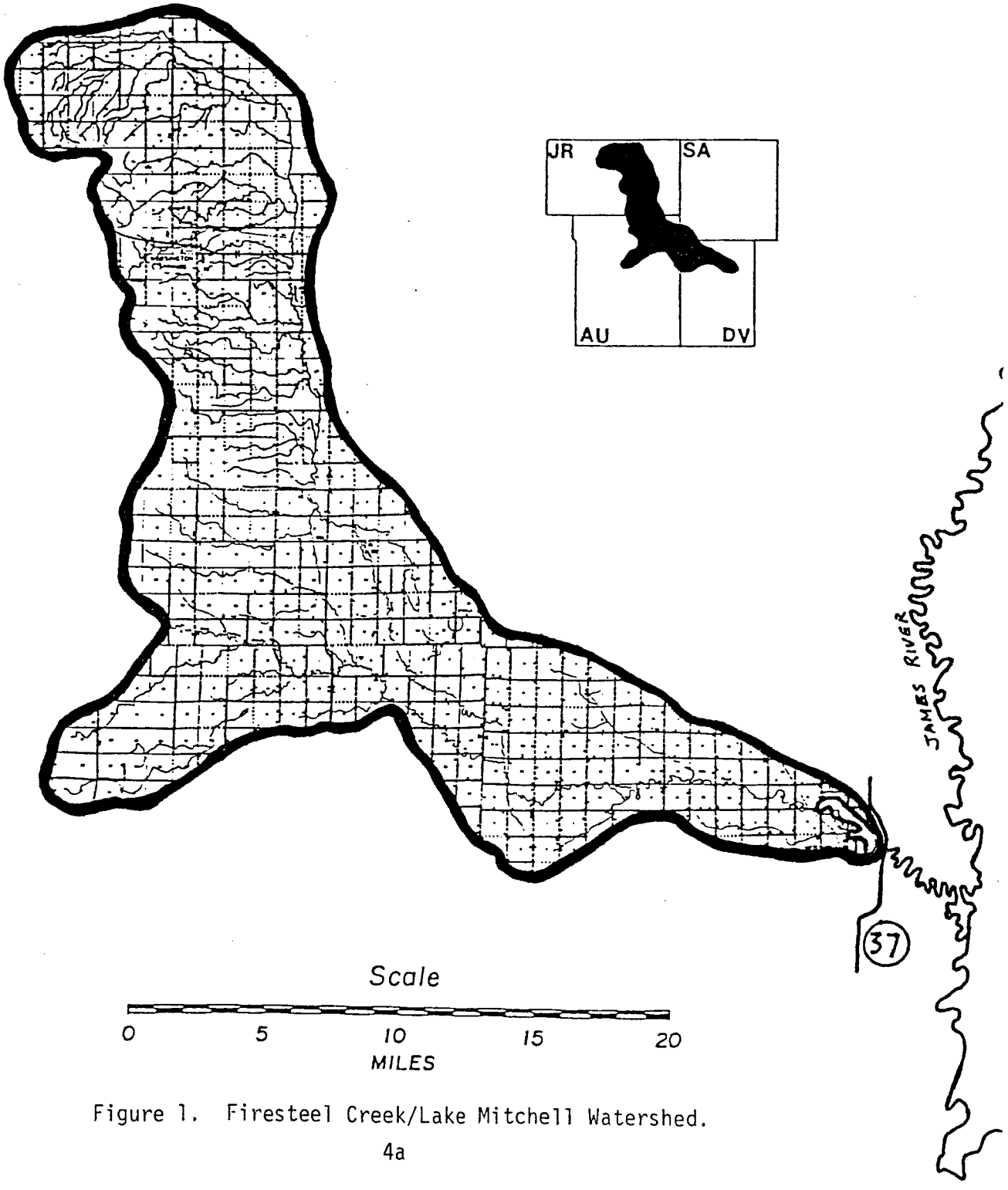

Figure 1. Firesteel Creek/Lake Mitchell Watershed.

B. Beneficial Uses and Impairments

Lake Mitchell is a popular recreation lake providing swimming, fishing, picnicking, waterskiing, and boating. It helps to serve the recreational needs of a population estimated at 242,807 within a 65-mile radius of the reservoir (Koth, 1981). Lake Mitchell is the major source of domestic water for the nearby City of Mitchell.

According to the South Dakota Board of Water and Natural Resources Regulations, Chapter 74:03:02, "Surface Water Quality Standards", Lake Mitchell is classified as having the beneficial use designations of domestic water supply, warm water permanent fish life propagation, immersion recreation, limited contact recreation, wildlife propagation and stockwatering.

All streams in South Dakota are assigned the beneficial uses of irrigation, wildlife propagation, and stock watering. Certain sections of Firesteel Creek also have the following beneficial use classifications: 1) Firesteel Creek from the James River to its confluence with the west fork of the Firesteel Creek (warm water permanent fish life propagation and limited contact recreation); 2) Firesteel Creek from its confluence with the west fork of Firesteel Creek to South Dakota Highway 34 (warm water semipermanent fish life propagation and limited contact recreation); and 3) the west fork of Firesteel Creek from Firesteel Creek to Wilmarth Lake (warm water marginal fish life propagation and limited contact recreation).

Although some upstream segments of Firesteel Creek have less stringent water quality criteria, they must not cause the more stringent criteria of downstream waters to be exceeded (Table 1).

Impairments to reservoir water quality include nutrient and sediment loading from the Firesteel Creek drainage as well as sediments and nutrients derived from streambank and lakeshore erosion. Secondary sources of nutrients and primary sources of fecal coliform contamination may be overgrazing on streamside land, runoff from watershed livestock operations, and seepage from individual septic tank systems around the reservoir periphery.

C. Land Use

Land use in the watershed is predominantly agricultural. Approximately 41% is estimated to be cropland and 59% rangeland or pasture. SCS estimated that about 58% of the watershed had been adequately treated in 1981.

At least half of the reservoir shoreline has been developed. Included are lakeside residences, beaches, and public access areas.

D. Climate, Geology, and Major Soils

Climate

The climate of southeastern South Dakota is continental with cold, dry winters, and relatively short springs marked by appreciable rainfall and rapid weather changes. About 70% of recorded yearly precipitation falls during the growing season (April-August) with highest precipitation occurring in June.

ARSD 74:03:02:30. Beneficial Uses of Public Waters Established

Parameters	1 Domestic water supply	2 Cold water permanent fish life propagation	3 Cold water marginal fish life propagation	4 Warm water permanent fish life propagation	5 Warm water semipermanent fish life propagation	6 Warm water marginal fish life propagation	7 Immersion recreation	8 Limited contact recreation	9 Wildlife propagation and stock watering	10 Irrigation waters (May 15 - Sept. 30)	11 Commerce and industry
Alkalinity, Total as $CaCO_3$ mg/l									750		
Arsenic mg/l	.05										
Barium mg/l	1.0										
Cadmium mg/l	.01										
Chloride mg/l	250	100									
Chlorine, Total Residual mg/l		.02	.02	.02	.02	.02					
Chromium mg/l	.05										
Coliform #/100 ml	5000										
Coliform Fecal #/100 ml							200	1000			
Conductivity Micromhos/cm @ 25° C									4000	2500	
Cyanide, Free mg/l		.005	.005	.005	.005	.005					
Cyanide, Total mg/l		.02	.02	.02	.02	.02					
Hydrogen Sulfide		.002	.002	.002	.002	.002					
Lead mg/l	.05										
Mercury mg/l	.002										
Nitrogen, Nitrates as N mg/l	10										
Nitrogen, Ammonia as N mg/l		.02	.02	.04	.04	.05			50		
Oxygen, Dissolved mg/l		6.0	5.0	5.0*	5.0	4.0	5.0	5.0			
Oxygen, Dissolved mg/l (spawning areas)		7.0		6.0*							
pH, Standard Units	6.5-9	6.6-8.6	6.5-8.5	6.5-9	6.3-9	6-9	6.5-8.3	6-9	6-9.5		6-9.5
Polychlorinated biphenyls		.000001	.000001	.000001	.000001	.000001					
Selenium mg/l	.01										
Sodium, absorption ratio										10	
Solids, suspended mg/l		30	90	90	90	150					
Solids, Total Dissolved mg/l	1000								2500		2000
Sulfate mg/l	500										
Temperature, Fahrenheit		65	75	80	90	90					
Silver mg/l	.05										
Fluoride mg/l	2.4										

* Greater than 6.0 in Big Stone and Traverse Lakes, May-April

Table 1.

Average minimum and maximum temperatures are 62° and 91°F in July; 6° and 28°F in January. Mean annual temperature is 47°F. Average annual precipitation and lake evaporation amount to 22 inches and 37 inches, respectively.

Geology

Most of the soils in the Firesteel Creek watershed formed in glacial material (drift) that was derived from preglacial formations of granite, gneiss, limestone, sandstone, and shale. The glacier ground up and mixed these materials as it transported them. It then redeposited them as it melted. Some deposits are unsorted material or glacial till; others are sorted either by water during deposition (outwash) or by wind after deposition (loess).

Major Soils

According to soil surveys conducted by the SCS in the watershed, the following major soil associations are found in the Firesteel Creek drainage area (Koth, 1981):

Houdeck-Prosper: Nearly level to gently undulating, well drained, and moderately well drained soils.

Houdeck-Stickney: Nearly level, well and moderately well drained, loamy soils formed in glacial till; on uplands.

Beadle-Stickney-Dudley: Nearly level, deep, loamy, well drained, and moderately well drained silty soils with claypan subsoils that formed in glacial till; on uplands.

Clarno-Houdeck Belts: Nearly level to steep, well to excessively drained, loamy soils formed in glacial till; on uplands.

Lane: Nearly level to gently sloping, well drained silty soils that formed in local clayey alluvial sediments.

II. Firesteel Creek/Lake Mitchell Water Quality Study Area Selection

Nominations for designation as a Water Quality Study Area (WQSA) within the Third Planning and Development District were solicited by DWNR from the Third District Commission. In February, 1980, nominations were open to all commissioners and the following watersheds were nominated: Burke Lake (Gregory County); Corsica Lake (Douglas County); State Lake (Yankton County); Wolf Creek (Hutchinson County); Firesteel Creek/Lake Mitchell (Davison County); and Rock Creek (Hanson County).

The criteria established for ranking purposes were the State Lakes Preservation Committee criteria, the South Dakota Lake Significance Ranking criteria, input from the Third Planning and Development District Commission, the availability of land use and soils data, plus water quality data and identification of water problems in the watershed. Each nominated watershed was examined under the same criteria.

The Firesteel Creek/Lake Mitchell watershed received designation as the WQSA in the Third Planning and Development District for 1980. The reasons for selecting this area for study included, that it is the source of community drinking water for the City of Mitchell, that it has been studied extensively in the past, and there had been a great deal of money spent on bank stabilization projects along Lake Mitchell.

III. Soil Erosion and Sediment Yield Summary

SCS conducted soil erosion and sediment yield studies of the Firesteel Creek/Lake Mitchell watershed during 1980 and 1981. The studies detailed the type and extent of erosion and sedimentation problems including the contribution from cropland, grassland, streambanks, gullies, and other sources. Detailed results of these studies are presented in Appendix A.

SCS estimated erosion in the watershed to be 308,318 tons per year with total sediment deposited in Lake Mitchell at 8,158 tons or 6.81 acre-feet per year. About 79% of this sediment is derived from watershed erosion, primarily from cropland, 13% from lakeshore erosion, and 8% from gully and streambank erosion.

SCS selected Best Management Practices (BMPs) for the watershed to reduce sediment and nutrients to Lake Mitchell. Examples of needed conservation practices are crop residue use, conservation tillage, proper range, and agricultural waste management, deferred grazing, proper grazing use, and seeding adapted grasses on critical erosion areas. Total cost for application of BMPs was at $1,062,920 or $4.62 per acre (Table 2). The SCS estimated that 132,665 acres or about 58% of the Firesteel Creek/Lake Mitchell watershed was adequately treated in 1981.

IV. Water Quality Status Report for Firesteel Creek/Lake Mitchell

Lake Mitchell is an impoundment of Firesteel Creek and is located in Davison County, South Dakota (Latitude 43 Deg., 45 Min., 0 Sec. N., Longitude 98 Deg., 2 Min., 6 Sec. W., Township 103, 104N, Range 60W, and Sections 4, 5, 9, 31, 32). Firesteel Creek is the major inflow. The major

Table 2.

BEST MANAGEMENT PRACTICES (Conservation Practices and Measures) 1/ 2/ 3/
FIRESTEEL CREEK - LAKE MITCHELL WATERSHED AREA

Conservation Practices	Unit	Unit 4/ Cost	Subwatershed "A"		Subwatershed "B"		Subwatershed "C"		Total Watershed	
			Amount Needed	Cost	Amount Needed	Cost	Amount Needed	Cost	Amount Needed	Cost
		(Dollars)		(Dollars)		(Dollars)		(Dollars)		(Dollars)
Cropland-97,728 Acres										
Conservation Cropping System	acre	-	8,836	-	70,844	-	18,048	-	97,728	-
Conservation Tillage System	acre	5	8,836	44,180	70,844	354,220	18,048	90,240	97,728	488,640
Grass & Legumes in Rotation	acre	18	904	16,272	7,249	130,482	1,847	33,246	10,000	180,000
Grass Waterways	acre	500	5	2,500	44	22,000	11	5,500	60	30,000
Waste Utilization	acre	3	814	2,442	6,524	19,572	1,662	4,986	9,000	27,000
Minimize Fall Tillage	acre	-	1,808	-	14,498	-	3,694	-	20,000	-
Pasture & Hayland Planting	acre	20	362	7,240	2,900	58,000	738	14,760	4,000	80,000
Minimize Pesticide Use	acre	-	452	-	3,625	-	923	-	5,000	-
Windstrip Cropping	acre	6	542	3,252	4,350	26,100	1,108	6,648	6,000	36,000
Terraces	mile	2,112	.5	1,056	3.5	7,392	1.0	2,112	5	10,560
			40,391		53,139		29,534			
Grassland -123,064 Acres										
Proper Grazing Use	acre	-	30,195		39,731		22,674	-	92,000	-
Pasture and Hayland Planting	acre	20	985	19,700	1,295	25,900	720	14,400	3,000	60,000
Deferred Grazing	acre	-	14,770	-	19,430	-	10,800	-	45,000	-
Planned Grazing Systems	acre	-	9,845	-	12,955	-	7,200	-	30,000	-
Livestock Water Stations	No.	1,000	3	3,000	4	4,000	3	3,000	10	10,000
Critical Area Planting	acre	1,000	7	7,000	9	9,000	4	4,000	20	20,000
Pasture & Hayland Management	acre	-	9,845	-	12,955	-	7,200	-	30,000	-
Waste Management Systems	No.	20,000	1	20,000	3	60,000	0		4	80,000
Wildlife Upland Habitat Mgmt.	acre	5	26	130	35	175	19	95	80	400
Wildlife Wetland Habitat Mtnce.	acre	4	26	104	35	140	19	76	80	320
Farmsteads, Urban & Other, 8,448 acres										
Sediment Control Measures 5/	acre	2,000	2	4,000	18	36,000	0	-	20	40,000
TOTALS - Total acres - 229,911 acres		-	-	130,876	-	752,981	-	179,063	-	1,062,920 or 4.62 per acre

1/ Needed to get (Land Adequately Treated).
2/ Refer to Soil Conservation Service Technical Guide for South Dakota 1981.
3/ On site investigation and planning are necessary to determine kinds, locations, sizes, extent & costs of practices (BMP's).
4/ Refer to Soil Conservation Service Cost-Return Handbook for South Dakota 1981.
5/ Examples of measures are: cover and green manure crop, filter strips, lined and grassed waterways, diversions, mulching, sediment basins, streambank protection, and critical area planting.

outflow is at the dam and water is released back into Firesteel Creek. Morphological characteristics of Lake Mitchell are given below:

Area	671 A (271.3 ha)
Shoreline Length	52,800 ft. (16,093 m)
Maximum Depth	29 ft. (8.8 m)
Mean Depth	12.2 ft. (3.7 m)
Volume	8,207 acre-feet ($1.012 \times 10^7 m^3$)
Watershed/Lake Surface Area Ratio	343
Origin of Lake Basin	Impoundment
Thermal Stratification	Yes

The following beneficial uses have been assigned to Lake Mitchell by the State of South Dakota.

° Domestic water supply;

° Warm water permanent fish life propagation;

° Immersion recreation;

° Limited contact recreation; and

° Wildlife propagation and stock watering.

Twelve sampling sights were chosen to monitor the Firesteel Creek/Lake Hanson system. Three of the sites (Sites 2, 3, and 6) were in-lake sites. The remaining were located on Firesteel Creek (Sites 1, 4, 7, 8, 9, 10, 11, and 12) and one small tributary (Site 5) of Lake Mitchell. Table IV-1 and Figure 2 describe in detail the location of the sampling sites.

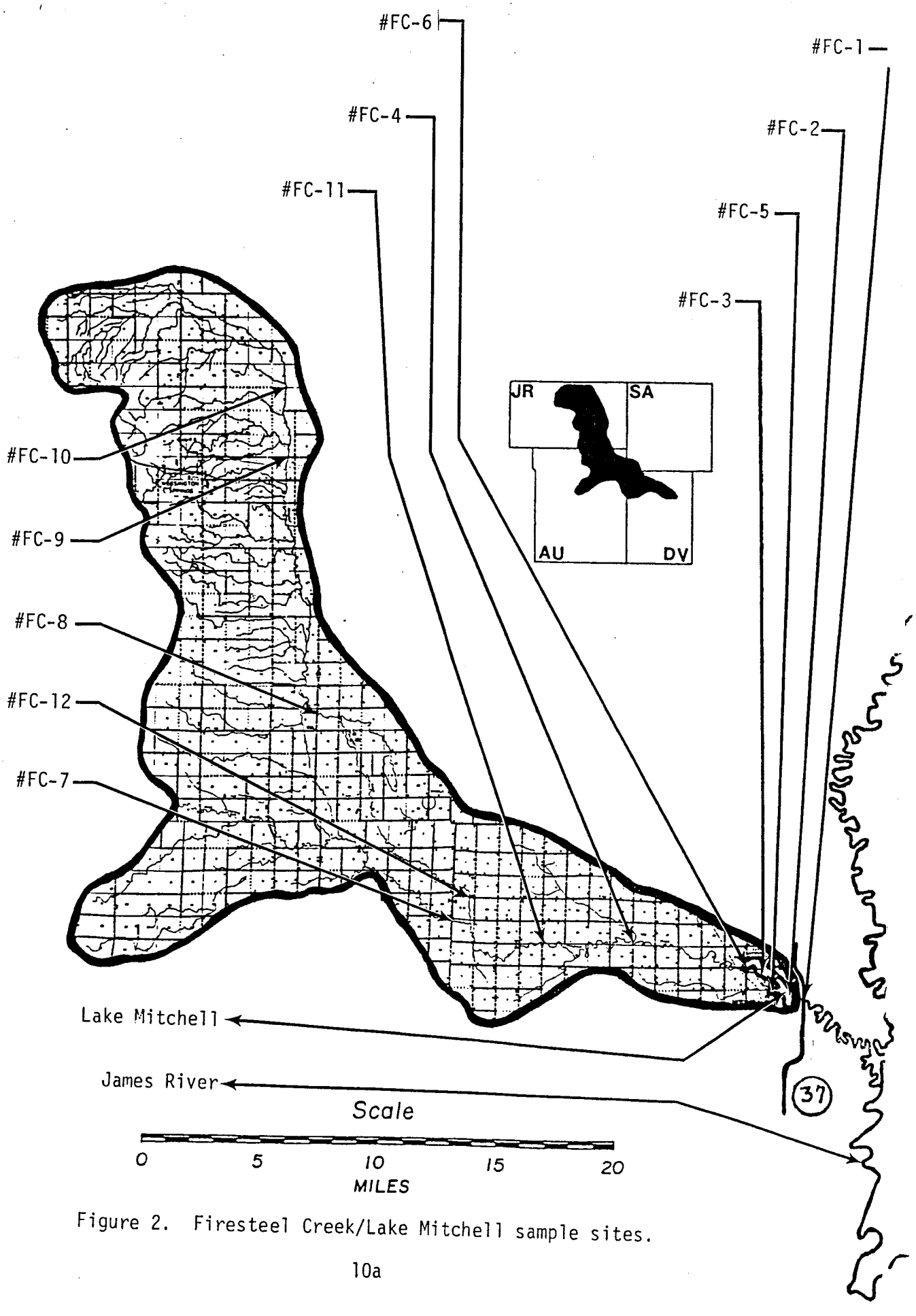

Figure 2. Firesteel Creek/Lake Mitchell sample sites.

Site	Description
46FC01 (FC-1)	Latitude 43 Deg., 44 Min., 25 Sec., Longitude 98 Deg., 1 Min., 32 Sec., Township 103N, Range 60W, Section 10. NE1/4, SW1/4, SW1/4, NW1/4. This site is located on the east side of the bridge over the spillway on Highway #37 north.
46FC02 (FC-2)	Latitude 43 Deg., 44 Min., 39 Sec., Longitude 98 Deg., 1 Min., 34 Sec., Township 103N, Range 60W, Section 10. SE1/4, NW1/4, NW1/4, NW1/4. This in-lake site is located in the northeast corner of Lake Mitchell, 0.5 miles north of the outlet.
46FC03 (FC-3)	Latitude 43 Deg., 45 Min., 22 Sec., Longitude 98 Deg., 3 Min., 26 Sec., Township 103N, Range 60W, Section 5. NW1/4, NW1/4, SW1/4, NE1/4. This in-lake site is located just off the west side of the boat ramp, .75 miles southeast of the Firesteel Creek inlet.
46FC04 (FC-4)	Latitude 43 Deg., 46 Min., 43 Sec., Longitude 98 Deg., 9 Min., 58 Sec., Township 104N, Range 61W, Section 28. SW1/4, SW1/4, NW1/4, SW1/4. This site is located 4.5 miles west of Lake Mitchell and .25 miles north on the road marked "travel at own risk".
46FC05 (FC-5)	Latitude 43 Deg., 44 Min., 41 Sec., Longitude 98 Deg., 2 Min., 51 Sec., Township 103N, Range 60W, Section 8. SE1/4, NE1/4, NE1/4, NE1/4. This site is located at the concrete bridge 1.5 miles south 100 feet west of the Firesteel Creek inlet.
46FC06 (FC-6)	Latitude 43 Deg., 45 Min., 34 Sec., Longitude 98 Deg., 4 Min., 14 Sec., Township 103N, Range 60W, Section 6. NE1/4, NW1/4, NE1/4, NE1/4. This in-lake site is near the bridge that spans the Firesteel Creek inlet.
46FC07 (FC-7)	Latitude 43 Deg., 47 Min., 22 Sec., Longitude 98 Deg., 19 Min., 32 Sec., Township 104N, Range 62W, Section 25. NE1/4, NE1/4, NE1/4, NE1/4. This site is located 50 feet approximately WNW of bridge, 12 miles west and 2 miles north of Firesteel Creek inlet.
46FC08 (FC-8)	Latitude 43 Deg., 55 Min., 9 Sec., Longitude 98 Deg., 27 Min., 4 Sec., Township 105N, Range 63W, Section 7. SW1/4, SW1/4, NW1/4, NW1/4. This site is located 19 miles west and 11 miles north of the Firesteel Creek inlet.
46FC09 (FC-9)	Latitude 44 Deg., 4 Min., 3 Sec., Longitude 98 Deg., 28 Min., 46 Sec., Township 107N, Range 64W, Section 23. NE1/4, NW1/4, NW1/4, NE1/4. This stream site is located 1.5 miles west of the junction of Highways 34 and 281 on Highway 34.
46FC10 (FC-10)	Latitude 44 Deg., 6 Min., 40 Sec., Longitude 98 Deg., 28 Min., 58 Sec., Township 107N, Range 64W, Section 2. NE1/4, NE1/4, NE1/4, NW1/4. This stream site is located 3 miles north and

Figure 2 (cont.). Firesteel Creek/Lake Mitchell sample site descriptions.

	1.5 miles west of the junction of Highways 34 and 281, ten feet south of north fence along road.
46FC11 (FC-11)	Latitude 43 Deg., 46 Min., 36 Sec., Longitude 98 Deg., 14 Min., 44 Sec., Township 104N, Range 62W, Section 27. NE1/4, SE1/4, SE1/4, SE1/4. This stream site is located 9 miles west and 1 mile north of the Firesteel Creek inlet.
46FC12 (FC-12)	Latitude 43 Deg., 48 Min., 16 Sec., Longitude 98 Deg., 18 Min., 32 Sec., Township 104N, Range 62W, Section 19. NE1/4, NE1/4, NW1/4, NE1/4. This stream site is located 3 miles north and 11 miles west of the Firesteel Creek inlet or 3 miles west and 2 miles north of Site 11.

B90601HB.wq

Figure 2 (cont.). Firesteel Creek/Lake Mitchell sample site descriptions.

The monitoring program was operational from 1981 to 1983. Most of the sampling during 1981 and 1983 was limited to the spring and summer months. During 1982, sampling was more intensive although the spring and summer months were also the months of highest sampling frequency.

The following parameters were monitored to assess the water quality of Firesteel Creek and Lake Mitchell: dissolved oxygen; fecal coliforms; pH; total solids; total suspended solids; total dissolved solids; nitrate; nitrite; ammonia, total Kjeldahl nitrogen; orthophosphate; and total phosphorus.

Summary statistics of the data are presented in Tables IV-2 to IV-24. Violation of the parameters' criteria or limits relative to an assigned beneficial use are given in Tables IV-25 to IV-48. Tables IV-49 to IV-52 show summary statistics or inorganic and organic nitrogen concentrations. Finally, graphical presentations of the data are given in Figures IV-1 to IV-190. Tables and Figures IV-1 to IV-190 are contained in Appendix B.

Dissolved Oxygen (DO)

The State of South Dakota has assigned the beneficial use of warm water permanent fish life propagation to Lake Mitchell. Therefore, DO concentrations should not decrease below 5.0 mg/l.

In general, DO concentrations were adequate (Tables IV-2 to IV-24 and Figures IV-1 to IV-12). Annual mean values for all the sampling sites ranged from 6.3 to 11.0 mg/l. Three exceedences occurred during the monitoring program: at Site 6 on 4 June 1982, 4.6 mg/l; and at Site 8 on 20 May 1982, 4.6 mg/l; and at Site 9 on 14 June 1983, 4.4 mg/l. Spatial or temporal differences or trends were not apparent.

Fecal Coliforms

Lake Mitchell is used for immersion recreation; therefore, fecal coliform counts should not exceed 400/100 ml in any one sample from May 1 to September 30.

The annual means for in-lake Sites 2, 3, and 6 ranged from 7 to 248/100 (Tables IV-2 to IV-24). In addition, only three exceedences occurred out of 46 fecal coliform counts which is about 7% of the in-lake samples. These data indicate that fecal coliforms are generally not a problem in Lake Mitchell.

Some reaches of Firesteel Creek are used for limited contact recreation; therefore, fecal coliforms should not exceed 1000/100 ml. The annual means of stream Sites 1, 4, 5, and 7 through 12 ranged from 12 to 3675/100 ml. Twenty out of seventy-seven samples (about 30%) exceeded 1000/10 ml when the limited contact recreation criterion is used. Using the immersion recreation criterion, about 40% of the samples would be violations. It is clear that fecal coliforms are excessive in Firesteel Creek. Although these high fecal coliform levels have not been reflected in the lake data, these coliforms may potentially pose a health hazard to users of Lake Mitchell and Firesteel Creek.

pH

The pH criterion for surface waters in South Dakota which are used for immersion recreation ranges from 6.5 to 8.3 units, this range applies to Lake Mitchell.

The pH values ranged from 6.3 to 9.0 and about 86% of the samples complied with the criterion (Tables IV-2 to Iv-48). The highest percentage of violations occurred with in-lake samples (Sites 2 and 3) and the tributary samples (Site 5). Samples taken from Firesteel Creek (Sites 4, 7-12) and in-lake Site 6 near the inlet violated the criterion 0 to 11% of the time whereas those sites

which were lake related (Sites 2 and 3 and outlet Site 1) violated the criterion 22 to 42% of the times sampled. Also, 40% of the samples from tributary Site 5 violated the criterion. These data imply that either the small tributary is having a large influence on Lake Mitchell pH or that in-lake processes are largely determining in-lake pH levels.

Total Solids, Suspended Solids, Total Dissolved Solids

The State of South Dakota does not have a standard for total solids concentrations. The 1981 samples had total solids concentrations ranging from 811 to 2,277 mg/l with a mean of 1,215 mg/l. In 1982, the concentrations ranged from 92 to 1,346 mg/l with a mean of 582 mg/l. In 1983, the mean concentration of total solids was 787 mg/l and ranged from 628 to 1,112 mg/l (Tables IV-2 to IV-24). Seasonal trends were not apparent (Figures IV-37 to IV-48).

Lake Mitchell has been assigned the beneficial use of warm water permanent fish life propagation; therefore, suspended solids concentrations must not exceed 90 mg/l. The annual means of all samples combined for 1981, 1982, and 1983 were 27, 36, and 49 mg/l. These values are not considered excessive. Thirteen violations occurred during the study and most of these were less than 150 mg/l. Only one violation involved an in-lake site and twelve violations were from stream waters. Some of these violations coincided with observed high flows, erosion, or road construction.

Since Lake Mitchell is used as a domestic water supply, total dissolved solids concentrations should not exceed 1,000 mg/l. This limit was never exceeded by water taken from in-lake Sites 2, 3, and 6 which had values ranging from 141 to 893 mg/l (Tables IV-2 to IV-24). Some stream site water samples, however, exceeded 1,000 mg/l and these comprised about 11% of the stream samples. These

violations had total dissolved solids concentrations ranging from 1,064 to 1,312 mg/l. Nine out of the eleven violations occurred in May and these may partially be a result of spring rains and high erosion.

Nitrate

Since Lake Mitchell is used for domestic water supply, nitrate nitrogen concentrations must not exceed 10 mg/l in order to comply with the surface water quality standards of South Dakota.

The nitrate nitrogen concentrations of the water samples were far below 10 mg/l (Tables IV-2 to IV-24 and Figures IV-73 to IV-84). The sample means for 1981, 1982, and 1983 were; less than .10 mg/l, .23 mg/l, and less than .10 mg/l, respectively. During 1982, the values ranged from below the detection limit to 1.6 mg/l and about 70% of the sample were below .10 mg/l. As with nitrite nitrogen, many of the samples containing nitrate nitrogen greater than .10 mg/l were collected on 22-23 February. In general, nitrate nitrogen concentrations were sufficiently low to enable domestic water supply use without the danger of nitrate pollution.

Nitrite

No State standards exist for nitrite nitrogen in South Dakota. However, nitrite concentrations in natural waters are usually between 0 and .01 mg/l (Wetzel, 1975).

The analytical detection limit for this parameter is .01 mg/l and this level was never exceeded in 1981 and 1983 (Tables IV-2 to IV-24 and Figures IV-85 to IV-96). Nitrite nitrogen concentrations greater than .01 mg/l did occur in 1982. The mean of all samples taken in 1982 was .013 mg/l and this value is not

appreciably greater than the detection limit. In fact, 94% of the samples had nitrite nitrogen concentrations less than .01 mg/l. Of the remaining 6% (10 samples), seven of these were collected on 22-23 February. This suggests either analytical error or a temporary but widespread phenomenon which is causing nitrite pollution.

Ammonia

The State of South Dakota has assigned to Lake Mitchell the beneficial use of warm water permanent fish life propagation. Therefore, un-ionized ammonia nitrogen concentrations must not exceed .04 mg/l.

This limit was never exceeded during the 1981-1983 monitoring program. The sampling sites' means ranged from .0008 to .0039 mg/l (Tables IV-2 to IV-24). These levels are relatively low.

Inorganic and Organic Nitrogen

Inorganic nitrogen concentrations were calculated by adding together nitrite nitrogen, nitrate nitrogen, and ammonia nitrogen concentrations. Many of the nitrite and nitrate nitrogen concentrations were below the detection limits of .01 and 0.1 mg/l, respectively. These data were assumed to be the same concentration as the appropriate detection limit. In addition, a general relationship between trophic state and epilimnetic nitrogen concentrations was used to relate the inorganic and organic nitrogen concentrations to trophic state (see Wetzel, 1975; Table 11-4).

The inorganic nitrogen concentrations of water from in-lake Sites 2, 3, 6 ranged from 0.13 to 1.43 mg/l and these data indicated ultra-oligotrophy to eutrophy (Tables IV-49 to IV-52). The annual mean inorganic nitrogen concentrations

ranged from 0.14 to 0.48 mg/l and indicated ultra-oligotrophy to meso-eutrophy. The water samples taken from the stream sites exhibited a wide range of values (0.13 to 3.00 mg/l) which implied ultra-oligotrophy to hypereutrophy.

Organic nitrogen concentrations were calculated by subtracting ammonia nitrogen concentrations from total Kjeldahl nitrogen concentrations. The organic nitrogen concentrations determined for in-lake Sites 2, 3, and 6 ranged from 0.04 to 2.59 mg/l and suggested ultra-oligotrophy to hypereutrophy. The annual means of the same sites ranged from 0.48 to 1.07 mg/l and implied meso-eutrophy to eutrophy. Water from the stream sites had organic nitrogen concentrations ranging from 0.02 to 2.36 mg/l. These data indicated ultra-oligotrophy to hypereutrophy.

In general, organic nitrogen is the major form of nitrogen in Firesteel Creek and Lake Mitchell. Organic nitrogen comprised from 55 to 90% of the total nitrogen in the samples.

Phosphorus

Three forms of phosphorus were monitored: total phosphorus (TP), orthophosphate (OP), and orthophosphate plus hydrolyzable phosphorus. Total phosphorus concentrations were determined throughout the study duration and OP concentrations were determined only in 1983. Orthophosphate plus hydrolyzable phosphorus concentrations were determined in 1981 and 1982 but were called OP in the Tables and Figures.

Although the State of South Dakota has not set any surface water standards for phosphorus, phytoplankton may be largely dependent on the soluble inorganic phosphorus available in the water column. In addition, total phosphorus has been commonly used as an index of lake productivity and trophic state.

One such index was proposed by Reckhow, et al., (1980) which related TP concentration to trophic state. This index is used in this report. In the index, TP concentrations between .02 and .05 mg/l are indicative of eutrophy and TP concentrations greater than .05 mg/l suggest hypereutrophy.

The OP concentrations of water from in-lake Sites 2, 3, and 6 ranged from .005 to .084 mg/l and the annual mean OP concentrations ranged from .010 to .039 mg/l (Table IV-2 to IV-24 and Figures IV-167 to IV-178). In general, the OP concentrations were higher in Firesteel Creek than in Lake Mitchell. This phenomenon could be due to algal uptake of OP in Lake Mitchell.

Orthophosphate plus hydrolyzable phosphorus concentrations from in-lake Sites 2, 3, and 6 ranged from .005 to .440 mg/l and the annual mean concentrations ranged from .033 to .146 mg/l. The stream sites had concentrations ranging from .017 to 1.52 mg/l and annual means from .040 to .823 mg/l (Tables IV-2 to IV-24).

The TP concentrations of water from in-lake Sites 2, 3, and 6 ranged from .031 to .495 mg/l. The annual mean TP concentrations from these sites ranged from .060 to .232 mg/l and denoted hypereutrophy. The stream sites had TP concentrations ranging from .058 to 2.31 mg/l. These concentrations also indicate hypereutrophy. Seasonally, TP concentrations were greatest in the spring and early summer (Figures IV-179 to IV-190).

Trophic State Index

Carlson's (1977) total phosphorus trophic state index was used to describe the trophic state of Lake Mitchell. This index uses a scale of 0 to 100 instead of the traditional descriptions (i.e., oligotrophic, mesotrophic, and eutrophic). Values greater than 50 are characteristic of eutrophic lakes (Carlson, 1979).

According to Carlson's Index, Lake Mitchell is eutrophic. The mean values for in-lake Sites 2, 3, and 6 were 67.65, 71.41, and 76.35, respectively (Table IV-53). Appreciable differences in the values between sampling years 1981, 1982, and 1983 were not apparent.

Nutrient Limitation

Total nitrogen:total phosphorus weight ratios were used to determine limiting nutrient in Lake Mitchell. Ratios below a value of 15 are indicative of nitrogen limitation and ratios above 15 are indicative of phosphorus limitation. Forsberg (1980) suggested that values between 10 and 17 indicate nutrient co-limitation.

The total nitrogen concentrations were calculated by adding together the concentrations of total Kjeldahl nitrogen, nitrite, and nitrate. In many cases the nitrite and/or nitrate concentrations were below the analytical detection limit. Therefore, for calculation purposes, these nitrite and nitrate concentrations were assumed to be the concentrations of the detection limits.

The nutrient ratios of samples taken from in-lake Sites 2, 3, and 6 suggested either nitrogen or co-limitation (Table IV-54). This was not unexpected and nitrogen limitation is common for lakes in eastern South Dakota (see SDDWNR, 1981).

Nutrient Loading

Total nitrogen and total phosphorus loadings were calculated with existing streamflow and nutrient concentration data. Only flow data collected in 1982 were adequate to estimate annual loads. The areal total nitrogen and total phosphorus loadings to Lake Mitchell during 1982 were 2.65 and 0.50 $g/m^2/yr$,

respectively. According to the dangerous loading levels proposed by Vollenweider (1968), these nutrient loads are dangerous.

Summary

Lake Mitchell is a shallow (mean depth 3.7 meters) impoundment of Firesteel Creek located in Davison County, South Dakota. The lake has been assigned the following beneficial uses.

° Domestic water supply;

° Warm water permanent fish life propagation;

° Immersion recreation;

° Limited contact recreation; and

° Wildlife propagation and stock watering.

The results of the 1981-1983 monitoring of Firesteel Creek and Lake Mitchell are summarized below:

1. Dissolved oxygen concentrations were usually greater than 5.0 mg/l and were not considered dangerously low.

2. Fecal coliforms were excessive in Firesteel Creek. About 30% of the Firesteel Creek samples violated the 1,000/100 ml criterion for limited contact recreation. Lake Mitchell was generally free of high fecal coliform levels. Only about 7% of its samples were greater than 400/100 ml.

3. The pH values ranged from 6.3 to 9.0 and about 86% of the samples complied with the 6.5-8.3 criterion. Values of pH greater than 8.3 were usually found in water taken from Lake Mitchell.

4. Total solids concentrations ranged from 92 to 2,277 mg/l. The annual means of all samples during 1981, 1982, and 1983 were 1,215, 582, and 787 mg/l.

5. Suspended solids concentrations were never greater than 90 mg/l, the standard applied to Lake Mitchell, and were not considered excessive.

6. Water from Lake Mitchell never exceeded the 1,000 mg/l limit for total dissolved solids. Some water samples taken from Firesteel Creek had total dissolved concentrations greater than 1,000 mg/l. These samples comprised about 11% of the samples taken on Firesteel Creek.

7. Nitrate and nitrite nitrogen concentrations were far below dangerous levels. Seventy and ninety-four percent of the samples analyzed for nitrate and nitrite nitrogen, respectively, had concentrations below the analytical detection limits.

8. Un-ionized ammonia concentrations never exceeded the .04 mg/l critical limit. Mean values ranged from .0008 to .0039 mg/l.

9. Water taken from in-lake Sites 2, 3, and 6 had inorganic nitrogen concentrations ranging from .013 to 1.43 mg/l. These levels indicated ultra-oligotrophy to eutrophy. Annual mean values indicated similar conditions although the upper limit was meso-eutrophy rather than eutrophy. The stream sites exhibited a wide range of organic nitrogen concentrations (0.13 to 3.00 mg/l) and indicated ultra-oligotrophy to hypereutrophy.

10. Organic nitrogen is the major form of nitrogen in Lake Mitchell and Firesteel Creek and concentrations varied widely from 0.02 to 2.59 mg/l. Most of the concentrations were indicative of meso-eutrophy to eutrophy.

11. Orthophosphate concentrations of Lake Mitchell water samples ranged from .005 to .084 mg/l. The annual mean OP concentrations of water from Sites 2, 3, and 6 ranged from .010 to .039 mg/l.

12. Total phosphorus concentrations ranged from .031 to .495 mg/l in water from Lake Mitchell. These values denote eutrophic to hypereutrophic conditions. The stream sites also had hypereutrohpic levels of total phosphorus.

13. According to Carlson's (1977) total phosphorus trophic state index, Lake Mitchell is eutrophic. Mean values ranged from 67.65 to 76.35.

14. Total nitrogen:total phosphorus weight ratios were usually less than 15:1 and indicated nitrogen limitation for Lake Mitchell.

Recommendations

Firesteel Creek has two major problems; excessive amounts of nitrogen and phosphorus, and high numbers of fecal coliforms. Although the fecal coliforms in Firesteel Creek did not seem to have an impact on Lake Mitchell, the potential for a health hazard is present. Fecal Coliforms are generally indicative of fecal contamination by warm blooded animals. On Firesteel Creek, cattle have been observed in the creek on numerous occasions and these animals could be causing high fecal coliform levels. If this is true, then keeping cattle (and cattle feces) away from the creek could lead to a decrease in fecal coliform levels. It is recommended that a statistically sound monitoring program be conducted to discern whether specific areas of high livestock density are linked to high fecal coliform levels.

The high nutrient levels in Firesteel Creek undoubtedly has an impact on Lake Mitchell and decreasing these nutrient loads may indirectly improve Lake Mitchell's water quality. The effectiveness of decreasing nutrient loading from Firesteel Creek cannot be estimated accurately until it is known whether the lake sediments contribute significant amounts of nitrogen and phosphorus to the overlying water. A study assessing the nutrient uptake and release capabilities of Lake Mitchell sediments is recommended.

V. Firesteel Creek/Lake Mitchell Watershed Problems and Recommendations

A. Watershed Problems and Recommendations

Problem:

Excessive nutrient and sediment loads from the Firesteel Creek watershed are primary causes for the present eutrophic condition of Lake Mitchell. The annual phosphorus and nitrogen areal loads to Lake Mitchell for 1982 were 0.50 and 2.65 g/m^2/year, respectively. For a lake with a mean depth of 5 meters or less, phosphorus and nitrogen loads greater than 0.13 and 2.0 g/m^2/year, respectively, are considered dangerous (Vollenweider, 1968).

A 1969 SCS report indicated that the reservoir had lost about 15.6% of its original water storage capacity since 1928 due to siltation primarily from the Firesteel Creek watershed and secondarily from shoreline erosion. Average annual siltation rates appear to have doubled since 1948 and further increases were reported by the 1981 SCS sediment yield study. Between 1958 and 1969, an average of 5.12 acre-feet of sediment per year was deposited in Lake Mitchell. Recent (1979) sedimentation rates have been estimated at 6.81 acre-feet per year or about .08% of reservoir water capacity. A comparison of the 1979 reservoir volume of 8,207 acre-feet with its original water capacity of 10,943 acre-feet in 1928, indicated that Lake Mitchell had lost 25% of its water storage capacity over its then 51-year life span.

Survey period only 1958-79 Should be 25.35

Fecal coliform levels were frequently excessive in Firesteel Creek during the study period. Twenty (20) out of 77 creek samples (30%) exceeded limited contact recreation standards (1,000/100 ml). Although these high coliform levels were not reflected in reservoir samples, they may indicate a potential a health hazard to users of Firesteel Creek and Lake Mitchell (Chapter IV).

Recommendations

Nutrient and sediment input to Lake Mitchell can be reduced by utilizing BMPs in the watershed. Appropriate BMPs include applying fertilizer management practices where needed, conservation tillage, and leaving crop residue to reduce erosion. Proper rangeland management should be used to prevent rangeland deterioration and streambank degradation. Vegetative sediment barrier strips can be seeded to protect overgrazed and eroding streamside land and thereby reduce sediment and nutrient input into the tributaries. Critical streamside erosion areas on lower Firesteel Creek need to be stabilized by appropriate structures.

Drainage patterns and nutrient contributions of existing livestock operations in the watershed need to be established and monitored to determine their impact on Lake Mitchell water quality. Appropriate waste treatment systems can then be constructed, where needed, to reduce nutrient levels and fecal coliform contamination entering the reservoir.

A comprehensive septic tank survey is required to establish the location of septic tank systems around the reservoir, their age,

construction, maintenance practices, and identify potential problem areas.

B. In-Lake Problems and Recommendations

Problems:

1. Eutrophication and Sedimentation

Eutrophication and loss of reservoir storage capacity are the principal problems in Lake Mitchell as evidenced by reduced water depth and clarity, high concentrations of phosphorus and nitrogen, and high reservoir algal densities.

Annual mean concentrations of organic nitrogen for in-lake sites in 1982 ranged from 0.48 to 1.07 mg/l. Corresponding values for total phosphorus ranged from .060 to .232 mg/l and are indicative of hypereutrophic conditions.

Recommendations

The watershed treatments recommended in the previous section will help alleviate the nutrient and sediment problems in Lake Mitchell. Following watershed stabilization, in-lake treatments such as selective dredging and chemical phosphorus precipitation may be considered. The latter involves the application of a chemical such as aluminum sulfate (alum) to the reservoir surface to tie up the soluble phosphorus which forms a precipitate, settles out, and creates a partial bottom seal. Treatment may have to be repeated every 1 to 3 years depending on lake conditions. Cost effectiveness of both in-lake treatments should be determined before any action is taken.

2. Shoreline Erosion

Lakeshore erosion contributes 1,060 tons (0.9 acre-foot) or about 13% of the total sediment volume deposited in Lake Mitchell each year.

Recommendations

Lake shoreline stabilization normally involves shaping existing slough banks to a flatter, stable 3:1 slope by cut and/or fill, placing stone riprap in the new slope and establishing grass above the riprap.

VI. Summary and Conclusions

The future use of Lake Mitchell, particularly as a source of drinking water for the City of Mitchell, will require management efforts to be focused in two areas. First, due to the large watershed drained by Firesteel Creek (230,000 acres) and the rate of accumulation of bottom sediments in the reservoir, loss of reservoir volume may become a significant problem with the passage of time. Efforts should be made to compare past with the most recent sedimentation rates and project when reservoir volume losses will become critical. Based on these estimates, efforts can be directed at dealing with sediment in the watershed and/or by selective dredging of Lake Mitchell.

Second, a significant amount of development is currently being planned on the James River. Future projects may have an impact on Lake Mitchell since water is diverted from the James River to Lake Mitchell. However, Lake Mitchell's diversion should have top priority since it is for public

consumption. The future use of Lake Mitchell therefore requires that the needs of the reservoir be considered in plans for any development projects and in the management of any diversions to the reservoir.

References Cited

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanoga. 22:361-369.

Carlson, R.E. 1979. A review of the philosophy and construction of trophic state indices. Pages 1-52 In T. Maloney, ed., Lake and reservoir classification systems. Ecol. Res. Ser. Environmental Protection Agency. EPA 600/3-79-074. Washington, D.C.

Forsberg, C. 1980. Present knowledge on limiting nutrients, p. 37. In restoration of lakes and inland waters. U.S. Environmental Protection Agency. EPA 440/5-81-010. Washington, D.C.

Koth, R.M., 1981. South Dakota Lakes Classification and Inventory. South Dakota Department of Water and Natural Resources, Office of Water Quality. 693 pp.

Reckhow, K.H., 1980. Beaulac, and J.T. Simpson, 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. U.S. Environmental Protection Agency. EPA 440/5-80-011. Washington, D.C. 214 p.

South Dakota Department of Water and Natural Resources, Office of Water Quality. 1981. South Dakota Lakes Classification and Inventory. Final report. Joe Foss Building. Pierre, South Dakota. 693 p.

Vollenweider, R.A., 1968. Scientific fundamentals of the eutrophication of lakes and flowing waters with reference to nitrogen and phosphorus as factors in eutrophication. O.E.C.D., Council Report. 155 pp.

Wetzel, R.G. 1975. Limnology. W.B. Saunders Company, Philadelphia. 743 p.