VARIATIONS IN LAND USE AND NONPOINT-SOURCE CONTAMINATION ON THE FORT BERTHOLD INDIAN RESERVATION, WEST-CENTRAL NORTH DAKOTA, 1990-93

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By Kathleen M. Macek-Rowland *and* Robert M. Lent

ABSTRACT

The effects of land-use activities on the water quality of five streams on the Fort Berthold Indian Reservation were evaluated. The five basins evaluated were East Fork Shell Creek, Deepwater Creek, Bear Den Creek, Moccasin Creek, and Squaw Creek. East Fork Shell Creek and Deepwater Creek Basins are located east of Lake Sakakawea and Bear Den Creek, Moccasin Creek, and Squaw Creek Basins are located west of the lake. Land-use data for the five selected basins on and adjacent to the Fort Berthold Indian Reservation were obtained for 1990-92. Discharge measurements were made and water-quality samples were collected at stations and sites on each of the five streams during October 1991 through September 1993.

Analysis of land-use data indicated that prairie was the largest land-use category in the study area. More prairie acreage was found in the basins located west of Lake Sakakawea than in the basins located east of the lake. Wheat was the predominant crop in the study area. More wheat acreage was found in the basins located east of Lake Sakakawea than in the basins located west of the lake.

Discharge data for the five selected streams indicated that all of the streams were ephemeral and had many days of no flow during the study period. High flows were usually the result of spring runoff or intense storms over the basins. East Fork Shell Creek and Deepwater Creek with larger basins and flatter stream slopes had high flows characterized by rapidly rising flows and gradually receding flows. In contrast, Bear Den Creek, Moccasin Creek, and Squaw Creek with smaller basins and steeper stream slopes had high flows characterized by rapidly rising flows and receding flows of shorter duration.

Analysis of water-quality samples indicated concentrations of nitrogen, phosphorus, and total organic carbon varied throughout the study area. Nitrogen concentrations were larger in the streams located east of Lake Sakakawea than in the streams located west of the lake. The largest nitrogen concentrations in all of the streams occurred during the nongrowing periods. Phosphorus (orthophosphate and total phosphorus) concentrations were larger in the streams located east of Lake Sakakawea than in the streams located west of the lake. The larger orthophosphate concentrations in the eastern streams may be indicative of insecticide application in the eastern streams' basins. Total organic carbon concentrations were fairly consistent in all five streams.

Water-quality samples were analyzed for the pesticides atrazine, carbofuran, cyanazine, and 2,4-D by using immunoassay testing. Pesticide concentrations above the minimum reporting levels were more prevalent in samples from streams located east of Lake Sakakawea than in the streams located west of the lake. The eastern streams drain areas where herbicides were applied to crops.

Fecal-bacteria concentrations were larger in the streams located west of Lake Sakakawea, where prairie is more dominant, than in the streams located east of the lake. The larger concentrations and loads were associated with intense storm events and the presence of livestock.

INTRODUCTION

The potential for surface-water contamination by land-use activities in North Dakota is receiving increased attention from Federal, State, and local agencies. Surface water is the principle source of water for many communities in North Dakota. In recent years, there have been a number of new and proposed projects to transport and deliver surface water to communities throughout North Dakota. Nonpoint-source contamination resulting from land-use activities may affect the water quality of these surface-water resources.

Streams in North Dakota, as in much of the central plains, are distinct from streams in other areas of the country. Many of the streams in North Dakota are ephemeral with relatively large drainage areas compared to the amount of discharge. In addition, many of the streams receive ground-water discharge that tends to have large concentrations of dissolved-solids. Little is known about the occurrence and transport of agricultural chemicals in these streams.

The Fort Berthold Indian Reservation is located in west-central North Dakota (fig. 1). Because this area is rural and dominated by agriculture, surface-water resources in the area may be susceptible to nonpoint-source contamination, including nutrients from agricultural fields and livestock (cattle and horses), pesticides used on crops and rangeland, and micro-organisms from the feces of grazing animals. The Three Affiliated Tribes of the Fort Berthold Indian Reservation needs information on land use and nonpoint-source contamination in order to make decisions concerning the regulation of land use and the protection of water resources on the Reservation.

The Fort Berthold Indian Reservation is bisected by Lake Sakakawea. The east side of the Reservation is characterized as glaciated prairie. The topography is hummocky. The area is drained by a number of small streams and primarily is used as cropland. Important cash crops include wheat, other small grains, and sunflower. In contrast, the west side of the Reservation is characterized as badlands. The topography is dissected by buttes and coulees incised by streams. The area primarily is used as rangeland. Therefore, different land-use activities on the two sides of the Reservation may have different effects on the chemical and bacteriological quality of the surface water.

The fate of many agricultural chemicals in agrarian soils is well defined; however, little is known about the occurrence and distribution of these agricultural chemicals in prairie streams. In 1992, the U.S. Geological Survey began an investigation in cooperation with the Three Affiliated Tribes to assess nonpoint-source contamination of surface water on the Fort Berthold Indian Reservation. Particular emphasis was placed on identifying the occurrences and concentrations of selected agricultural chemicals in surface water and on evaluating the quality of surface water affected by livestock grazing on riparian lands.

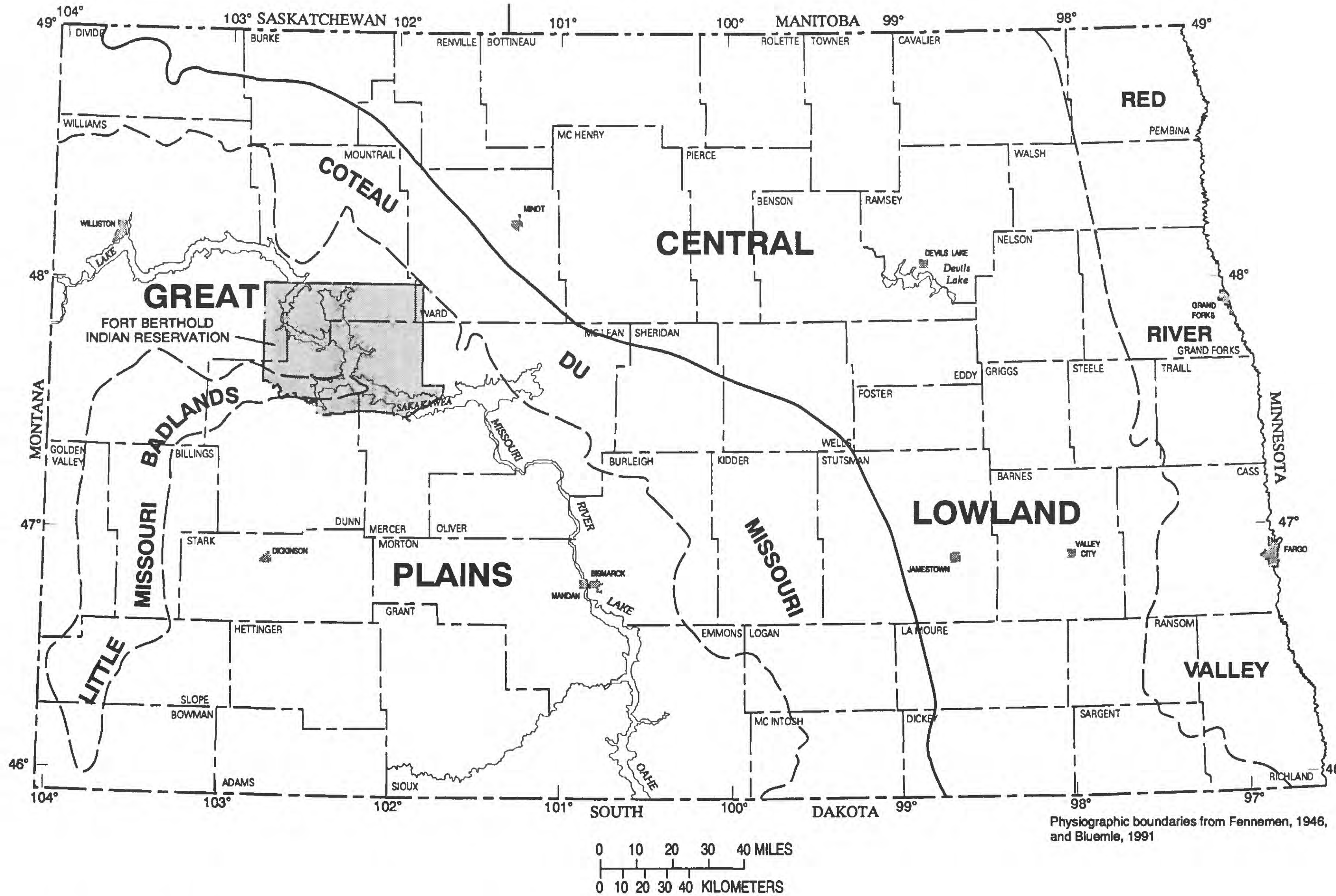

Figure 1. Location of the Fort Berthold Indian Reservation and physiographic divisions of North Dakota.

Purpose and Scope

The purpose of this report is to describe the effects of land-use activity on the water quality of five ephemeral streams on the Fort Berthold Indian Reservation (fig. 2). Specific objectives of the study were to:

1. Document recent variations in agricultural land-use patterns.

2. Document spatial and temporal variability of selected nutrients, total organic carbon, selected pesticides, and selected bacteria concentrations in five ephemeral streams on the Reservation.

3. Compare the land-use data to the water-quality data to determine relations between agricultural land-use practices and stream-water quality on the Reservation.

The scope of the study included obtaining land-use data for the area that covers the Fort Berthold Indian Reservation, including those parts of the five selected basins which extend outside the Reservation boundary. Land-use data were obtained for 1990-92. Stream-discharge measurements were made and water samples were collected at a site on each of the five streams during October 1991 through September 1993. Additional data (physical properties, selected major ions, and trace elements) collected but not discussed in this report are published in U.S. Geological Survey Water-Data reports (Harkness and others, 1992, 1993).

Description of Study Area

The study area consists of five drainage basins located on and adjacent to the Reservation (fig. 2). The five basins are East Fork Shell Creek, Deepwater Creek, Bear Den Creek, Moccasin Creek, and Squaw Creek. These basins were chosen for detailed analysis based on their areal extent and to maximize coverage of the Reservation land.

East Fork Shell Creek and Deepwater Creek Basins are located northeast and east of Lake Sakakawea where cropland is the major land use. This part of the Fort Berthold Indian Reservation, east of Lake Sakakawea, is located on the eastern edge of the Great Plains Province near an area known as the Coteau du Missouri (fig. 1). Most of the East Fork Shell Creek noncontributing area is in the Coteau du Missouri. The Coteau du Missouri is an area of complex glacial moraines. Much of the area does not have integrated drainage and does not contribute surface runoff to streams in the area.

Bear Den Creek, Moccasin Creek, and Squaw Creek Basins are located west and south of Lake Sakakawea where rangeland is the major land use. This part of the Fort Berthold Indian Reservation, west of Lake Sakakawea, is located in the glaciated area of the Great Plains Province. The area is characterized by low relief interrupted by prominent buttes and ridges. The streams run through an area of badlands topography.

The Fort Berthold Indian Reservation has a semiarid continental climate characterized by long, cold winters and short, hot summers. Average annual precipitation on the Reservation ranges from about 16 inches in the east to about 14 inches in the west. The majority of precipitation on the Reservation occurs as showers and thunderstorms during the summer months and as infrequent snow during the colder months.

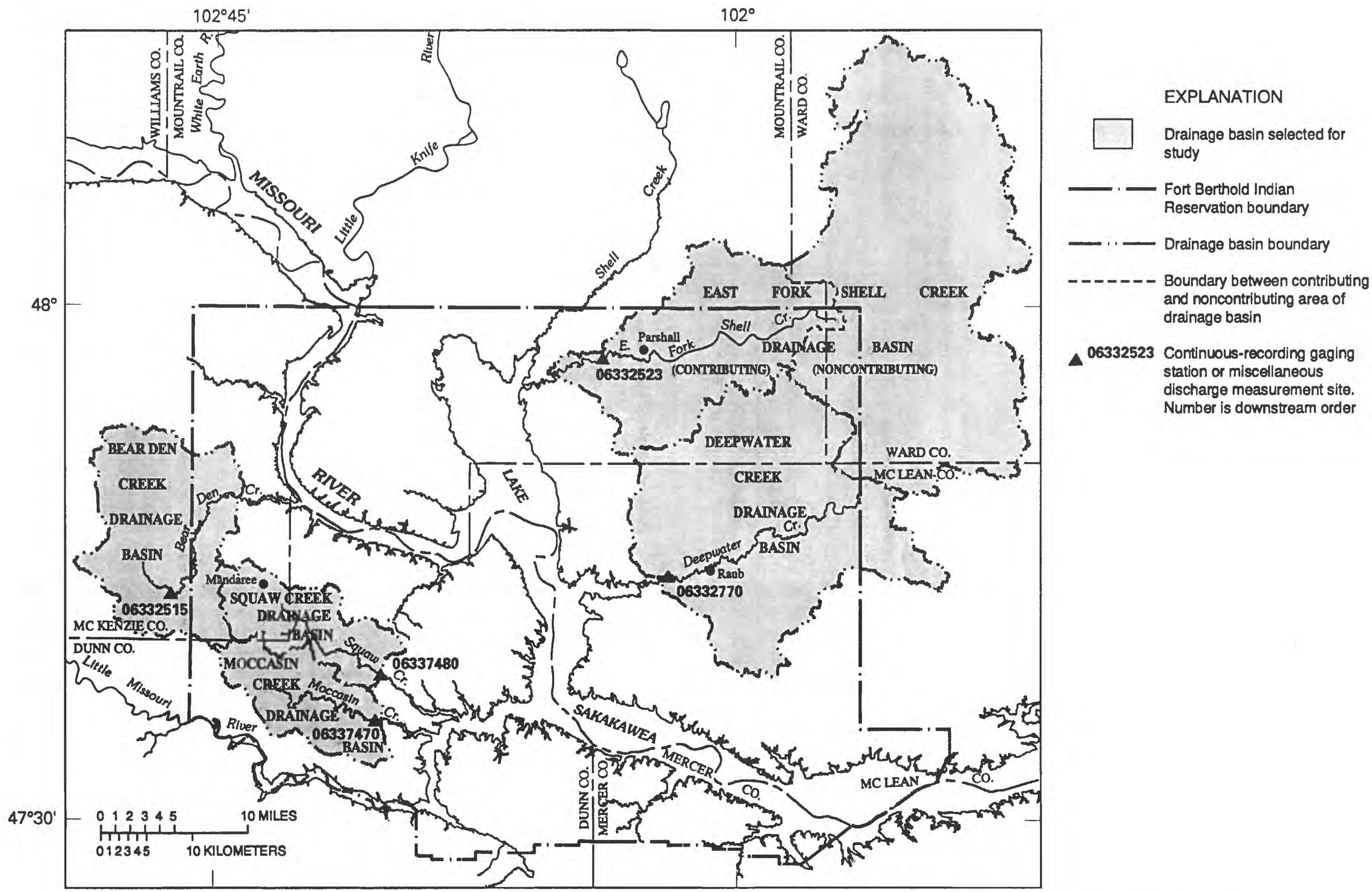

Figure 2. Location of selected streams, drainage basins, continuous-recording gaging stations, and miscellaneous discharge measurement sites on and adjacent to the Fort Berthold Indian Reservation, west-central North Dakota.

Acknowledgments

The collection of data for this report was made possible by the cooperation of residents and officials of the Fort Berthold Indian Reservation. These individuals provided important information regarding pesticide type and application and gave permission to access private property for data collection. The U.S. Agricultural Stabilization and Conservation Service provided the land-use data.

DATA COLLECTION

Land-Use Data

Land-use data were obtained from the U.S. Agricultural Stabilization and Conservation Service for the entire Fort Berthold Indian Reservation including the parts of East Fork Shell Creek, Deepwater Creek, and Bear Den Creek Basins outside the Reservation boundaries. Land-use data were obtained for 1-square-mile sections for each year from 1990-92. Each section was divided, by percent, into 12 categories of land use. These categories were wheat, barley, oats, corn, sunflower, summer fallow, Conservation Reserve Program (CRP) land, alfalfa hay, other hay, pasture, cropland, prairie, and other. The land-use data were incorporated into a geographic information system data base for analysis and interpretation.

Stream-Discharge and Water-Quality Data

Stream-discharge measurements were made and water samples were collected at three continuous-recording gaging stations and two miscellaneous discharge measurement sites (fig.2). The three continuous-recording gaging stations are East Fork Shell Creek near Parshall, N. Dak. (U.S. Geological Survey station number 06332523), Deepwater Creek at mouth near Raub, N. Dak. (06332770), and Bear Den Creek near Mandaree, N. Dak. (06332515). The two miscellaneous discharge measurement sites are Moccasin Creek at mouth near Mandaree, N. Dak. (06337470), and Squaw Creek above mouth near Mandaree, N. Dak. (06337480). Discharge measurements were made and water samples were collected about the same time at all locations except for Bear Den Creek near Mandaree, N. Dak. Because Bear Den Creek near Mandaree, N. Dak., is part of the National Hydrologic Benchmark Network, more discharge measurements were made and more water samples were collected from this station during the study period.

Discharge measurements were made during October 1991 through September 1993. Measurements were made using a Price pygmy meter, a Price AA current meter, a modified 3-inch Parshall flume, or a 1-cubic foot bucket (Rantz and others, 1982). Mean daily discharges for the continuous-recording gaging stations were computed by using stage-discharge ratings and corresponding water-level stages (Rantz and others, 1982).

Water samples for major ions, nutrients, and trace elements were collected during October 1991 through September 1993. Total organic carbon data were collected during the summer of 1993. Samples for major ions, nutrients, trace elements, and total organic carbon were collected by using a D-74AL sampler for high flows, a DH81 sampler for medium flows, or an open-mouth glass bottle for very low flows. Samples were filtered into clean, polypropylene bottles. Acid was added to certain bottles as a preservative for selected constituents. The bottles were shipped chilled (Ward and Harr, 1990) to the U.S. Geological Survey's National Water Quality Laboratory in Arvada, Colo. for analysis.

Pesticide samples were collected approximately biweekly between May and August of 1992 and May and August of 1993 on the eastern streams. Pesticide samples were collected monthly at Bear Den Creek near Mandaree, N. Dak., and in May (before pesticide application) and June and July (after pesticide application) on the remaining western streams. Pesticide sampling was limited on Moccasin Creek and Squaw Creek because they did not have appreciable flow during much of the summer. Pesticide samples were not collected when flow was less than 0.01 cubic foot per second.

Samples analyzed for selected pesticides were collected by grab sample using sterilized, 4-liter brown, glass bottles. Immediately after the samples were collected, they were chilled. The bottles were returned to the U.S. Geological Survey laboratory in Bismarck, N. Dak.; filtered into baked, 1,000-milliliter, brown, glass bottles; and chilled. Two methods for determining pesticides in water were used in this study. First, immunoassay tests were conducted in the laboratory in Bismarck as a screening process for specific classes of pesticides. Immunoassay testing procedures were followed according to the manufacturer's instructions. The second method is gas chromatography-mass spectrometry (GC/MS), done at the U.S. Geological Survey's National Water Quality Laboratory. This method tests samples for specific compounds rather than a class of compounds as the immunoassay tests do. If the results for immunoassay tests were positive for a certain class of compounds, further analyses using GC/MS were conducted to see which specific compounds were present in the samples. Immunoassay results from the sampling done in 1992 were used to design subsequent pesticide data collection. During 1993, both immunoassay testing and GC/MS were used.

Bacteria samples were collected only at Bear Den Creek near Mandaree, N. Dak., during 1992. Bacteria samples were collected at all five locations during the spring and summer of 1993. Samples for fecal-streptococci and fecal-coliform bacteria were collected by grab sample using sterilized, glass bottles; filtered on site; and placed in temperature-controlled incubators (Britton and Greeson, 1989). Blank filters were processed using buffered dilution water prior to and after each sample set was filtered to ensure that proper sterilization procedures were being followed.

Selected physical properties of water, such as temperature, specific conductance, pH, and dissolved-oxygen also were measured at the time of each discharge measurement. The manufactures' instructions for selected instrumentation and standard U.S. Geological Survey procedures were followed for the onsite measurements.

Procedures that were followed for collecting, treating, and shipping samples are given in publications by Barnett and Mallory (1971), Wershaw and others (1987), Britton and Greeson (1989), Fishman and Freidman (1989), and Ward and Harr (1990).

VARIATIONS IN LAND USE

Land-use data for the Fort Berthold Indian Reservation, including those portions of the five basins which extended outside the Reservation boundary, were obtained for 1990-92. Although land-use data were not available for 1993, it is doubtful that 1993 data would have revealed land-use practices dramatically different from those during 1990-92. Land use of selected basins are listed, by year, in table 1. Minor variations in the total number of acres in each basin among years are the result of small amounts of missing data each year. When comparing land use of all five basins, percentages are used in this report rather than number of acres to better illustrate the effect of land use on nonpoint-source contamination in streams. The area of East Fork Shell Creek Basin is larger than the combined area of the four basins of Deepwater Creek, Bear Den Creek, Moccasin Creek, and Squaw Creek. Because of its size, East Fork Shell Creek Basin is divided into contributing and noncontributing areas to illustrate the effect land use has on nonpoint-source contamination that results from runoff. When discussing land use for East Fork Shell Creek Basin, the distinction between contributing area and noncontributing area is noted. For all other basins, land use is for the total area of each basin.

Prairie was the largest category of land use in the study area. Prairie acres were 39 percent of the total acres in each of the 3 years. Wheat was the second largest category of land use and the predominant crop in the study area. Wheat acres ranged from 22 percent of the total acres in 1991 to 26 percent in 1992. Summer fallow and CRP land were the next largest categories of land use in the study area. Summer fallow acres ranged from 13 percent of the total acres in 1992 to 15 percent in 1991. CRP land acres were 6 percent of the total acres in each of the 3 years. All other categories of land use tended to be minor components of the total land use in the study area.

Land-Use Overview of Eastern Basins

Wheat was the largest category of land use in the eastern basins. Wheat production in the contributing area of East Fork Shell Creek Basin was significantly more than wheat production in the noncontributing area of East Fork Shell Creek Basin. Wheat acres ranged from 35 percent of the total acres in the contributing area of the East Fork Shell Creek Basin in 1991 to 42 percent in 1992, from 19 percent of the total acres in the noncontributing area of East Fork Shell Creek Basin in 1991 to 22 percent in 1992, and from 37 percent of the total acres in Deepwater Creek Basin in 1991 to 44 percent in 1992.

In contrast, the amount of land classified as prairie in the eastern basins was small compared to the western basins. Prairie acres ranged from 13 percent of the total acres in the contributing area of the East Fork Shell Creek Basin in 1992 to 15 percent in 1990, and from 9 percent of the total acres in the Deepwater Creek Basin in 1991 to 10 percent in 1990.

Land-Use Overview of Western Basins

Prairie was the largest category of land use in the western basins and was known to be used as rangeland. In each of the 3 years, prairie acres were 78 percent of the total acres in Bear Den Creek Basin, 95 percent in Moccasin Creek Basin, and 94 percent in Squaw Creek Basin.

In contrast, the amount of land classified as wheat in the western basins was small compared to the eastern basins. In each of the 3 years, wheat acres were 6 percent of the total acres in Bear Den Creek Basin, and wheat acres were less than 1 percent of the total acres in Moccasin Creek Basin and in Squaw Creek Basin.

Spatial Variations in 1992 Land-Use Data

To better understand the spatial variations in land-use practices on the Fort Berthold Indian Reservation and to show the importance of the basins' geographic location on land use, the 1992 land-use data were plotted on maps. To limit the number of maps, land-use categories that had the potential for similar nonpoint-source contamination were grouped together. The grouped categories included cereal crops (wheat, barley, and oats), row crops (corn and sunflower), summer fallow and CRP land, hay (alfalfa and other hay), and pasture and prairie. Maps for the cropland and other categories were not included because specific use for these lands were unknown.

Table 1. Land-use areas in selected basins in and adjacent to the Fort Berthold Indian Reservation, west-central North Dakota, 1990-92

[Data from the U.S. Agricultural Stabilization and Conservation Service; areas are in acres[1], CRP, Conservation Reserve Program]

Basin	Wheat	Barley	Oats	Corn	Sun-flower	Summer fallow	CRP land	Alfalfa hay	Other hay	Pasture	Crop-land[2]	Prairie	Other[2]	Total
						1990								
East Fork Shell Creek														
Total	73,700	7,370	6,760	782	2,270	46,600	21,300	2,270	9,020	61	5,270	87,500	7,390	270,293
Contributing area	34,200	3,020	1,490	176	1,240	20,700	4,200	450	1,200	0	3,290	12,900	4,180	87,046
Noncontributing area	39,500	4,350	5,270	606	1,030	25,900	17,100	1,820	7,820	61	1,980	74,600	3,210	183,247
Deepwater Creek	57,600	7,590	3,000	221	4,300	27,800	4,510	648	2,690	385	9,390	15,000	10,500	143,634
Bear Den Creek	4,450	645	577	229	0	5,060	1,740	998	2,380	435	1,260	62,700	181	80,655
Squaw Creek	388	53	273	0	0	0	76	20	51	98	1,580	42,300	1	44,840
Moccasin Creek	0	0	123	0	0	132	359	362	437	0	689	36,900	0	39,002
						1991								
East Fork Shell Creek														
Total	64,400	13,700	4,780	1,160	2,980	47,100	20,200	4,460	8,090	194	5,250	87,200	9,490	269,004
Contributing area	30,200	5,360	1,180	262	2,500	20,400	3,170	1,980	1,020	122	3,610	11,800	5,490	87,094
Noncontributing area	34,200	8,340	3,600	898	480	26,700	17,030	2,480	7,070	72	1,640	75,400	4,000	181,910
Deepwater Creek	50,200	11,300	1,710	164	4,110	28,100	4,310	700	2,070	222	7,250	12,600	11,800	134,536
Bear Den Creek	4,750	756	804	218	0	4,690	1,770	1,160	1,820	556	1,260	62,700	99	80,583
Squaw Creek	0	0	193	0	0	267	76	0	497	118	1,390	41,600	0	44,141
Moccasin Creek	0	0	50	0	0	23	359	362	437	0	821	37,600	50	39,702
						1992								
East Fork Shell Creek														
Total	77,100	9,680	4,170	1,300	1,230	41,400	21,200	2,250	7,600	748	4,880	87,600	11,100	270,258
Contributing area	36,300	4,000	624	310	1,030	16,400	3,710	390	1,170	210	3,640	11,700	7,570	87,054
Noncontributing area	40,800	5,680	3,546	990	200	25,000	17,490	1,860	6,430	538	1,240	75,900	3,530	183,204
Deepwater Creek	61,800	14,400	1,770	590	706	24,900	4,990	773	2,200	325	2,440	14,000	10,900	139,794
Bear Den Creek	4,800	719	942	261	0	4,950	1,740	1,200	1,490	396	1,340	62,700	87	80,625
Squaw Creek	0	132	174	0	0	212	76	0	324	232	1,390	41,600	0	44,140
Moccasin Creek	0	0	182	0	0	23	359	362	489	0	612	37,600	75	39,702

[1]For ease of calculation, the areas were assigned by section (for example, if more than half of a section was in the basin, then the entire section was assigned to the basin).
[2]The specific use of this land was not known.

The percentage of land used for cereal crop production in 1992 is shown in figure 3. The contributing area of East Fork Shell Creek Basin and Deepwater Creek Basin had the largest percentages of acres classified as cereal crops. Cereal crop acres were 47 percent of the total acres in the contributing area of East Fork Shell Creek Basin and 56 percent in Deepwater Creek Basin. In contrast, the amount of land classified as cereal crops was small in the noncontributing area of East Fork Shell Creek Basin and those basins located west of Lake Sakakawea compared to the contributing area of East Fork Shell Creek Basin and Deepwater Creek Basin. Cereal crop acres were 27 percent of the total acres in the noncontributing area of East Fork Shell Creek Basin, 8 percent in Bear Den Creek Basin, and less than 1 percent in Moccasin Creek Basin and in Squaw Creek Basin.

The percentage of land used for row crop production in 1992 is shown in figure 4. Generally, row crops were a minor component of the total agricultural activity in the study area. Row crop acres were 2 percent of the total acres in the contributing area of East Fork Shell Creek Basin and less than 1 percent in the noncontributing area of East Fork Shell Creek Basin, in Deepwater Creek Basin, and in Bear Den Creek Basin. There were no acres devoted to row crop production in Moccasin Creek and Squaw Creek Basins.

The percentage of land used for summer fallow and CRP land in 1992 is shown in figure 5. Generally, the contributing and noncontributing areas of East Fork Shell Creek Basin and Deepwater Creek Basin had the largest percentages of acres classified as summer fallow and CRP land. Summer fallow and CRP land acres were 23 percent of the total acres in the contributing and noncontributing areas of East Fork Shell Creek Basin and 21 percent in Deepwater Creek Basin. In contrast, the basins located west of Lake Sakakawea, including Bear Den Creek, Moccasin Creek, and Squaw Creek had the smallest percentages of acres classified as summer fallow and CRP land. Summer fallow and CRP land acres were 8 percent of the total acres in Bear Den Creek Basin and less than 1 percent in Moccasin Creek Basin and in Squaw Creek Basin.

The percentage of land used for hay production in 1992 is shown in figure 6. Generally, the percentages of acres for hay production were evenly distributed throughout the study area. Hay acres ranged from less than 1 percent of the total acres in Squaw Creek Basin to 5 percent in the noncontributing area of East Fork Shell Creek Basin.

The percentage of land used for pasture and prairie in 1992 is shown in figure 7. Generally, Bear Den Creek, Moccasin Creek, and Squaw Creek Basins had the largest percentages of acres classified as pasture and prairie. Pasture and prairie acres were 78 percent of the total acres in Bear Den Creek Basin and 95 percent in Moccasin Creek Basin and in Squaw Creek Basin. Pasture and prairie acres also were high in the noncontributing area of East Fork Shell Creek Basin. Pasture and prairie acres were 42 percent of the total acres in the noncontributing area of East Fork Shell Creek Basin compared to 14 percent of the total acres in the contributing area of East Fork Shell Creek Basin and 10 percent in Deepwater Creek Basin.

SURFACE-WATER HYDROLOGY

The surface-water resources on the Fort Berthold Indian Reservation are composed of Lake Sakakawea and numerous ephemeral streams which are tributary to the lake. Discharge data were collected for this study at three continuous-recording gaging stations and two miscellaneous discharge measurement sites during October 1991 through September 1993. Generally, discharge at the three stations and two sites can be characterized as low flow, less than 1 cubic foot per second, during most years. In fact, during extended dry periods, there is no flow in any of these streams. During dry

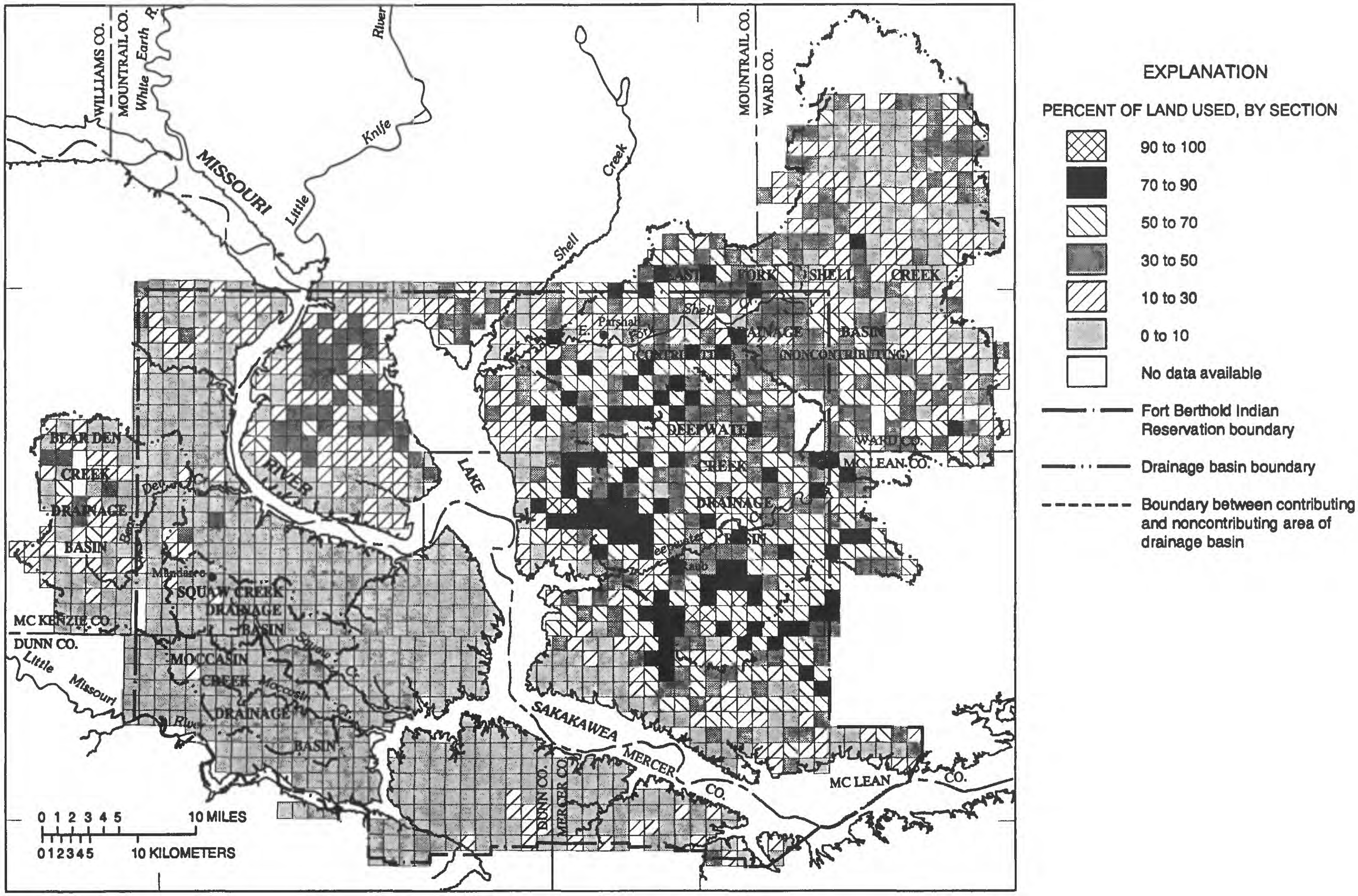

Figure 3. Percentage of land used for cereal crop production in 1992 on the Fort Berthold Indian Reservation and adjacent area, west-central North Dakota.

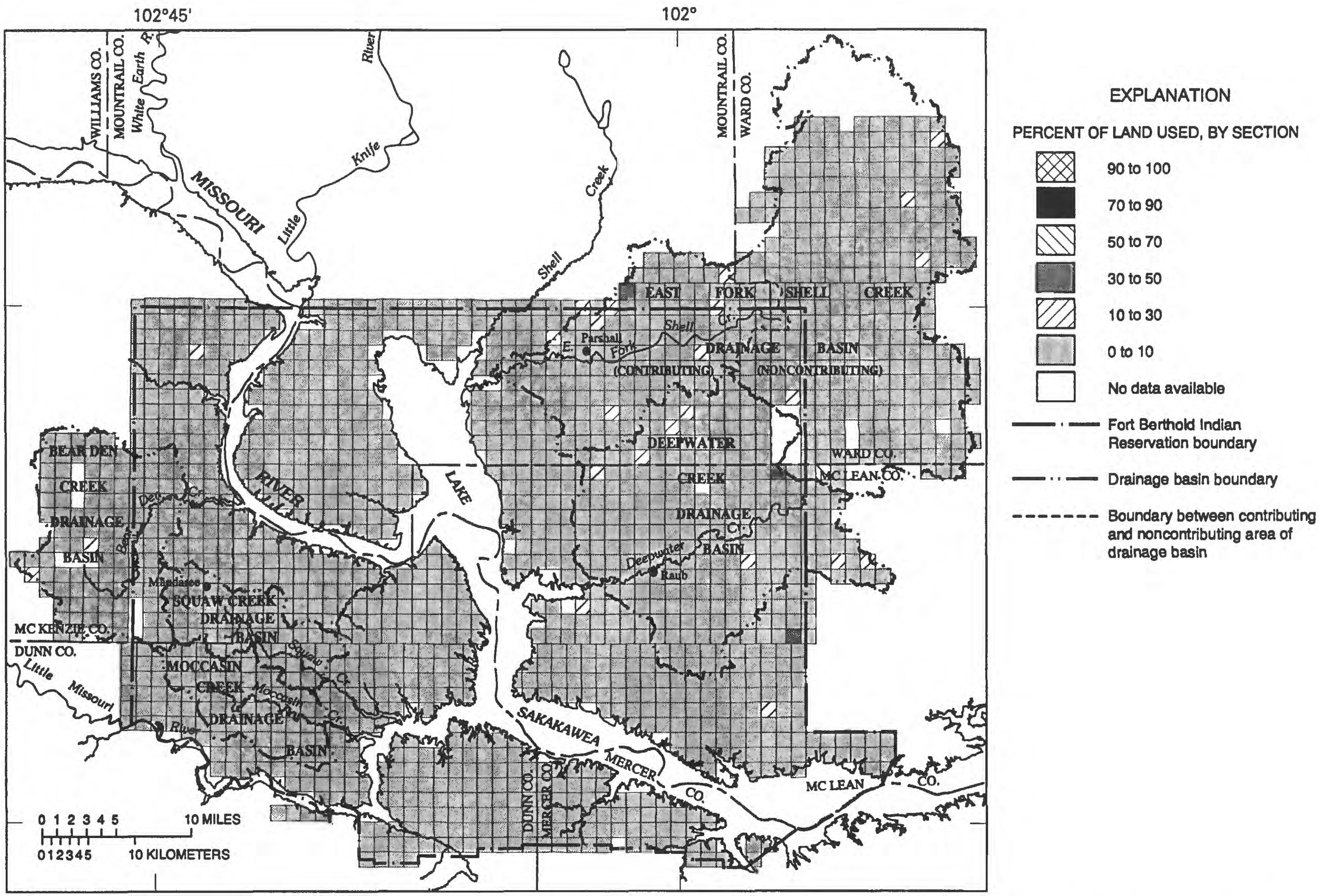

Figure 4. Percentage of land used for row crop production in 1992 on the Fort Berthold Indian Reservation and adjacent area, west-central North Dakota.

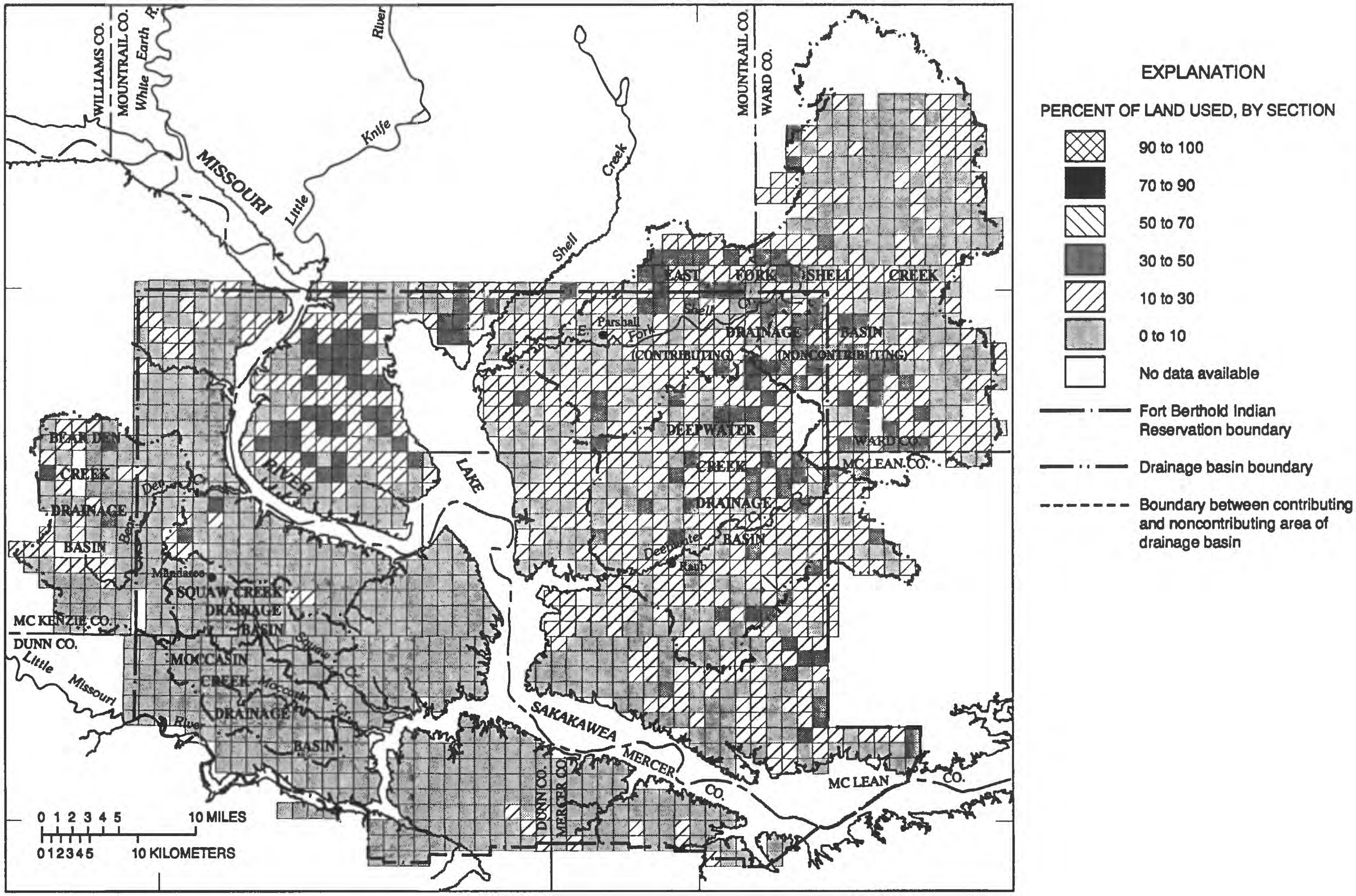

Figure 5. Percentage of land used for summer fallow and Conservation Reserve Program land in 1992 on the Fort Berthold Indian Reservation and adjacent area, west-central North Dakota.

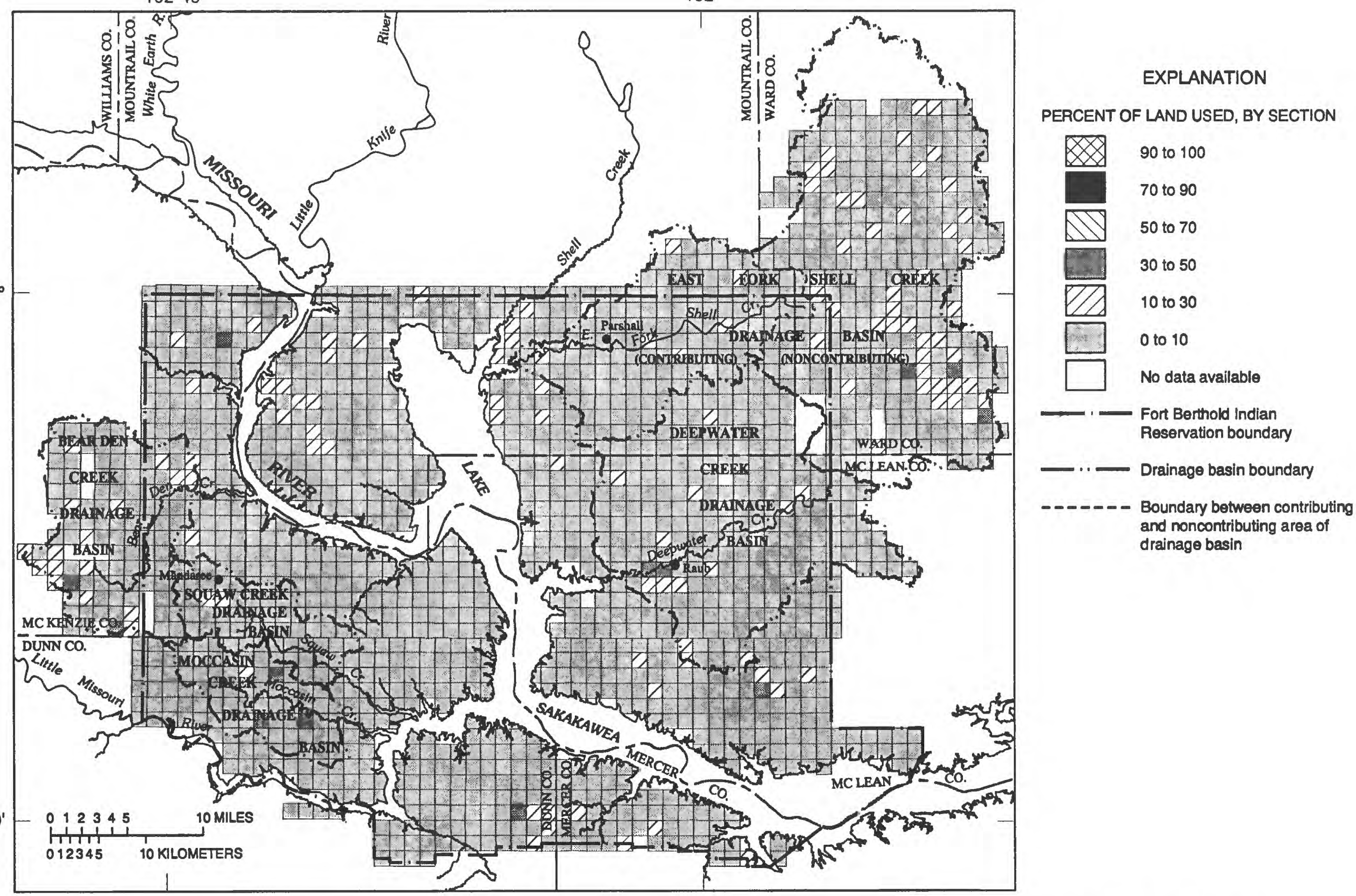

Figure 6. Percentage of land used for hay production in 1992 on the Fort Berthold Indian Reservation and adjacent area, west-central North Dakota.

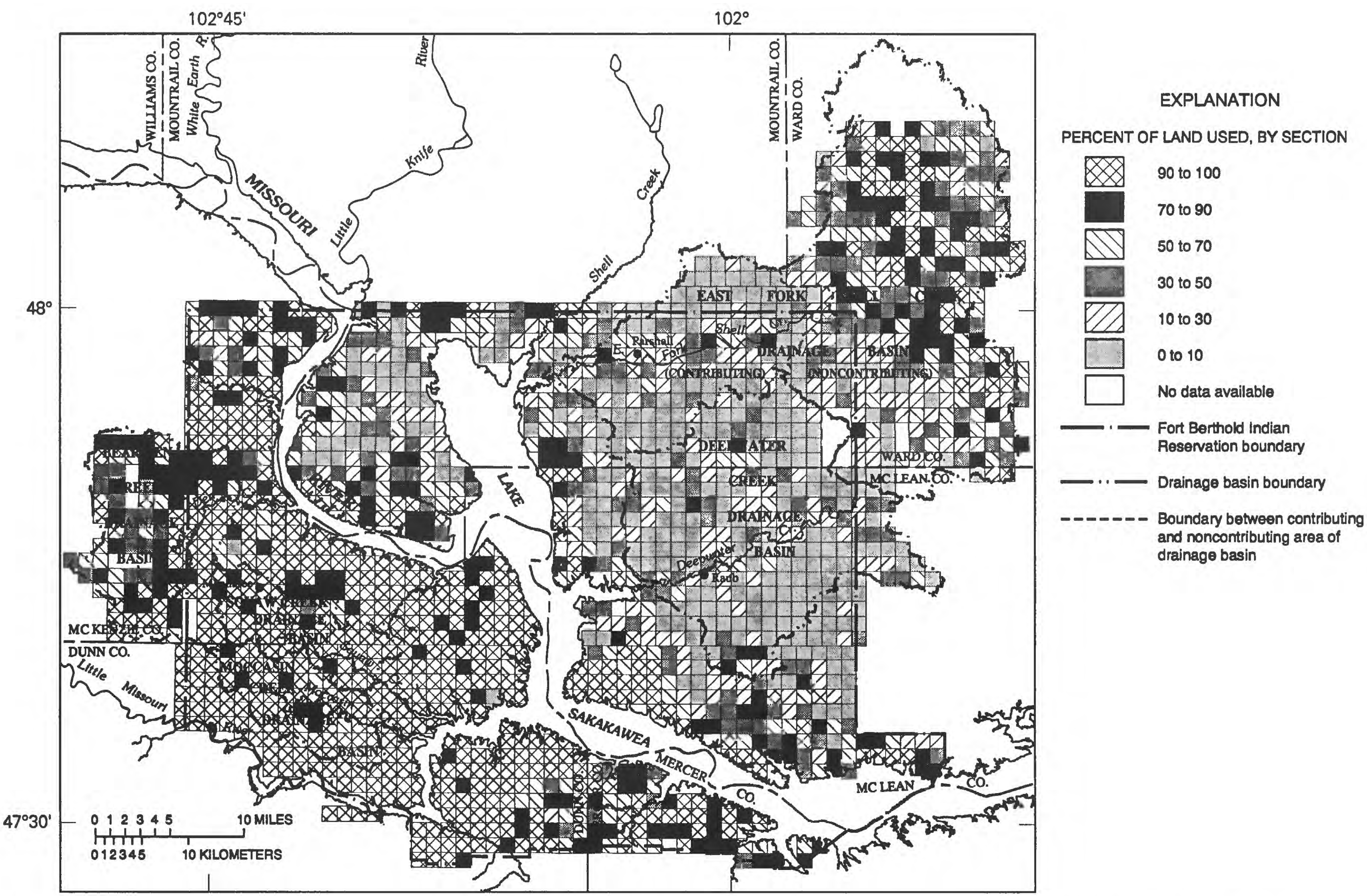

Figure 7. Percentage of land used for pasture and prairie in 1992 on the Fort Berthold Indian Reservation and adjacent area, west-central North Dakota.

conditions, these streams, particularly East Fork Shell Creek and Deepwater Creek, resemble a series of ponded wetlands. However, during spring runoff and occasional summer storms, discharge can exceed 100 cubic feet per second. For example, the measured discharge at Bear Den Creek was 333 cubic feet per second on July 28, 1993. A peak discharge of 1,360 cubic feet per second was recorded at the Bear Den Creek gaging station on July 27, 1993.

Selected basin characteristics for the three continuous-recording gaging stations and two miscellaneous discharge measurement sites are presented in table 2. East Fork Shell Creek Basin includes a large area of prairie potholes and poorly defined surficial drainage that is noncontributing. Therefore, the stream length, slope, and elevation are for the contributing area of the basin only. The basins of East Fork Shell Creek and Deepwater Creek, located northeast and east of Lake Sakakawea, are larger and have flatter stream slopes. In contrast, the basins of Bear Den Creek, Moccasin Creek, and Squaw Creek, located west of the lake, are smaller and have steeper stream slopes. These basin characteristics influence the volume and timing of surface runoff. Rising flows of peak runoff occurred rapidly in all of the basins due to brief but intense storms over the area. However, the receding flows in the eastern basins tended to be slightly more gradual than receding flows in the western basins. This difference was due to the differences in land relief between the eastern and western basins. At times, runoff peaks occurred so quickly after thunderstorms moved through the area that obtaining discharge measurements and water samples at or near the time of peak discharge on all of the monitored streams was not possible.

Table 2. Selected characteristics for the basins of three continuous-recording gaging stations and two miscellaneous discharge measurement sites on and adjacent to the Fort Berthold Indian Reservation, west-central North Dakota

[nd, not determined]

Station or site	Total drainage area (square miles)	Stream length (miles)	Stream slope (feet per mile)	Mean basin elevation (feet above sea level)
East Fork Shell Creek near Parshall, N. Dak. (06332523) (noncontributing)	338	nd	nd	nd
East Fork Shell Creek near Parshall, N. Dak. (06332523) (contributing)	129	50.2	6.3	2,114
Deepwater Creek near Raub, N. Dak. (06332770)	235	28.7	10.7	2,065
Bear Den Creek near Mandaree, N. Dak. (06332515)	117	31.2	15.4	2,317
Moccasin Creek at mouth near Mandaree, N. Dak. (06337470)	54	26.6	18.3	2,248
Squaw Creek above mouth near Mandaree, N. Dak. (06337480)	52	23.4	12.5	2,212

East Fork Shell Creek is located northeast of Lake Sakakawea and flows from the northeast to the west-southwest. During October 1991 through September 1993, mean daily discharge ranged from no flow for many days to 83 cubic feet per second on July 31, 1993 (fig. 8).

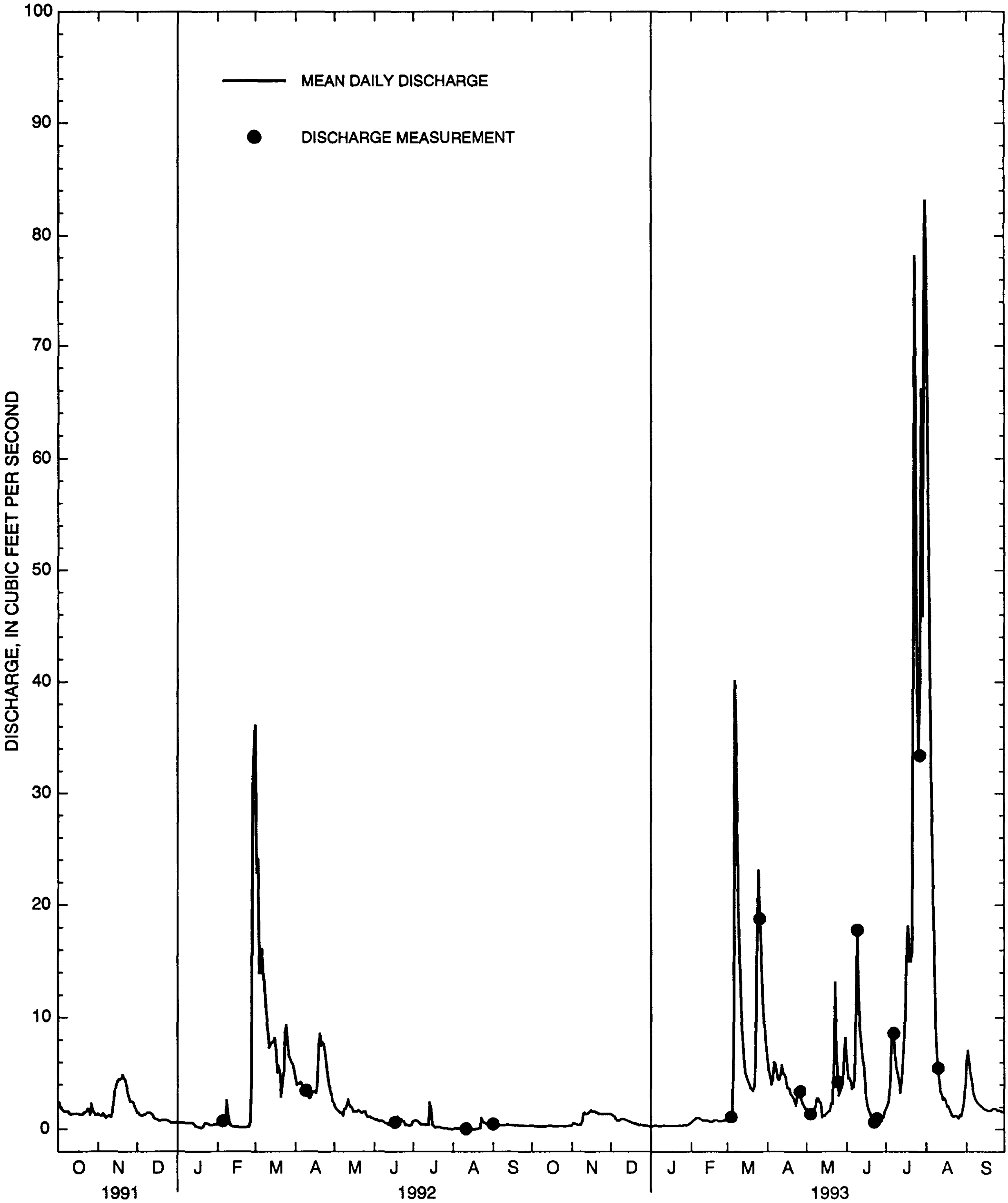

Figure 8. Mean daily discharge and discharge measurements for East Fork Shell Creek near Parshall, North Dakota, October 1991 through September 1993.

Deepwater Creek is located east of Lake Sakakawea and flows from the northeast to the southwest. During October 1991 through September 1993, mean daily discharge ranged from no flow for many days to 65 cubic feet per second on July 29, 1993 (fig. 9).

Bear Den Creek is located along the western boundary of the Fort Berthold Indian Reservation and flows from the north to the south, then northeastward. During October 1991 through September 1993, mean daily discharge ranged from no flow for many days to 380 cubic feet per second on July 27, 1993 (fig. 10).

Moccasin Creek is located in the southwest part of the Fort Berthold Indian Reservation and flows from the northwest to the southeast. During October 1991 through September 1993, discharge ranged from no flow for many days to 106 cubic feet per second on July 28, 1993 (fig. 11).

Squaw Creek is located in the southwest part of the Fort Berthold Indian Reservation and flows from the northwest to the southeast. During October 1991 through September 1993, discharge ranged from no flow for many days to 60 cubic feet per second on July 28, 1993 (fig. 12).

VARIATIONS IN NONPOINT-SOURCE CONTAMINATION

Water samples were collected and analyzed for selected nutrients, total organic carbon, pesticides, and bacteria. Water quality in all North Dakota streams is regulated by State standards (North Dakota State Department of Health and Consolidated Laboratories, 1991). Not all the constituents discussed in this report have State standards. The standards set for nitrates and phosphorus are interim guideline limits and may change after the State evaluates each stream's individual characteristics because the characteristics affect the levels of those constituent concentrations. The State reserves the right to set the standard for other selected constituents for each stream after further study; therefore, the standards are not given for those constituents.

Nutrients and Total Organic Carbon

Nutrients can cause eutrophication in water bodies and when found in sufficient quantities are indicators of different types of water pollution. Nitrogen concentrations in water can be found in several different forms. The form and quantity of nitrogen compounds present in water can indicate the source from which the compounds were derived and their chemical alteration process. Organic nitrogen will decompose to ammonia, ammonia will decompose to nitrite, and nitrite will decompose to nitrate. Livestock waste is in the form of organic nitrogen and ammonia. Fertilizer is in the form of ammonia or nitrate. The North Dakota water-quality standard for dissolved nitrate is 1.0 milligram per liter and is intended as an interim guideline limit. However, the standard shall not exceed 10 milligrams per liter.

Nitrite plus nitrate concentrations varied throughout the study area (table 3). Nitrite plus nitrate concentrations ranged from <0.05 to 1.6 milligrams per liter as N at East Fork Shell Creek near Parshall, N. Dak., and Deepwater Creek near Raub, N. Dak. Nitrite plus nitrate concentrations ranged from <0.05 to 0.12 milligram per liter as N at Bear Den Creek near Mandaree, N. Dak., Moccasin Creek at mouth near Mandaree, N. Dak., and Squaw Creek above mouth near Mandaree, N. Dak.

Phosphorus is found in sewage effluent and is always present in livestock wastes because the element is essential in metabolism. Also, a reduced form of phosphorus (orthophosphate) is found in some synthetically-produced chemicals such as insecticides. The North Dakota water-quality standard for total phosphorus is 0.1 milligram per liter and is intended as an interim guideline limit. There is no State water-quality standard for orthophosphate.

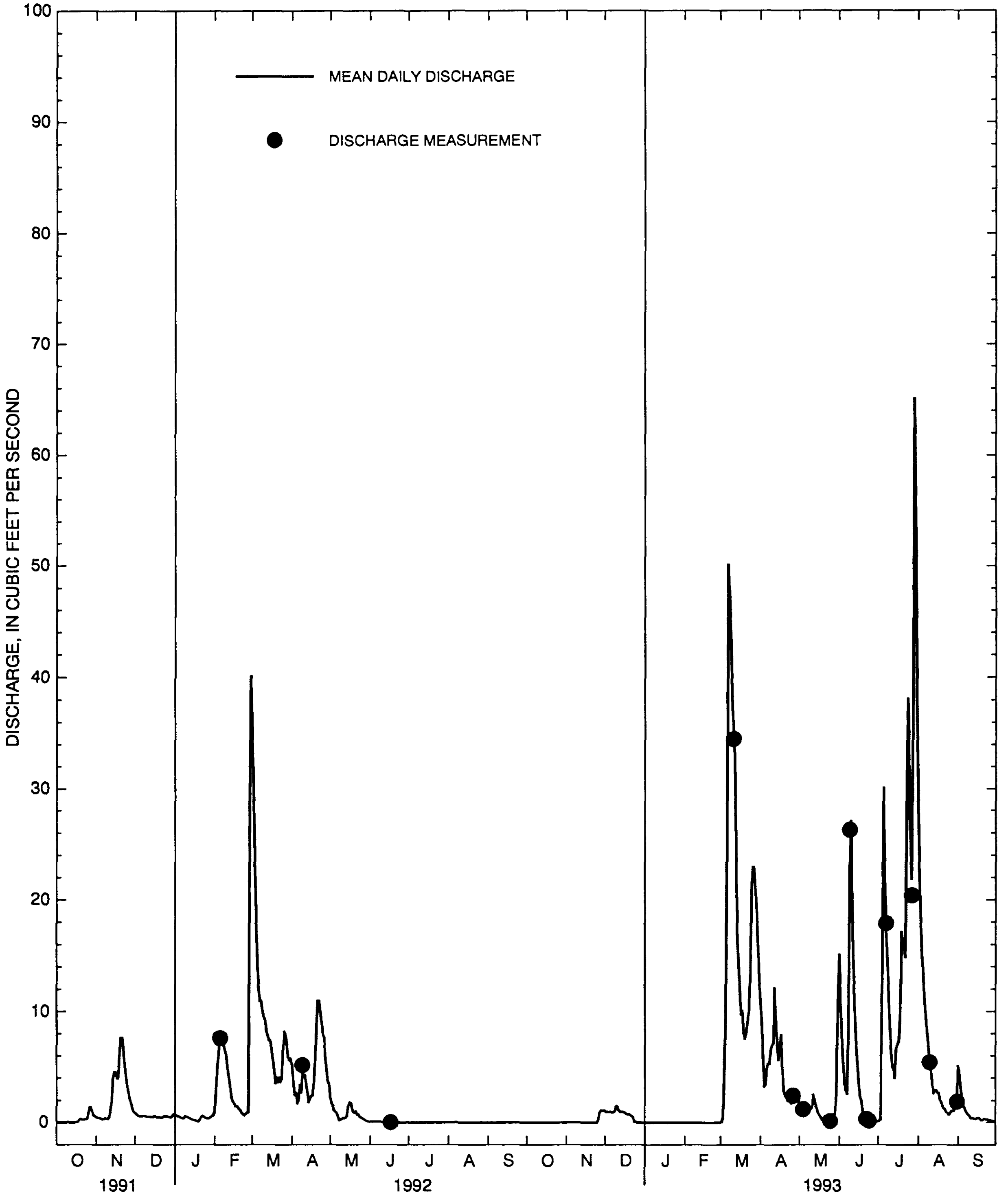

Figure 9. Mean daily discharge and discharge measurements for Deepwater Creek near Raub, North Dakota, October 1991 through September 1993.

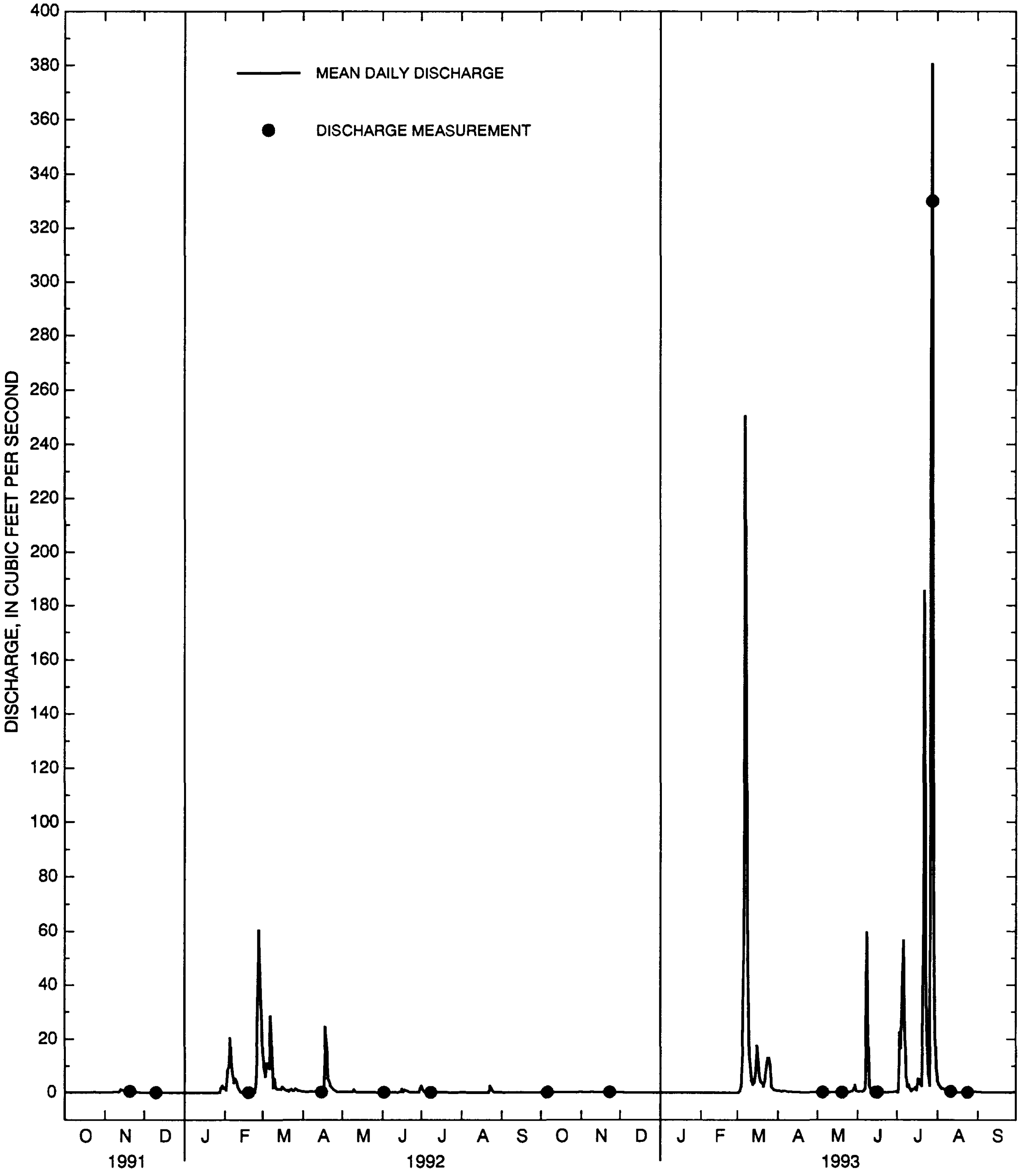

Figure 10. Mean daily discharge and discharge measurements for Bear Den Creek near Mandaree, North Dakota, October 1991 through September 1993.

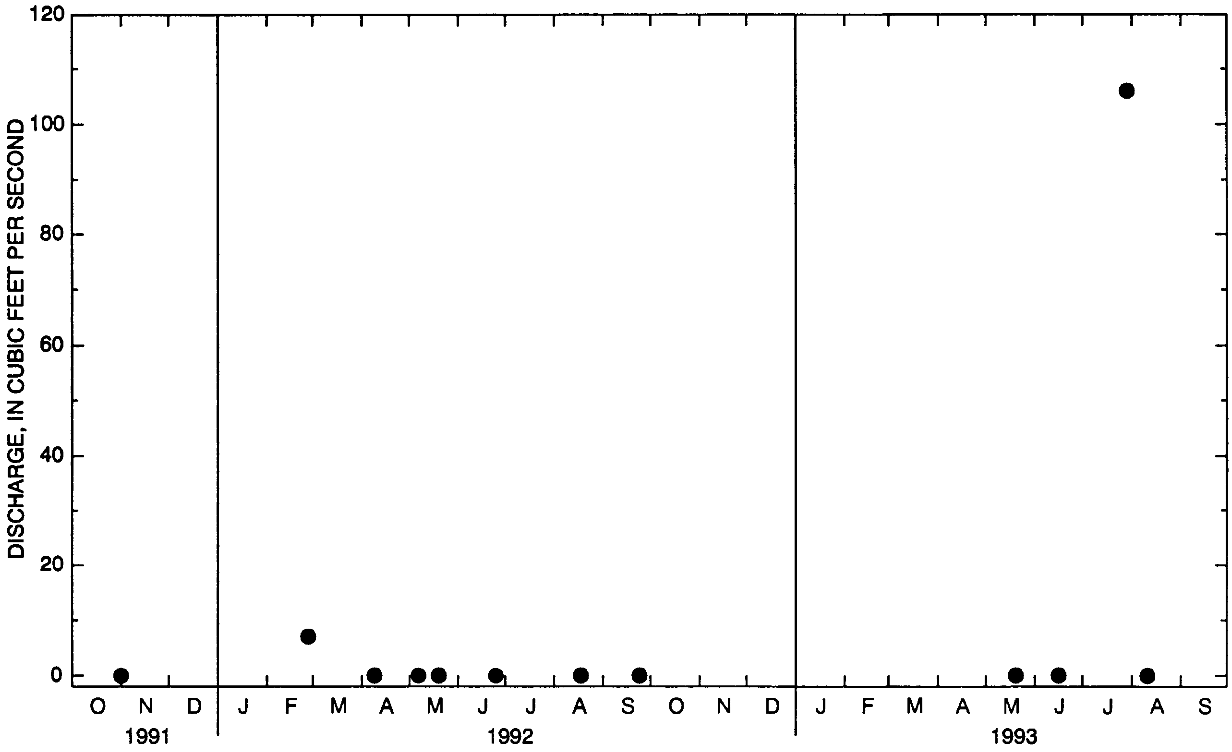

Figure 11. Discharge measurements for Moccasin Creek at mouth near Mandaree, North Dakota, October 1991 through September 1993.

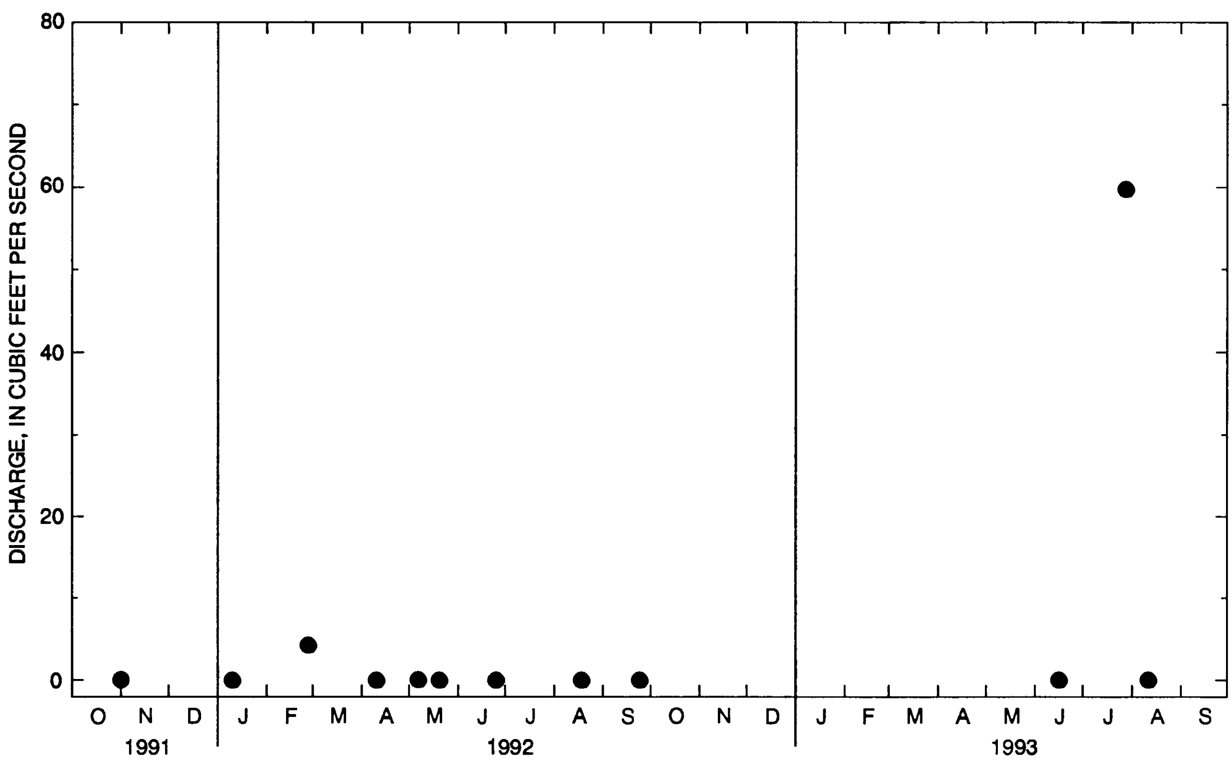

Figure 12. Discharge measurements for Squaw Creek above mouth near Mandaree, North Dakota, October 1991 through September 1993.

Table 3. Discharge, selected nutrient concentrations, and total organic carbon concentrations for three continuous-recording gaging stations and two miscellaneous discharge measurement sites on the Fort Berthold Indian Reservation, west-central North Dakota, 1991-93

[ft^3/s, cubic foot per second; mg/L, milligrams per liter; --, no data]

Date	Discharge (ft^3/s)	Nutrients							Total organic carbon (mg/L)
		Nitrite, dissolved (mg/L as N)	Nitrate, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, total (mg/L as N)	Phosphorus, total (mg/L as P)	Orthophosphate, dissolved (mg/L as P)	
East Fork Shell Creek near Parshall, N. Dak. (06332523)									
1992-02-05	0.74	0.02	0.24	0.26	0.58	--	--	0.42	--
1992-04-09	3.5	<.01	--	<.05	.02	--	--	.10	--
1992-06-17	.60	<.01	--	<.05	<.03	--	--	.44	--
1992-08-11	.02	<.01	--	<.05	.02	--	--	.02	--
1992-09-01	.44	<.01	--	<.05	.04	--		.12	--
1993-03-11	14	.05	1.6	1.6	.21	--	--	.29	--
1993-03-26	19	.02	--	<.05	.04	--	--	.11	--
1993-04-26	3.4	<.01	--	<.05	.05	--	--	.02	--
1993-05-04	1.4	<.01	--	<.05	.06	1.2	0.18	.11	--
1993-05-25	4.2	.08	.15	.23	.04	1.7	.48	.34	--
1993-06-09	18	<.01	--	<.05	.05	1.7	.36	.24	27
1993-06-22	.63	<.01	--	<.05	<.06	1.7	.28	.21	23
1993-06-24	.97	.01	--	<.05	.07	--	--	.22	--
1993-07-07	8.6	<.01	--	<.05	.06	1.5	.38	.30	24
1993-07-27	33	<.01	--	<.01	.10	1.9	.49	.25	24
1993-08-10	5.5	<.01	--	<.05	.11	1.8	.45	.29	22
Deepwater Creek near Raub, N. Dak. (06332770)									
1992-02-05	7.6	0.02	0.34	0.36	0.26	--	--	0.09	--
1992-04-09	5.1	<.01	--	<.05	.02	--	--	<.01	--
1992-06-17	.03	.01	.11	.12	.06	--	--	.03	--
1993-03-11	35	.06	1.4	1.5	.28	--	--	.36	--
1993-04-26	2.4	<.01	--	<.05	.03	--	--	.06	--

Table 3. Discharge, selected nutrient concentrations, and total organic carbon concentrations for three continuous-recording gaging stations and two miscellaneous discharge measurement sites on the Fort Berthold Indian Reservation, west-central North Dakota, 1991-93—Continued

[ft^3/s, cubic foot per second; mg/L, milligrams per liter; --, no data]

Date	Discharge (ft^3/s)	Nutrients							Total organic carbon (mg/L)
		Nitrite, dissolved (mg/L as N)	Nitrate, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, total (mg/L as N)	Phos-phorus, total (mg/L as P)	Ortho-phosphate, dissolved (mg/L as P)	
Deepwater Creek near Raub, N. Dak. (06332770)--Continued									
1993-05-04	1.2	<0.01	--	<0.05	<0.08	1.3	0.11	0.04	--
1993-05-25	.16	<.01	--	<.05	.04	1.5	.12	.04	--
1993-06-09	26	<.01	--	<.05	.03	1.4	.10	.03	19
1993-06-22	.34	<.01	--	<.05	.05	1.7	.23	.18	22
1993-06-24	.17	<.01	--	<.05	.06	--	--	.23	--
1993-07-07	18	<.01	--	<.05	.07	1.3	.25	.19	22
1993-07-27	20	<.01	--	<.05	.10	1.8	.44	.26	24
1993-08-10	5.4	<.01	--	<.05	.05	1.7	.40	.29	24
1993-08-31	1.9	<.01	--	<.05	.03	--	--	.10	--
Bear Den Creek near Mandaree, N. Dak. (06332515)									
1991-11-20	0.53	0.01	0.10	0.11	0.11	1.0	0.15	0.01	--
1991-12-10	.04	.01	.05	.06	.31	.70	.04	.01	--
1992-02-19	.12	<.01	--	.12	.38	.80	.04	.01	--
1992-04-15	.25	<.01	--	<.05	.02	.60	.05	.01	--
1992-06-02	.13	<.01	--	<.05	.05	.60	.08	.02	--
1992-07-08	.12	<.01	--	<.05	.02	.90	.14	.01	--
1992-10-06	.18	<.01	--	<.05	.02	.70	.07	.01	--
1992-11-23	.25	.02	.04	.06	.01	.40	.05	.01	--
1993-05-05	.17	.01	--	<.05	.05	.60	.03	.01	--
1993-05-20	.12	.01	--	<.05	.03	.50	.05	.01	--
1993-06-15	.25	.03	--	<.05	.04	1.1	.16	.01	--
1993-06-16	.20	.01	--	<.05	.04	.90	.11	.01	19
1993-07-28	333	.01	--	.08	.11	1.6	.35	.03	23
1993-08-11	.52	.01	--	<.05	.04	1.1	.17	.04	16
1993-08-24	.19	<.01	--	<.05	.04	.70	.06	.01	--

Table 3. Discharge, selected nutrient concentrations, and total organic carbon concentrations for three continuous-recording gaging stations and two miscellaneous discharge measurement sites on the Fort Berthold Indian Reservation, west-central North Dakota, 1991-93—Continued

[ft^3/s, cubic foot per second; mg/L, milligrams per liter; --, no data]

Date	Discharge (ft^3/s)	Nutrients							Total organic carbon (mg/L)
		Nitrite, dissolved (mg/L as N)	Nitrate, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, total (mg/L as N)	Phosphorus, total (mg/L as P)	Orthophosphate, dissolved (mg/L as P)	
Moccasin Creek at mouth near Mandaree, N. Dak (06337470)									
1993-05-20	0.01	<0.01	--	<0.05	0.03	0.60	0.04	0.01	--
1993-06-16	.04	.01	--	<.05	.02	.70	.06	.01	16
1993-07-28	106	<.01	--	<.05	.21	3.6	1.1	.02	34
1993-08-11	.06	.02	--	<.05	.10	1.0	.10	.02	16
Squaw Creek above mouth near Mandaree, N. Dak. (06337480)									
1993-07-28	60	0.01	--	0.08	0.09	1.4	0.10	0.04	32
1993-08-11	.04	.03	0.02	.05	.15	1.3	.21	.08	23

During the study period, phosphorus concentrations (orthophosphate and total phosphorus), on average, were larger in the streams located east of Lake Sakakawea than in the streams located west of the lake. Orthophosphate concentrations ranged from <0.01 to 0.44 milligram per liter at East Fork Shell Creek near Parshall, N. Dak., and Deepwater Creek near Raub, N. Dak. Orthophosphorus concentrations ranged from 0.01 to 0.08 milligram per liter at Bear Den Creek near Mandaree, N. Dak., Moccasin Creek at mouth near Mandaree, N. Dak., and Squaw Creek above mouth near Mandaree, N. Dak. The larger orthophosphate concentrations in the eastern streams may be indicative of some insecticide application because the eastern basins are dominated by cropland.

Total phosphorus concentrations also were larger in the eastern streams than in the western streams. Total phosphorus concentrations ranged from 0.10 to 0.49 milligram per liter at East Fork Shell Creek near Parshall, N. Dak., and Deepwater Creek near Raub, N. Dak. Total phosphorus concentrations ranged from 0.03 to 0.35 milligram per liter at Bear Den Creek near Mandaree, N. Dak., Moccasin Creek at mouth near Mandaree, N. Dak., and Squaw Creek above mouth near Mandaree, N. Dak., with the exception of 1.1 milligrams per liter at Moccasin Creek at mouth near Mandaree, N. Dak., on July 28, 1993. This large total phosphorus concentration was collected after an intense rainstorm with livestock present in the basin.

Total organic carbon concentrations, in large amounts, could make water unsuitable for human use and toxic to certain life forms. There is no North Dakota water-quality standard for total organic carbon. During the study period, total organic carbon concentrations were slightly smaller in the streams located east of Lake Sakakawea than in the streams located west of the lake. Total organic carbon concentrations ranged from 19 to 27 milligrams per liter at East Fork Shell Creek near Parshall, N. Dak., and Deepwater Creek near Raub, N. Dak. Total organic carbon concentrations ranged from 16 to 34 milligrams per liter at Bear Den Creek near Mandaree, N. Dak., Moccasin Creek at mouth near Mandaree, N. Dak., and Squaw Creek above mouth near Mandaree, N. Dak.

Pesticides

Samples were collected and analyzed for atrazine, carbofuran, cyanazine, and 2,4-D using immunoassay analysis (table 4). These pesticides were chosen because they are commonly used in North Dakota. Atrazine, cyanazine, and 2,4-D are common herbicides used in wheat production. Carbofuran is a common insecticide used in sunflower and potato production. There is no North Dakota water-quality standard for pesticides. The minimum reporting levels for the four pesticides using immunoassay analysis are:

Pesticide	Minimum reporting level (micrograms per liter)
Atrazine (dissolved & total)	<0.05
Carbofuran (dissolved & total)	<.06
Cyanazine (dissolved & total)	<.04
2,4-D (dissolved & total)	<.7

Table 4. Discharge and selected pesticide concentrations determined by immunoassay analysis for three continuous-recording gaging stations and two miscellaneous discharge measurement sites on the Fort Berthold Indian Reservation, west-central North Dakota, 1992-93

[Concentrations are in micrograms per liter; --, no data]

Date	Discharge (ft^3/s)	Atrazine Dissolved	Atrazine Total	Carbofuran Dissolved	Carbofuran Total	Cyanazine Dissolved	Cyanazine Total	2,4-D Dissolved	2,4-D Total
East Fork Shell Creek near Parshall, N. Dak. (06332523)									
1992-05-20	--	--	<0.05	--	--	--	<0.04	--	<0.7
1992-06-17	0.60	--	.06	--	0.10	--	--	--	<.7
1992-06-25	--	--	<.05	--	<.06	--	--	--	.74
1992-07-01	--	--	--	--	<.06	--	--	--	1.3
1992-08-11	.02	--	<.05	--	<.06	--	--	--	--
1993-03-11	14	--	--	--	<.06	--	<.04	--	<.7
1993-03-26	19	--	--	--	<.06	--	<.04	--	<.7
1993-05-04	1.4	--	--	<0.06	--	<0.04	--	<0.7	--
1993-05-25	4.2	--	<.05	--	<.06	--	<.04	--	<.7
1993-06-22	.63	<0.05	--	<.06	--	<.04	--	<.7	--
1993-06-24	.97	<.05	--	<.06	--	<.04	--	<.7	--
1993-07-07	8.6	.09	--	<.06	--	<.04	--	<.7	--
1993-07-27	33	<.05	--	<.06	--	<.04	--	.74	--
1993-08-10	5.5	<.05	--	<.06	--	<.04	--	--	--
Deepwater Creek near Raub, N. Dak. (06332770)									
1992-05-20	--	--	<0.05	--	--	--	<0.04	--	<0.7
1992-06-17	0.03	--	.07	--	<0.06	--	--	--	25
1992-06-25	--	--	<.05	--	<.06	--	--	--	33
1992-07-01	--	--	--	--	<.06	--	--	--	2.8
1993-03-11	35	--	--	--	<.06	--	<.04	--	<.7
1993-05-04	1.2	--	--	<0.06	--	<0.04	--	<0.7	--
1993-05-25	.16	--	<.05	--	<.06	--	<.04	--	4.6
1993-06-22	.34	<0.05	--	<.06	--	<.04	--	<.7	--
1993-06-24	.17	--	--	--	--	<.04	--	<.7	--
1993-07-07	18	<.05	--	<.06	--	<.04	--	.95	--
1993-07-27	20	<.05	--	<.06	--	<.04	--	.74	--
1993-08-10	5.4	<.05	--	<.06	--	<.04	--	--	--

Table 4. Discharge and selected pesticide concentrations determined by immunoassay analysis for three continuous-recording gaging stations and two miscellaneous discharge measurement sites on the Fort Berthold Indian Reservation, west-central North Dakota, 1992-93—Continued

[Concentrations are in micrograms per liter; --, no data]

Date	Discharge (ft^3/s)	Atrazine		Carbofuran		Cyanazine		2,4-D	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Bear Den Creek near Mandaree, N. Dak. (06332515)									
1992-05-20	--	--	<0.05	--	--	--	<0.04	--	--
1992-06-25	--	--	<.05	--	<0.06	--	--	--	<0.7
1992-07-01	--	--	--	--	<.06	--	--	--	<.7
1993-05-20	0.12	--	<.05	--	<.06	--	<.04	--	<.7
1993-06-16	.20	--	<.05	--	<.06	--	<.04	--	<.7
1993-07-28	333	<0.05	--	<0.06	--	<0.04	--	<0.7	--
1993-08-11	.52	--	--	<.06	--	<.04	--	--	--
Moccasin Creek at mouth near Mandaree, N. Dak. (06337470)									
1992-05-20	<0.01	--	<0.05	--	--	--	<0.04	--	<0.7
1992-06-25	.01	--	<.05	--	--	--	--	--	--
1992-07-01	--	--	--	--	<0.06	--	--	--	<.7
1993-05-20	.01	--	<.05	--	<.06	--	<.04	--	<.7
1993-06-16	.04	--	<.05	--	<.06	--	<.04	--	<.7
1993-07-28	106	<0.05	--	<0.06	--	<0.04	--	<0.7	--
1993-08-11	.06	<.05	--	<.06	--	<.04	--	--	--
Squaw Creek above mouth near Mandaree, N. Dak. (06337480)									
1992-05-20	<0.01	--	0.10	--	--	--	<0.04	--	<0.7
1992-06-25	.02	--	<.05	--	<0.06	--	--	--	.94
1992-07-01	--	--	--	--	<.06	--	--	--	.83
1993-07-28	60	<0.05	--	<0.06	--	<0.04	--	<0.7	--
1993-08-11	.04	<.05	--	<.06	--	<.04	--	--	--

With relatively few exceptions, concentrations of atrazine, carbofuran, and cyanazine, were below the minimum reporting levels in samples from all five streams during the study period. Atrazine was above the minimum reporting level in two samples (0.06 and 0.09 microgram per liter) from East Fork Shell Creek near Parshall, N. Dak., in one sample (0.07 microgram per liter) from Deepwater Creek near Raub, N. Dak., and in one sample (0.10 microgram per liter) from Squaw Creek above mouth near Mandaree, N. Dak. Carbofuran was above the minimum reporting level in one sample (0.10 microgram per liter) from East Fork Shell Creek near Parshall, N. Dak. Cyanazine was below the minimum reporting level in all samples from the five streams.

Samples with detectable concentrations of 2,4-D were relatively common in the streams located east of Lake Sakakawea. Detected concentrations of 2,4-D (dissolved and total) ranged from 0.74 to 1.3 micrograms per liter at East Fork Shell Creek near Parshall, N. Dak., and from 0.74 to 33 micrograms per liter at Deepwater Creek near Raub, N. Dak. Maximum 2,4-D concentrations were observed during May, June, and July. These results indicate that the cropped areas in the study area represent potential sources of herbicide contamination to Lake Sakakawea. In contrast, 2,4-D was above the minimum reporting level in only two samples from the streams located west of Lake Sakakawea and both samples were from Squaw Creek above mouth near Mandaree, N. Dak. At the time samples were collected, local officials were in the area spraying for the noxious weed, leafy spurge. The general lack of detectable 2,4-D concentrations in the streams located west of Lake Sakakawea is consistent with the results of the land-use investigation.

The instantaneous load of pesticides being transported by streams can be computed by multiplying the concentrations by stream discharge. The instantaneous loads of pesticides are influenced by variations in discharge. While the largest 2,4-D concentrations at Deepwater Creek near Raub, N. Dak., were measured during June and July of 1992, the calculated load of 2,4-D was relatively small. For example, the calculated load for 2,4-D was 21 micrograms per second on June 25, 1992. In contrast, while a much smaller 2,4-D concentration at Deepwater Creek near Raub, N. Dak., was measured on July 27, 1993, the calculated load of 2,4-D was much larger (414 micrograms per second).

None of the samples analyzed using GC/MS showed pesticide concentrations above the minimum reporting levels for atrazine, carbofuran, cyanazine, and 2,4-D, even though the immunoassay results indicated otherwise. Differences in the results between the two analyses are due to the differences in the methods themselves. Some immunoassay tests identify not only a specific pesticide, but also related degradation products. Thus, a sample tested by immunoassay analysis might test positive for a class of pesticides and degradation products, but the specifically targeted pesticide might not be detected when analyzed by the GC/MS method.

Using the GC/MS method, another pesticide, metribuzin, was identified with concentrations above the minimum reporting level. The minimum reporting level for metribuzin is <0.01 microgram per liter. Metribuzin was above the minimum reporting level in four samples from East Fork Shell Creek near Parshall, N. Dak. Concentrations ranged from 0.01 to 0.02 microgram per liter. Metribuzin is a herbicide used for controlling many grass and broadleaf weeds infesting corn, wheat, and other agricultural crops.

Bacteria

Fecal-coliform and fecal-streptococci bacteria concentrations are used as indicators of fecal contamination and help to define the water quality of streams. Both types of bacteria are present in the intestines of warm-blooded animals, including man, and may indicate the presence of intestinal microorganisms capable of causing disease. The North Dakota water-quality standard for fecal-coliform is

200 colonies per 100 milliliters of water. This standard only applies during the recreation season May 1 through September 30. None of the streams sampled for this study are considered by the State to be recreational streams.

The ratio of fecal-coliform bacteria to fecal-streptococci bacteria in surface water can provide information on the source of contamination (table 5). Possible sources of contamination as indicated by the ratio of fecal-coliform bacteria to fecal-streptococci bacteria are:

Source	Ratio of fecal coliform to fecal streptococci
Human	4.6
Ducks	.6
Sheep	.4
Pigs	.4
Cows	.2
(Data from Bordner and others, 1978)	

Fecal-coliform to fecal-streptococci ratios are not always recommended as a means of differentiating human and animal sources of pollution in many areas of the country. This is because of the variable survival rates of some fecal-streptococcus group species when exposed to an aquatic environment and the influence of disinfected wastewater on fecal material already present in water. However, the streams in the study area are known not to be subject to wastewater treatment, and actual sightings of certain animal species in the area of the streams indicate the fecal-coliform to fecal-streptococci ratio is a viable indicator of sources of waste contamination for this study area.

Fecal-bacteria concentrations varied substantially from stream to stream during the study period (table 5). The ranges in fecal-bacteria concentrations were larger in the streams located west of Lake Sakakawea, where prairie is more predominant, than in the streams located east of the lake, where cropland is more dominant. At Bear Den Creek near Mandaree, N. Dak., fecal-coliform concentrations ranged from 2 to 2,600 colonies per 100 milliliters, and fecal-streptococci concentrations ranged from 4 to 6,700 colonies per 100 milliliters. In contrast, at Deepwater Creek near Raub, N. Dak., fecal-coliform concentrations ranged from 53 to 180 colonies per 100 milliliters, and fecal-streptococci concentrations ranged from 150 to 580 colonies per 100 milliliters. The large concentrations of fecal bacteria in the streams located west of Lake Sakakawea coincided with periods of livestock grazing in those areas.

The larger fecal-bacteria concentrations in the streams located west of Lake Sakakawea coincided with periods of high discharge during summer months and presumably are the result of surface runoff from rangeland during storm events (figs. 13 and 14). In contrast, large fecal-bacteria concentrations in the streams located east of Lake Sakakawea did not always coincide with periods of high flow. The streams located east of Lake Sakakawea tended to flow more often than the streams located west of the lake, and the basins located east of Lake Sakakawea had less rangeland than the basins located west of the lake. Therefore, large fecal-bacteria concentrations normally associated with large discharge were not as evident as in the western streams.

Table 5. Discharge, fecal-coliform concentrations, and fecal-streptococci concentrations for three continuous-recording gaging stations and two miscellaneous discharge measurement sites on the Fort Berthold Indian Reservation, west-central North Dakota, 1992-93

[ft^3/s, cubic feet per second; --, no data]

Date	Discharge (ft^3/s)	Fecal coliform (colonies per 100 milliliters)	Fecal streptococci (colonies per 100 milliliters)	Ratio of fecal coliform to fecal streptococci
		East Fork Shell Creek near Parshall, N. Dak. (06332523)		
1993-05-04	1.4	21	640	0
1993-05-25	4.2	110	310	.35
1993-06-09	18	1,200	1,500	.80
1993-06-22	.63	700	840	.83
1993-07-07	8.6	300	880	.34
1993-07-27	33	78	1,800	.04
1993-08-10	5.5	64	75	.85
		Deepwater Creek near Raub, N. Dak. (06332770)		
1993-05-04	1.2	120	260	0.46
1993-05-25	.16	180	190	.95
1993-06-09	26	160	200	.80
1993-06-22	.34	--	580	--
1993-07-07	18	130	250	.52
1993-07-27	20	140	320	.44
1993-08-10	5.4	53	150	.35
		Bear Den Creek near Mandaree, N. Dak. (06332515)		
1992-02-19	0.12	9.0	40	0.22
1992-04-15	.25	2.0	23	.09
1992-07-08	.12	840	1,600	.52
1992-10-06	.18	700	4.0	175
1993-05-05	.17	420	61	6.89
1993-05-20	.12	31	17	1.82
1993-06-16	.20	380	140	2.7
1993-07-28	333	2,600	6,700	.39
1993-08-11	.52	210	580	.36
		Moccasin Creek at mouth near Mandaree, N. Dak. (06337470)		
1993-05-20	0.01	230	52	4.42
1993-06-16	.04	100	240	.42
1993-07-28	106	8,400	18,000	.47
1993-08-11	.06	350	90	3.89
		Squaw Creek above mouth near Mandaree, N. Dak. (06337480)		
1993-07-28	60	10,000	18,000	0.56
1993-08-11	.04	1,100	320	3.44

The instantaneous load of fecal bacteria being transported by the streams can be computed by multiplying the concentration by the discharge. As previously noted, the fecal-bacteria concentration is more proportional to discharge in the western basins than the eastern basins. During high discharge events, such as occurred in Bear Den Creek, Moccasin Creek, and Squaw Creek on July 28, 1993, increased fecal-bacteria concentrations resulted in elevated loads of fecal bacteria as much as six orders of magnitude or larger above base flow conditions. Two conditions which accounted for the larger fecal-bacteria loads in these streams were an intense rainstorm over the area and the large numbers of livestock nearby.

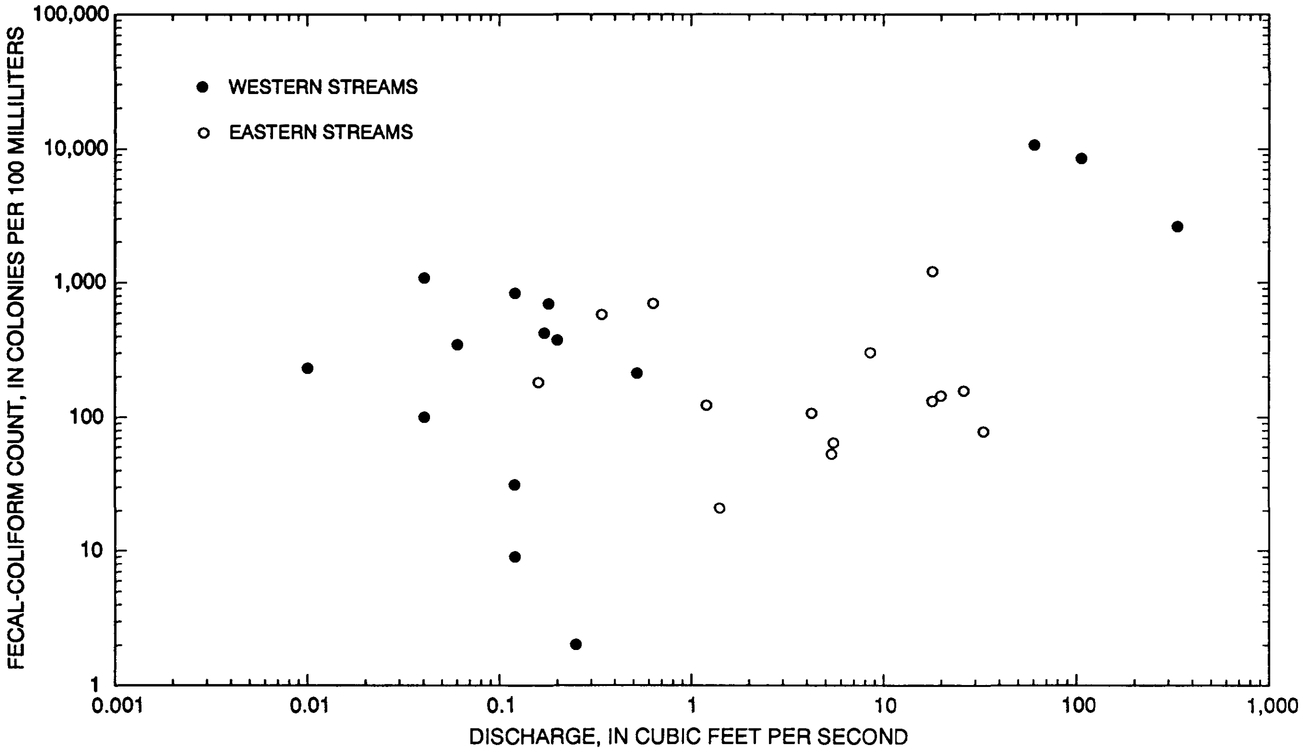

Figure 13. Discharge and count of fecal-coliform colonies from selected streams on the Fort Berthold Indian Reservation, west-central North Dakota, 1992-93.

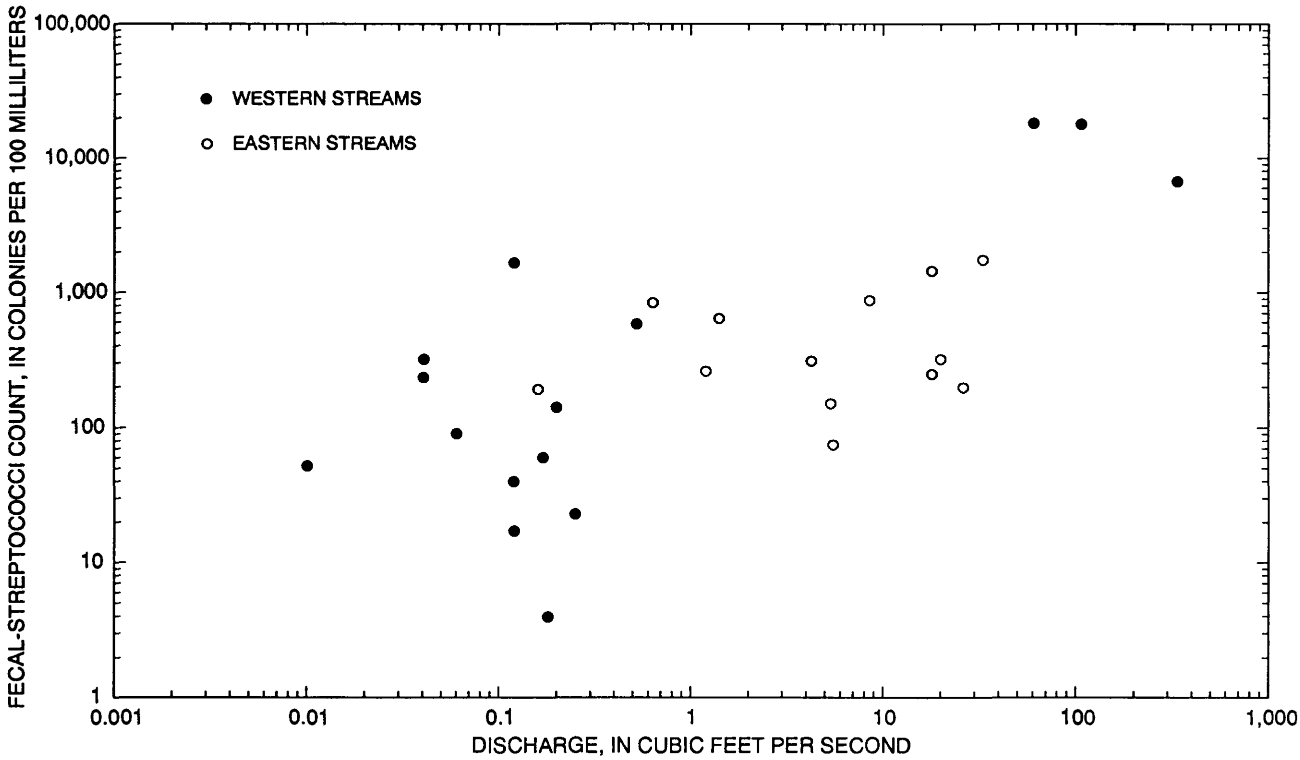

Figure 14. Discharge and count of fecal-streptococci colonies from selected streams on the Fort Berthold Indian Reservation, west-central North Dakota, 1992-93.

SUMMARY AND CONCLUSIONS

Spatial and temporal variations in nonpoint-source contamination in surface water in the Fort Berthold Indian Reservation area during 1990-93 were related to variations in land-use patterns and streamflow. Land-use and streamflow data can be used to help explain possible sources of nonpoint-source contamination. A thorough understanding of land-use variations and streamflow from streams in an area may be used to help design a water-quality monitoring program for human needs and help in the interpretation of water-quality data.

Land use varied over the study area. Prairie was the largest land-use category in the study area. Wheat was the second largest land-use category and the predominant crop in the study area. Bear Den Creek, Moccasin Creek, and Squaw Creek Basins had more acres devoted to prairie than East Fork Shell Creek and Deepwater Creek Basins. Generally, East Fork Shell Creek and Deepwater Creek Basins had more acres planted in crops, particularly wheat, than Bear Den Creek, Moccasin Creek, and Squaw Creek Basins.

Discharge for all five streams in the study area ranged from zero flow for many days to peaks of high flow from spring runoff or intense storms. East Fork Shell Creek and Deepwater Creek (northeast and east of Lake Sakakawea) with larger basins and flatter stream slopes had high flows characterized by rapidly rising flows and gradually receding flows. In contrast, Bear Den Creek, Moccasin Creek, and Squaw Creek (west of the lake) with smaller basins and steeper stream slopes had high flows characterized by rapidly rising flows and receding flows of shorter duration.

Nitrogen concentrations varied throughout the study area. Nitrogen concentrations were larger in the streams located east of Lake Sakakawea than in the streams located west of the lake. The largest nitrogen concentrations in all of the streams occurred during the nongrowing periods. Phosphorus concentrations were larger for the streams located east of Lake Sakakawea than for the streams located west of the lake and may be indicative of insecticide application in the eastern basins. Total organic carbon concentrations were found to be fairly consistent in all the streams sampled.

With few exceptions, concentrations of atrazine, carbofuran, and cyanazine were below minimum reporting levels for all five streams sampled. Immunoassay results indicated 2,4-D was the most commonly detected pesticide of the four pesticides analyzed. The herbicide 2,4-D is commonly used in wheat production. Concentrations of 2,4-D were present in several water samples taken at East Fork Shell Creek near Parshall, N. Dak., and Deepwater Creek near Raub, N. Dak. The largest wheat production in the study area is found in these two basins. Only two water samples taken from the streams located west of Lake Sakakawea had 2,4-D concentrations above the minimum reporting level and both of those water samples were from Squaw Creek above mouth near Mandaree, N. Dak. One other pesticide, metribuzin, found at East Fork Shell Creek near Parshall, N. Dak., was above the minimum reporting level in four samples as determined by gas chromatography analysis.

The fecal-bacteria concentrations found in the streams located west of Lake Sakakawea generally were larger than in the streams located east of the lake. The larger fecal-bacteria concentrations coincided with the presence of livestock in the area. Discharge can have a significant effect on the instantaneous load of fecal bacteria in surface water.

With the development of surface-water resources as potential water sources for human and animal use, consideration must be given to nonpoint-source contamination. Variations in land-use patterns were shown to affect spatial and temporal variations in nonpoint-source contamination. A more intense monitoring program would more fully characterize the areal extent, longevity, and intensity of nonpoint-source contamination on the Fort Berthold Indian Reservation.

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