OCCURRENCE OF SELENIUM AND MERCURY IN SURFACE WATER, WIND RIVER INDIAN RESERVATION, WYOMING, 1995

by Melanie L. Clark and Wilfrid J. Sadler

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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

$$°C = 5/9(°F-32)$$
$$°F = 9/5(°C)+32$$

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

Abbreviated water-quality units used in this report:

kg/d	kilogram per day
mg/L	milligram per liter
mL	milliliter
µm	micrometer
µg/L	microgram per liter

Abbreviations used in this report:

DOI	Department of the Interior
NIWQP	National Irrigation Water Quality Program
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Occurrence of Selenium and Mercury in Surface Water, Wind River Indian Reservation, Wyoming, 1995

By Melanie L. Clark *and* Wilfrid J. Sadler

ABSTRACT

Surface-water samples for chemical analyses were collected during May and August 1995 from 13 sites in an irrigated area of the Wind River Federal Irrigation Project, Wind River Indian Reservation, Wyoming. Sites included irrigation drains, ponds, and streams in an irrigated area partially underlain by seleniferous geologic materials described as having the potential to support vegetation that may be toxic to animals. Samples were analyzed for dissolved selenium, mercury, and other inorganic constituents. The study was done in cooperation with the Shoshone Tribe and the Northern Arapaho Tribe.

Six samples analyzed from the May sampling period had dissolved selenium concentrations greater than the aquatic-life chronic criterion of 5 μg/L (micrograms per liter) established by the U.S. Environmental Protection Agency (USEPA). The largest dissolved selenium concentration (49 μg/L) exceeded the aquatic-life acute criterion of 20 μg/L established by the USEPA. Selenium concentrations in all 12 samples collected during the August sampling period were less than the laboratory minimum reporting level of 5 μg/L. The Goose Pond Drain site was dry in August.

The dissolved solids concentrations were larger in samples collected in May than in August from all but two sites. The large dissolved selenium concentrations in the May samples, collected prior to the start of the irrigation season, were associated with large dissolved solids concentrations.

Dissolved mercury concentrations were less than the minimum reporting level of 0.1 μg/L for 24 of the 25 samples collected during May and August. One sample collected in May had a concentration of 0.3 μg/L. This concentration was less than the aquatic-life acute criterion of 2.4 μg/L for mercury established by the USEPA.

INTRODUCTION

Research by the U.S. Fish and Wildlife Service in the Western United States have related incidences of aquatic bird and fish mortality, embryo teratogenesis, and reproductive failures to large concentrations of selenium in irrigation-drainage water. These effects were first identified in 1983 at the Kesterson National Wildlife Refuge in the western San Joaquin Valley, California, where irrigation-drainage water was impounded (National Research Council, 1989).

In response to widespread concern about the general nature and extent of contaminant problems associated with irrigation-drainage, the U.S. Department of the Interior (DOI) developed the Irrigation Drainage Program (currently the National Irrigation Water Quality Program (NIWQP)) in 1985 and formed an interbureau Task Group on Irrigation Drainage to address water-quality problems related to irrigation drainage for which the DOI may have responsibility. Subsequently, 26 areas that warranted reconnaissance-level studies were identified. The study areas relate to three areas of DOI responsibility: (1) irrigation or drainage facilities constructed or managed by the DOI; (2) National Wildlife Refuges that receive irrigation-drainage water managed by the DOI; and (3) other migratory-bird or endangered-species management areas that receive water from DOI-funded projects.

The identification of the effects of selenium on the health of biota has led to more than a decade of scientific investigations regarding the quality of irrigation water and its potential harmful effects on humans, fish, and wildlife (Case and others, 1990; Sylvester and others, 1990). Selenium concentrations larger than the water-quality criterion for the protection of aquatic life (U.S. Environmental Protection Agency, 1987) have been detected in surface and subsurface-drainage from irrigated land (Feltz and Engberg, 1994); arsenic, heavy metals, and pesticide residues also have been detected in numerous areas of the Western United States that receive irrigation drainage. Toxic concentrations of selenium can occur where naturally occurring selenium and associated constituents are leached from soil or underlying geologic formations by irrigation water and can accumulate by evapotranspiration and bioaccumulation. Lemly and Smith (1987) and Lemly (1993) indicate that selenium concentrations larger than 2 µg/L (micrograms per liter) can bioaccumulate in food chains and cause adverse reproductive effects in fish and aquatic birds. Wetlands and closed-basin ponds are particularly susceptible to evapotranspiration and bioaccumulation. Aquatic plants, invertebrates, fish, birds, and mammals at Kesterson National Wildlife Refuge contained larger concentrations of selenium (sometimes as much as 100 times larger) than those at background sites (Ohlendorf, 1989).

Several studies have been conducted as part of the NIWQP to document the conditions of Federal irrigation projects in Wyoming (Peterson and others, 1991; See and others, 1992; Grasso and others, 1995). Chemical data for 1992-93 surface-water samples indicated concentrations of most trace elements in surface-water samples collected from three of the four irrigation units of the Wind River Federal Irrigation Project, Wind River Indian Reservation, Wyoming (fig. 1) were less than the aquatic-life criteria (Grasso and others, 1995). In one unit, however, the Little Wind Unit near Ethete, concentrations of dissolved selenium and dissolved mercury exceeded the U.S. Environmental Protection Agency (USEPA) aquatic-life criteria. Surface-water samples collected from six sites in the Little Wind Unit had selenium concentrations exceeding the aquatic-life chronic criterion of 5 µg/L established by the USEPA (U.S. Environmental Protection Agency, 1987). Dissolved mercury in one water sample exceeded the USEPA aquatic-life acute criterion for mercury, 2.4 µg/L (U.S. Environmental Protection Agency, 1980). The aquatic-life chronic criterion for selenium (4-day average concentration) and the aquatic-life acute criterion for mercury (1-hour average concentration) are equivalent to the aquatic-life criteria adopted by the State of Wyoming for these constituents (Wyoming Department of Environmental Quality, 1990).

Based on the results from the Wind River Indian Reservation field screening, additional surface-water samples were collected from irrigation drains, ponds, and streams in the Little Wind Unit during May and August 1995 to determine the temporal and spatial variation of dissolved selenium and mercury concentrations in water. The investigation was conducted in cooperation with the Shoshone Tribe and the Northern Arapaho Tribe.

Purpose and Scope

This report describes the occurrence of dissolved selenium and dissolved mercury in surface-water samples collected from the Sharp Nose Draw and Mill Creek drainage areas and from the Little Wind River on the Wind River Indian Reservation, Wyoming. Descriptions of the general physiography and hydrology of the study area, and the concentrations of selected inorganic constituents detected in water samples are presented. Selenium and mercury were studied to identify dissolved concentrations that may exceed aquatic-life criteria, to determine the temporal variation, and to determine the spatial variation in concentrations prior to and during the 1995 irrigation season. Water-quality data are presented in tables and graphs for the May and August sampling periods. All references to selenium and mercury concentrations are concentrations in the dissolved phase. Dissolved constituents were selected for this study because aquatic-life criteria are dissolved concentrations and because they are the most bioavailable. Water-quality-criteria are established as average concentrations. Because the samples in this study represent water quality at one time, the sample cannot be used to classify water as suitable for a specific use. The water samples can be used, however, as a general indicator of water quality in the stream at the time and location of sampling.

Description of Study Area

The study area is located within the Little Wind Unit, Wind River Federal Irrigation Project, within the Wind River Indian Reservation (fig. 1), and includes the Sharp Nose Draw drainage area, a small section of the Mill Creek drainage area adjacent to Sharp Nose Draw, and the Little Wind River (fig. 2). The study area contained within the Little Wind Unit, includes alluvial valleys of the Little Wind River and its tributaries generally south and southeast of Ethete and west of Arapahoe. The geology is composed of Quaternary alluvial

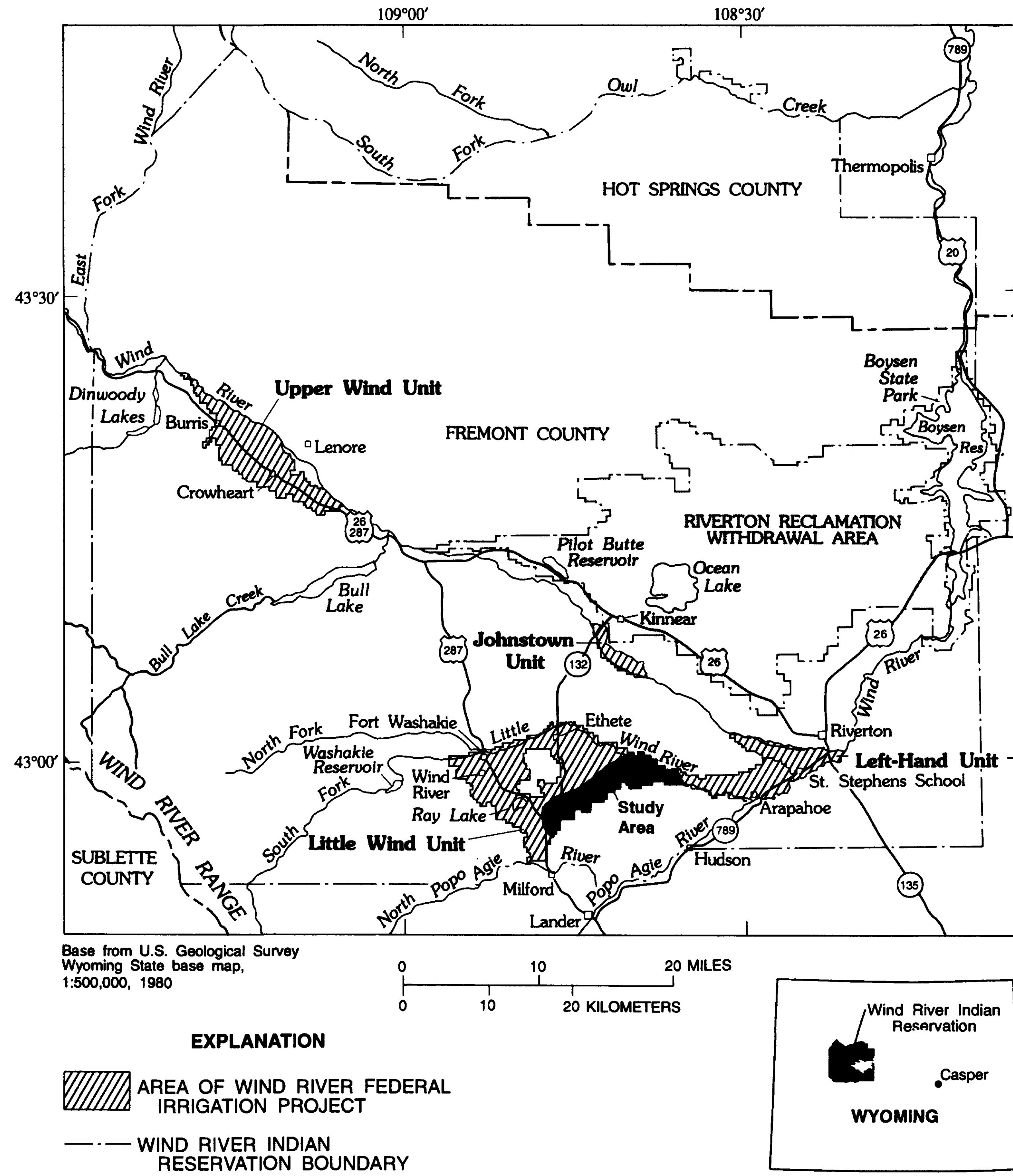

Figure 1. Location of study area in the Wind River Federal Irrigation Project, Wind River Indian Reservation, Wyoming.

sands and gravels and colluvial slope deposits and sedimentary rocks, including the Wind River and Fort Union Formations of Tertiary age and the Cody Shale, Frontier Formation, and Mowry and Thermopolis Shales of Cretaceous age (McGreevy and others, 1969). Quaternary deposits are derived, in part, from the adjacent sedimentary Tertiary and Cretaceous outcrops.

Geologic formations and locally-derived sediment and soil that have the potential to support seleniferous vegetation, which may be toxic to animals (Case and Cannia, 1988), underlie irrigated lands within the Sharp Nose Draw and Mill Creek drainage areas (fig. 2). The Cody Shale, known to contain large concentrations of selenium throughout Wyoming (Case and Cannia, 1988), trends northwest to southeast through the study area and is coincident with the area described as having the potential to support vegetation that may be highly toxic to animals in localized areas (fig. 2). Enrichment of selenium in geologic materials is thought to have occurred through increased volcanic activity during the Cretaceous (McNeal and Balistrieri, 1989). Selenium is associated with the clay fraction of sedimentary rocks and total amounts usually are larger in shales than in sandstones or limestones. For this study, irrigated sites which are underlain by Cody Shale were sampled.

Irrigated land within the study area receives irrigation water mainly from Coolidge Canal and several of its lateral ditches (fig. 2). Coolidge Canal diverts water from the Little Wind River between the towns of Fort Washakie and Ethete (fig. 1). Return

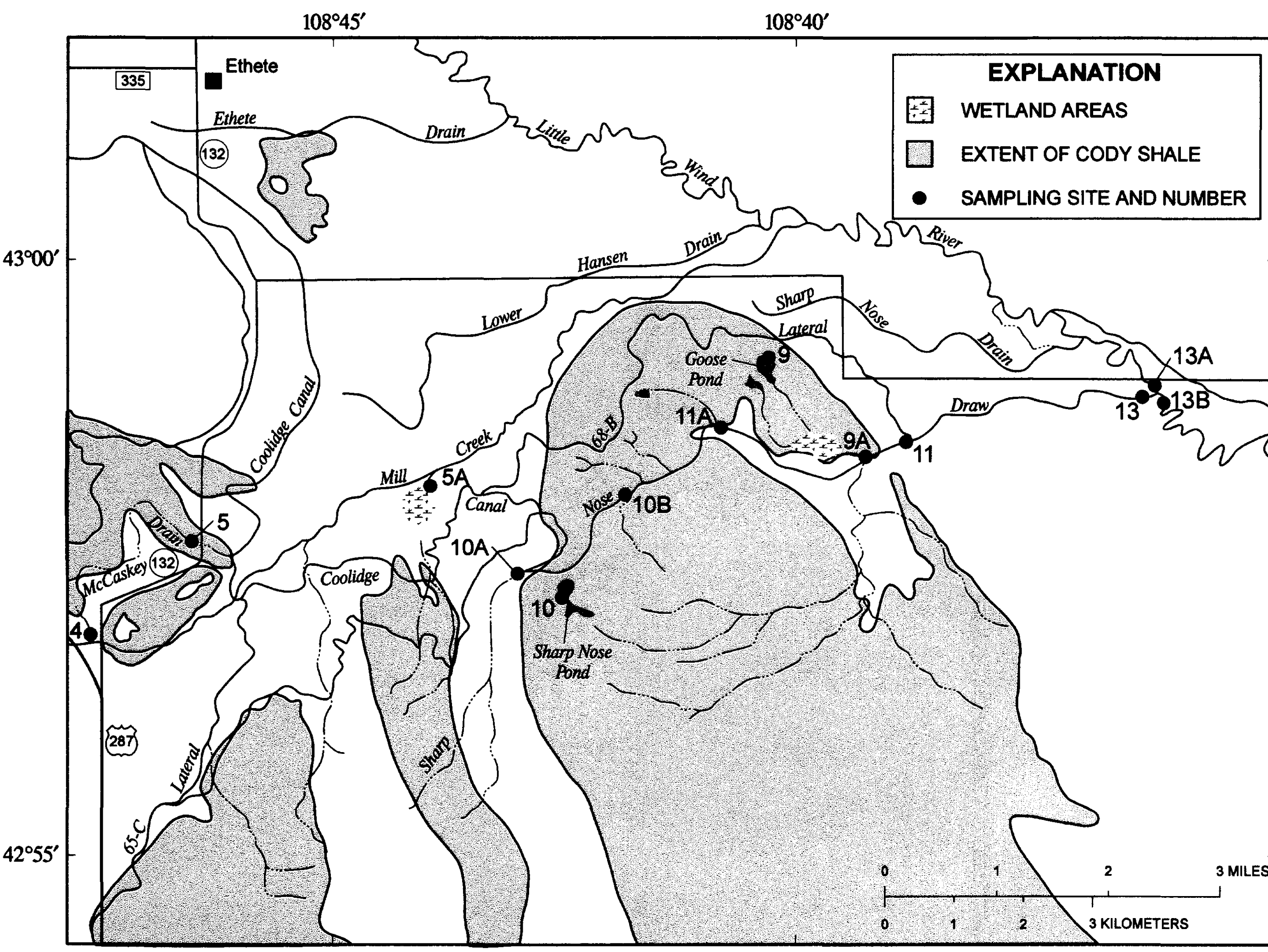

Figure 2. Study area and surface-water sampling sites in the Mill Creek and Sharp Nose Draw drainage areas and the Little Wind River, Wind River Indian Reservation, Wyoming.

flow from irrigated areas served by Coolidge Canal is discharged into a network of natural creeks and draws and constructed drains that divert water back into the Little Wind River. Both Sharp Nose Draw and Mill Creek are tributaries to the Little Wind River. During the irrigation season, discharge of Sharp Nose Draw mainly is return flow from Coolidge Canal. The Mill Creek drainage area is connected hydrologically to the Sharp Nose Draw drainage area through Coolidge Canal. Several ponds and wetlands, including Goose Pond (site 9) and Sharp Nose Pond (site 10), provide wildlife habitat in low-lying basin areas.

Acknowledgments

For their assistance in site selection, special thanks are due to the Shoshone Tribe and the Northern Arapaho Tribe and the Joint Business Council. Appreciation is extended to the Wind River Environmental Quality Commission who provided personnel to assist with planning and sample collection activities. Appreciation also is extended to those residents and landowners who provided access on private lands and information useful to the investigation.

Sample Collection, Measurement, and Analysis

Surface-water sampling sites and the surficial drainage pattern in the study area are shown in figure 2 and the site numbers and station names are listed in table 1. Eight surface-water sampling sites are located in the Sharp Nose Draw drainage area. Four of the Sharp Nose Draw sampling sites, Goose Pond (site 9), Sharp Nose Pond (site10), Sharp Nose Draw above 68-B Lateral (site 11) and Sharp Nose Draw near mouth (site 13) were sampled during the 1992-93 study (Grasso and others, 1995) and were resampled in this study. Goose Pond Drain (site 9A), Sharp Nose Draw above Coolidge Canal (site 10A), Sharp Nose Draw near R1E/R2E boundary (site 10B), and Sharp Nose Draw above Goose Pond Drain (site 11A) were first sampled in this study. Three sampling sites are located in the Mill Creek drainage area. Unnamed Draw to Mill Creek on Ethete Road (site 4) and McCaskey Drain above Coolidge Canal (site 5) were sampled during the 1992-93 study and were resampled in this study. Mill Creek unnamed tributary below Plunkett Road (site 5A) was first sampled in this study. Two sites are located on the Little Wind River: Little Wind River near Arapahoe above Sharp Nose Draw (site 13A), and Little Wind River below Sharp Nose Draw (site 13B).

Table 1. *Surface-water sampling sites in the Mill Creek and Sharp Nose Draw drainage areas and on the Little Wind River, Wind River Indian Reservation, Wyoming, 1995*

Site number (fig. 2)	Station number	Station name
	Mill Creek drainage area	
4	425646108473901	Unnamed Draw to Mill Creek on Ethete Road
5	425730108461201	McCaskey Drain above Coolidge Canal
5A	425808108435601	Mill Creek unnamed tributary below Plunkett Road
	Sharp Nose Draw drainage area	
9	425905108401001	Goose Pond
9A	425821108390301	Goose Pond Drain
10	425718108424201	Sharp Nose Pond
10A	425722108425101	Sharp Nose Draw above Coolidge Canal
10B	425801108414501	Sharp Nose Draw near R1E/R2E boundary
11A	425837108404401	Sharp Nose Draw above Goose Pond Drain
11	425828108384001	Sharp Nose Draw above 68-B Lateral
13	425850108355001	Sharp Nose Draw near mouth
	Little Wind River	
13A	06230500	Little Wind River near Arapahoe
13B	425849108353801	Little Wind River below Sharp Nose Draw

Surface-water samples were collected in May and August 1995, using equal-width-increment sampling method for water-quality analyses. Exceptions were sites where water was too shallow for the sampler and mid-flow dip samples were collected, and at pond sites where depth-integrated samples were collected. Onsite measurements of air temperature, water temperature, barometric pressure, pH, specific conductance, and dissolved oxygen were made immediately after the sample was collected. Samples were collected, preserved, and analyzed according to U.S.

Geological Survey (USGS) guidelines and quality-control procedures for surface-water samples for the determination of inorganic constituents in filtered water (Knapton, 1985; Horowitz and others, 1994). Discharge measurements were made at stream and irrigation-drain sites using techniques described in Rantz and others (1982).

Before each field trip, standard cleansing and rinsing procedures were followed to prepare equipment for sampling. The procedures included cleansing with non-phosphate laboratory detergent, followed by three tap-water rinses, a dilute 5-percent hydrochloric acid rinse, and three deionized water rinses. Finally, equipment was rinsed with native water immediately prior to sampling. Samples to be analyzed for inorganic constituents were filtered onsite using a 0.45-μm (micrometer) capsule filter to remove suspended material. Samples for analyses of dissolved iron, manganese, and selenium, and major cations were filtered into acid-rinsed 250-mL (milliliter) polyethylene bottles and preserved onsite using nitric acid. Samples for analysis of dissolved mercury were filtered into 250-mL glass bottles and preserved onsite using nitric acid/potassium dichromate. Samples for analysis of dissolved major anions were filtered into 500-mL polyethylene bottles and no preservatives were added. One field blank using laboratory-grade inorganic blank water was processed during each sampling period for quality assurance of the cleansing procedures.

Chemical analyses were conducted by the USGS National Water Quality Laboratory in Arvada, Colorado. Selenium concentrations were determined by hydride generation and atomic absorption spectrometry (Fishman and Friedman, 1989). A minimum reporting level of 5 μg/L was used owing to matrix interference during analysis. Mercury concentrations were determined using cold-vapor atomic absorption (Fishman and Friedman, 1989).

OCCURRENCE OF SELENIUM AND MERCURY

Physical properties and inorganic-constituent concentrations in surface-water samples collected during May and August 1995, are listed in table 2. Statistical summaries of selected inorganic constituents, including dissolved selenium and mercury concentrations, are listed in table 3. The median value, or 50th-percentile value, was selected as a measure of central tendency because it is resistant to extreme outlier values. No data are available for Goose Pond Drain (site 9A) for August because the site was dry during the sampling visit.

Selenium

Dissolved selenium concentrations ranged from less than 5 to 49 μg/L for all samples (fig. 3). Dissolved selenium concentrations were less than the minimum reporting level of 5 μg/L for two equipment blank samples. The maximum concentration, 49 μg/L, occurred in the sample collected from Sharp Nose Draw above Goose Pond Drain (site 11A) during May. The 49 μg/L concentration exceeds the aquatic-life acute criterion established by the USEPA, which is a 1-hour average concentration of 20 μg/L not to be exceeded more than once every 3 years on the average (U.S. Environmental Protection Agency, 1987). Selenium concentrations exceeded the aquatic-life chronic criterion of 5 μg/L in 6 of 13 samples collected during May 1995. The aquatic-life chronic criterion for dissolved selenium, established by the USEPA, is a 4-day average of 5 μg/L not to be exceeded more than once every 3 years on the average (U.S. Environmental Protection Agency, 1987).

Temporal variations occurred in selenium concentrations. Dissolved selenium concentrations ranged from less than 5 to 49 μg/L for samples collected during May, prior to the start of the irrigation season. Dissolved selenium concentrations were less than the laboratory minimum reporting level of 5 μg/L for samples collected in August when irrigation canals were operating. Although the median selenium concentration was less than 5 μg/L for both sampling periods, the mean concentration for samples collected during May was 11 μg/L compared to less than 5 μg/L for samples collected during August.

Seeps and salt crusts on the soil were observed during the May sampling period. Salts may accumulate through evaporation and transpiration in the soil after one irrigation season has ended and before irrigation begins the following season. Selenium and sulfur are in the same chemical family and exhibit similar chemical behavior. Under oxidizing and alkaline conditions, both elements can occur in the 6+ oxidation state; selenium as selenate (SeO_4^{2-}) and sulfur as sulfate (SO_4^{2-}). Selenate may substitute for sulfate in the lattice structure of soluble sulfate salts (Presser and Swain, 1990). Dissolution of the seleniferous sulfate salts by precipitation may transport selenium and other

Table 2. *Physical properties and inorganic-constituent concentrations in surface-water samples collected in the Mill Creek and Sharp Nose Draw drainage areas and from the Little Wind River, Wind River Indian Reservation, Wyoming, 1995*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm of Hg, millimeters of mercury. Analytical results in milligrams per liter except as indicated; µg/L, micrograms per liter; <, less than laboratory minimum reporting level; --, no data]

Site number (fig. 2)	Station name	Date sampled (month-day-year)	Discharge, instantaneous (ft^3/s)	Specific conductance, field (µS/cm)	pH, whole water (standard units)	Temperature, air (°C)	Temperature, water (°C)	Barometric pressure (mm of Hg)	Oxygen, dissolved	Oxygen, dissolved (percent saturation)	Hardness, total ($CaCO_3$)	Calcium, dissolved (Ca)	Magnesium, dissolved (Mg)
					Mill Creek drainage area								
4	Unnamed Draw to Mill Creek	05-01-95	0.49	12,800	8.5	6.0	6.0	626	14.2	146	2,700	260	500
	on Ethete Road	08-28-95	<.1	1,330	7.6	19.0	15.0	629	5.6	68	330	56	46
5	McCaskey Drain above	05-01-95	<.1	4,720	8.0	8.0	10.0	626	9.2	102	2,300	400	320
	Coolidge Canal	08-28-95	1.0	1,060	7.6	20.0	18.0	630	5.9	76	520	110	60
5A	Mill Creek unnamed tributary	05-01-95	1.1	2,180	8.4	11.0	8.0	625	12.1	126	760	140	100
	below Plunkett Road	08-28-95	1.3	1,130	8.3	17.0	19.0	630	9.6	126	470	99	54
					Sharp Nose Draw drainage area								
9	Goose Pond	05-03-95	--	1,250	8.4	9.0	14.0	631	10.2	120	490	89	65
		08-30-95	--	1,310	9.2	17.0	20.0	636	7.5	100	460	64	74
9A	Goose Pond Drain	05-03-95	.54	7,000	8.3	10.0	16.0	631	10.0	126	3,000	320	540
		08-30-95	DRY	--	--	--	--	--	--	--	--	--	--
10	Sharp Nose Pond	05-02-95	--	366	9.2	9.5	9.0	620	10.4	111	150	33	16
		08-28-95	--	380	10.2	21.0	24.0	630	14.0	203	120	23	16
10A	Sharp Nose Draw above	05-02-95	.05	4,890	8.3	11.0	10.0	622	12.1	134	1,100	280	100
	Coolidge Canal	08-29-95	.01	4,110	8.0	17.5	16.0	632	9.9	123	1,600	400	150
10B	Sharp Nose Draw near	05-02-95	.08	5,800	8.6	12.0	11.0	626	12.0	136	1,400	250	180
	R1E/R2E boundary	08-29-95	1.4	470	8.8	29.0	24.0	630	10.9	158	170	40	17
11A	Sharp Nose Draw above	05-02-95	.17	7,580	8.4	15.0	14.0	627	12.1	147	2,000	310	300
	Goose Pond Drain	08-29-95	4.8	615	8.5	24.0	23.0	633	8.2	116	220	51	23
11	Sharp Nose Draw above 68-B	05-04-95	1.1	4,520	8.3	17.0	12.0	633	9.2	105	1,300	210	190
	Lateral	08-30-95	5.4	650	8.5	20.0	19.0	637	9.8	127	240	55	26
13	Sharp Nose Draw near Mouth	05-04-95	1.9	3,620	8.2	18.0	12.0	635	9.2	104	1,000	170	140
		08-30-95	11	1,030	8.1	21.0	17.0	638	6.8	85	370	81	40
					Little Wind River								
13A	Little Wind River near	05-04-95	170	1,320	8.4	18.0	14.0	634	8.6	102	460	96	54
	Arapahoe	08-31-95	67	618	8.2	15.0	16.5	639	8.8	108	250	61	24
13B	Little Wind River below Sharp	05-04-95	172	1,420	8.4	18.0	14.0	633	8.7	102	470	97	56
	Nose Draw	08-31-95	78	682	8.2	15.0	17.5	640	9.3	116	270	63	27

Table 2. *Physical properties and inorganic-constituent concentrations in surface-water samples collected in the Mill Creek and Sharp Nose Draw drainage areas and from the Little Wind River, Wind River Indian Reservation, Wyoming, 1995--Continued*

Site number (fig. 2)	Sodium, dissolved (Na)	Sodium (percent)	Sodium adsorption ratio	Potassium, dissolved (K)	Alkalinity, laboratory (as $CaCO_3$)	Sulfate, dissolved (SO_4)	Chloride, dissolved (Cl)	Fluoride, dissolved (F)	Silica, dissolved (SiO_2)	Dissolved solids (residue at 180°C)	Dissolved solids (sum of constituents)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Selenium, dissolved (µg/L as Se)
Mill Creek drainage area															
4	2,600	68	22	20	354	8,100	90	0.3	6.1	13,100	11,800	30	10	0.3	16
	180	54	4	3.0	191	510	2.4	.2	11	918	923	16	6	<.1	<5
5	410	28	4	13	380	2,900	24	.7	11	4,830	4,310	19	14	<.1	<5
	36	13	.7	3.2	157	430	3.0	.2	12	792	749	68	27	<.1	<5
5A	210	38	3	8.3	388	820	19	1.1	16	1,700	1,550	28	120	<.1	7
	70	24	1	4.0	318	280	4.6	.7	21	764	724	26	54	<.1	<5
Sharp Nose Draw drainage area															
9	83	27	2	7.8	151	500	11	.6	.8	934	848	18	8	<.1	<5
	100	32	2	5.4	67	630	8.7	.6	2.9	970	926	<3	3	<.1	<5
9A	900	40	7	17	289	4,200	130	.3	8.0	7,580	6,290	30	30	<.1	<5
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	14	17	.5	3.1	76	99	3.7	.3	.3	244	215	31	5	<.1	<5
	20	25	.8	4.0	61	110	4.0	.3	.9	220	215	5	2	<.1	<5
10A	830	62	11	7.8	363	2,400	43	1.3	9.2	4,210	3,890	16	320	<.1	<5
	500	40	5	7.1	277	2,200	46	.9	21	3,670	3,490	12	53	<.1	<5
10B	960	61	11	9.7	268	3,100	48	.8	1.2	5,160	4,710	<9	31	<.1	11
	30	27	1	3.0	112	130	4.1	.2	12	307	304	48	6	<.1	<5
11A	1,400	61	14	16	324	4,200	62	.5	2.1	7,320	6,490	30	190	<.1	49
	40	28	1	4.5	155	160	4.6	.3	16	402	392	50	17	<.1	<5
11	650	52	8	10	249	2,400	67	.5	9.8	4,100	3,690	<9	390	<.1	11
	48	29	1	4.4	164	170	5.7	.2	16	426	424	28	17	<.1	<5
13	510	53	7	9.0	220	1,800	53	.5	9.1	3,110	2,820	<9	89	<.1	15
	78	31	2	4.3	222	320	9.5	.4	15	703	681	21	28	<.1	<5
Little Wind River															
13A	120	36	2	4.9	175	520	11	.5	11	1,020	922	7	54	<.1	<5
	32	22	.9	2.2	139	170	5.0	.3	6.3	390	384	6	9	<.1	<5
13B	120	36	2	4.9	177	520	12	.5	10	1,060	927	8	56	<.1	<5
	39	24	1	2.4	150	200	5.6	.4	6.6	443	434	6	17	<.1	<5

Table 3. *Statistical summaries of physical properties and inorganic-constituent concentrations in surface-water samples collected in the Mill Creek and Sharp Nose Draw drainage areas and from the Little Wind River, Wind River Indian Reservation, Wyoming, 1995*

[Analytical results in milligrams per liter, except as indicated; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius;
µg/L, micrograms per liter; <, less than laboratory minimum reporting level]

Water-quality constituent	Minimum	Maximum	May median	August median
Specific conductance (µS/cm)	366	12,800	4,520	856
Calcium, dissolved (Ca)	23	400	210	62
Magnesium, dissolved (Mg)	16	540	140	33.5
Sodium, dissolved (Na)	14	2,600	510	44
Alkalinity (as $CaCO_3$)	61	388	268	156
Sulfate, dissolved (SO_4)	99	8,100	2,400	240
Chloride, dissolved (Cl)	2.4	130	43	4.8
Dissolved solids (residue at 180°C)	220	13,100	4,100	573
Mercury, dissolved (µg/L as Hg)	<.1	.3	<.1	<.1
Selenium, dissolved (µg/L as Se)	<5	49	<5	<5

salt-forming constituents to surface water or ground water. Dissolved selenium concentrations above the laboratory minimum reporting level of 5 µg/L generally were associated with large dissolved solids concentrations in surface-water samples collected in May (fig. 4). Larger median values for specific conductance, and larger median concentrations of calcium, magnesium, sodium, sulfate, alkalinity, and total dissolved solids were present in water samples collected in May compared to samples collected in August (table 3). Ground-water discharge to streams accounts for a larger part of the stream discharge in May, prior to the irrigation season, than in August, when irrigation canals are in operation and contributing large return flows. Ground-water discharge, the thawing of frost in the subsurface, and natural precipitation may transport selenium to surface-water drainages prior to the start of the irrigation season.

The seeps and salt crusts on the soil that were observed during the May sampling period were not observed during the August sampling period. The absence of salts in August indicates that the accumulated salts were either leached into the ground-water system or into a stream before the August sampling period. For sites that had larger discharges during August, dilution from irrigation-return flows also was likely a factor in decreasing selenium concentrations. Evaporation and flushing of salts during natural runoff were reported to increase selenium concentrations in wetlands and ground water in the Kendrick area, which is another Federal irrigation area underlain by the Cody Shale (See and others, 1992) near Casper, Wyoming, about 120 miles east of Riverton (fig. 1). Salt crust samples from the Kendrick area contained selenium concentrations as large as 70 micrograms per gram (See and others, 1992).

Spatial variations only were observed in dissolved selenium concentrations in the samples collected in May because all the August samples were less than the minimum reporting level of 5 µg/L. Concentrations of dissolved selenium ranged from less than 5 to 49 µg/L for water samples collected from drains, ponds, and tributaries in the Sharp Nose Draw drainage area. Selenium concentrations in all samples collected during May from Sharp Nose Draw were larger than the aquatic-life chronic criterion, except a sample collected from Sharp Nose Draw above Coolidge Canal (site 10A). Concentrations of dissolved selenium ranged from less than 5 to 16 µg/L for water samples collected from drains and tributaries in the Mill Creek drainage area. Two of the three samples collected in

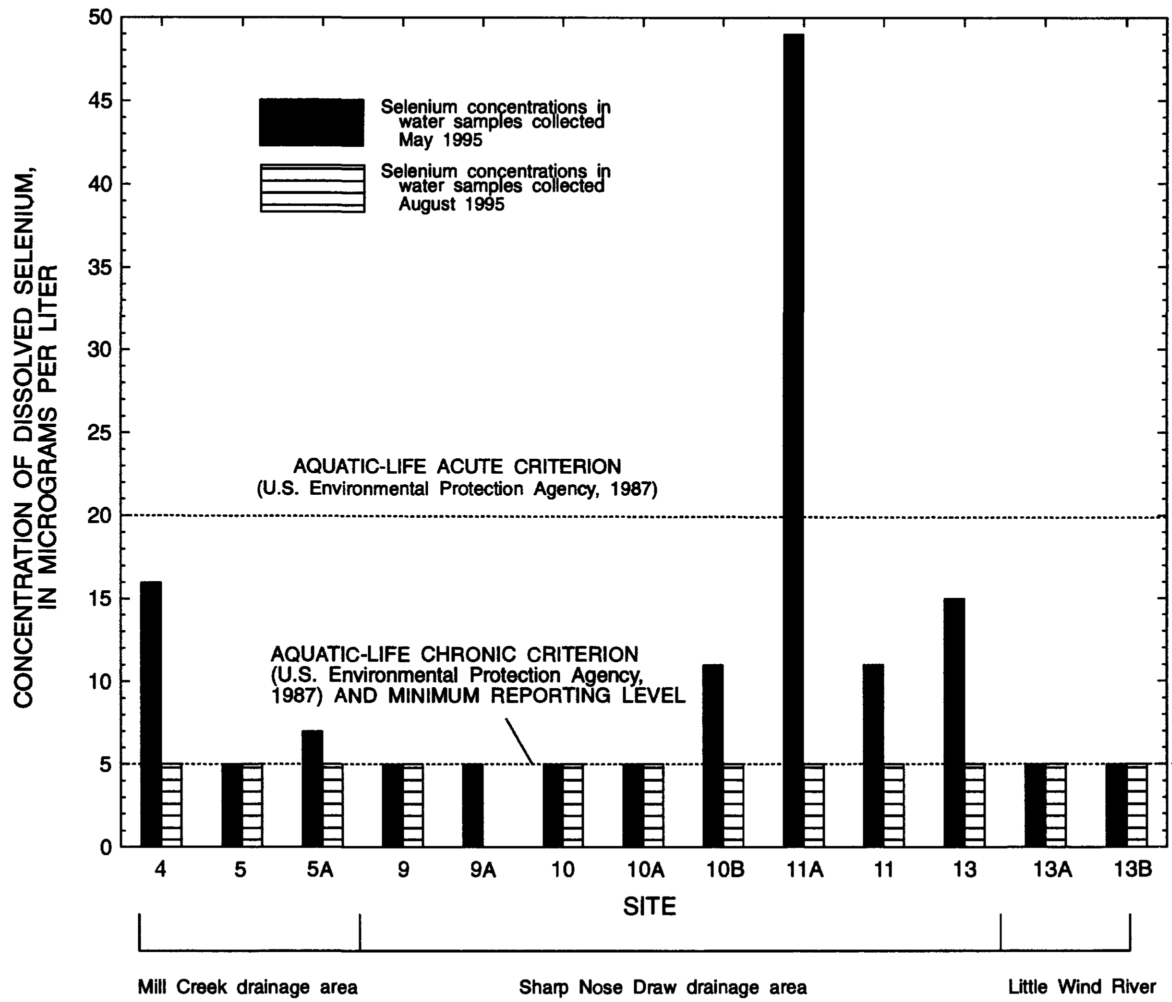

Figure 3. Selenium concentrations in surface-water samples collected in the Mill Creek and Sharp Nose Draw drainage areas and from the Little Wind River, Wind River Indian Reservation, Wyoming, 1995. (Site locations are shown on figure 2).

May in the Mill Creek drainage area, Unnamed Draw to Mill Creek on Ethete Road (site 4) (16 µg/L) and Mill Creek unnamed tributary below Plunkett Road (site 5A) (7 µg/L), had selenium concentrations larger than the aquatic-life chronic criterion (fig. 3). The effect of selenium input from the Sharp Nose Draw and Mill Creek drainage areas was not observed in the concentrations of selenium in water samples collected from the Little Wind River; upstream (site 13A) and downstream (site 13B) concentrations were both less than the minimum reporting level of 5 µg/L. These data indicate that large selenium concentrations occurred in isolated areas and were not a widespread problem.

Sites with samples containing selenium concentrations greater than 5 µg/L were sites that received irrigation drainage water. Not every site receiving irrigation drainage, however, had large selenium concentrations; McCaskey Drain above Coolidge Canal (site 5), Goose Pond (site 9), and Goose Pond Drain (site 9A) are adjacent to irrigated areas but selenium concentrations were less than 5 µg/L. Sharp Nose Pond (site 10) and Sharp Nose Draw above Coolidge Canal (site 10A) had concentrations less than 5 µg/L but did not receive much, if any, irrigation drainage. Both Goose Pond and Sharp Nose Pond are low-lying basins underlain by the Cody Shale, but selenium concentrations were less than the laboratory minimum reporting level. Low-

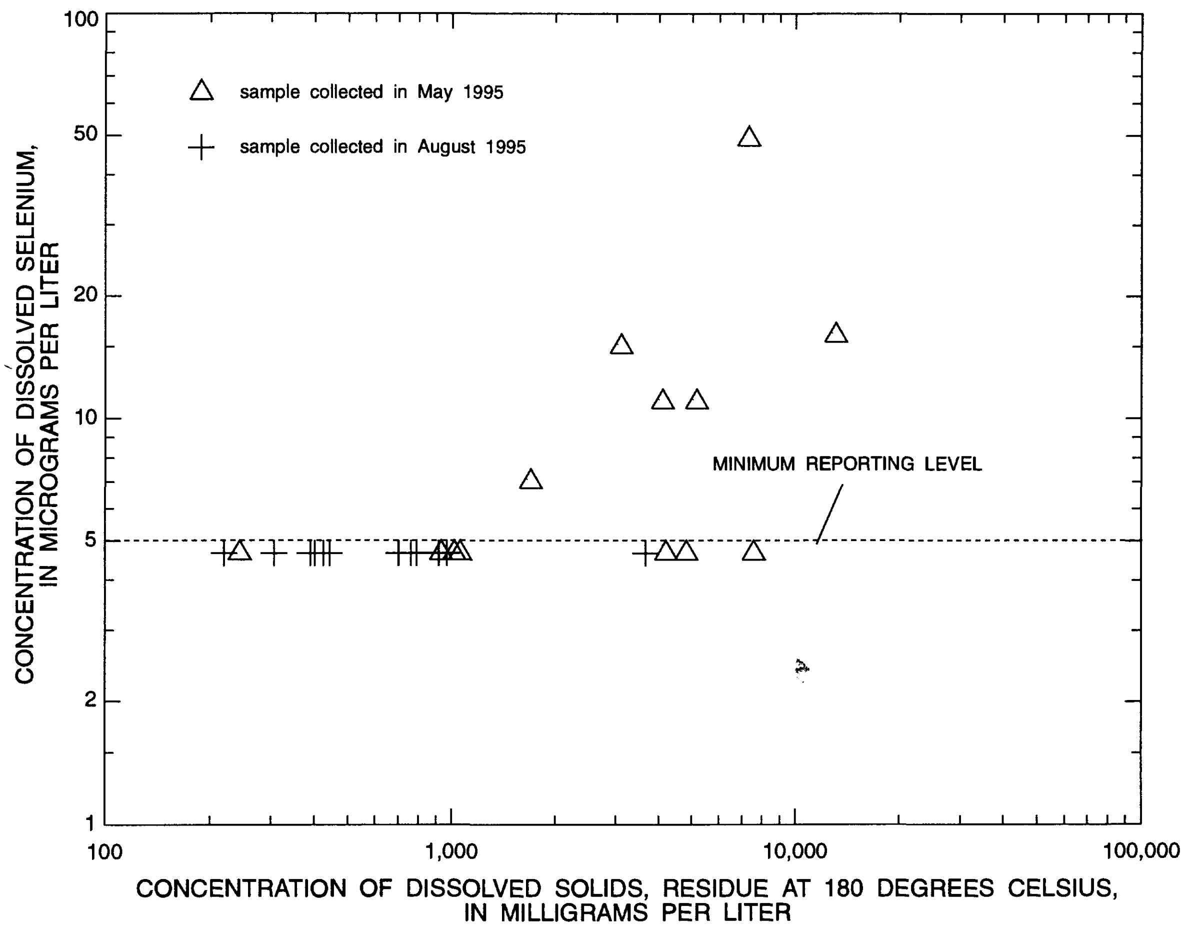

Figure 4. Dissolved selenium concentrations in comparison to dissolved solids concentrations in surface-water samples collected in the Mill Creek and Sharp Nose Draw drainage areas and from the Little Wind River, Wind River Indian Reservation, Wyoming, 1995.

lying basins that receive irrigation drainage and are underlain by the Cody Shale have caused selenium problems in the Kendrick area (See and others, 1992). The larger flows on the Little Wind River probably dilute the local effects of irrigation drainage.

During the sampling of Sharp Nose Draw, a rainfall event occurred after sampling sites 10B and 11A and before sampling sites 11 and 13. This event could have diluted the selenium concentrations through surface inflow. In order to compare selenium concentrations between sites on Sharp Nose Draw, instantaneous loads of selenium were calculated. The selenium loads for the sites on Sharp Nose Draw were less than 0.0003 kg/d (kilograms per day) (site 10A), 0.002 kg/d (site 10B), 0.02 kg/d (site11A), 0.03 kg/d (site 11), and 0.07 kg/d (site 13).

Mercury

Mercury concentrations were less than the minimum reporting level of 0.1 µg/L for all but one of the surface-water samples collected during May and August 1995 during this study (fig. 5). Dissolved-mercury concentrations were less than the minimum reporting level of 0.1 µg/L for two equipment blank samples. A concentration of 0.3 µg/L was detected at Unnamed Draw to Mill Creek on Ethete Road (site 4) during the May sampling period and exceeded the aquatic-life chronic criterion. The aquatic-life chronic criterion for mercury established by the USEPA is a 4-day average concentration of 0.012 µg/L (U.S. Environmental Protection Agency, 1980) not to be exceeded more than once every 3 years on the average.

Since the minimum reporting level (less than 0.1 µg/L) is larger than the chronic criterion, exceedance of the criterion could not be determined. The 0.3 µg/L concentration (site 4) is near the minimum reporting level when the precision of the method is taken into account. During the field screening (August 1992 and June 1993, Grasso and others, 1995) and the sampling of August 1995, mercury concentrations in water samples collected at site 4 were less than 0.1 µg/L.

Concentrations of mercury for all samples collected during May and August 1995 were less than the aquatic-life acute criterion of 2.4 µg/L. The aquatic-life acute criterion for mercury established by the USEPA is a 1-hour average concentration of 2.4 µg/L (U.S. Environmental Protection Agency, 1980). The large mercury concentration of 4.9 µg/L reported for the sample collected from Sharp Nose Draw above 68-B Lateral (site 11) during June 1993 (Grasso and others, 1995) was not confirmed in 1995.

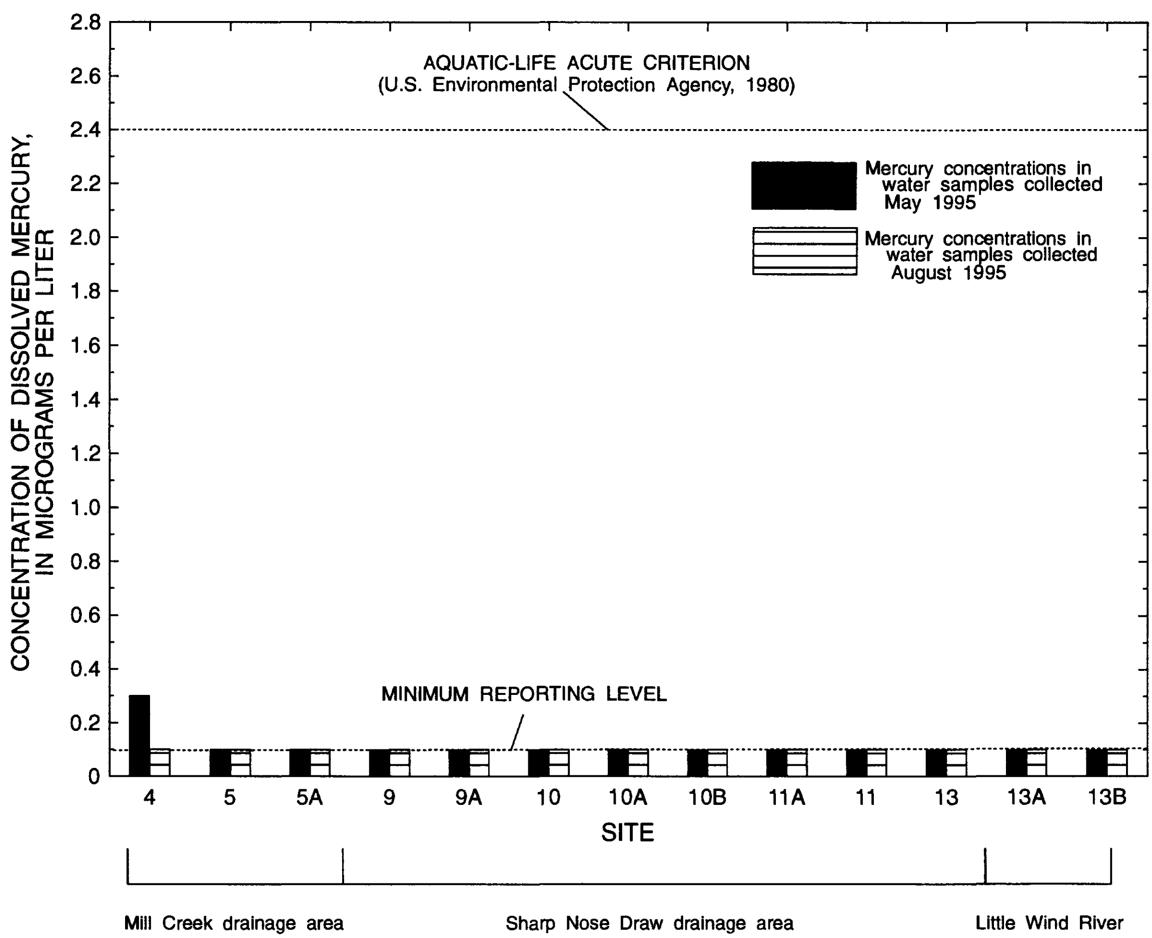

Figure 5. Mercury concentrations in surface-water samples collected in the Mill Creek and Sharp Nose Draw drainage areas and from the Little Wind River, Wind River Indian Reservation, Wyoming, 1995. Fresh water aquatic-life chronic criterion of 0.012 micrograms per liter, (U.S. Environmental Protection Agency, 1980) is not shown. (Site locations are shown on figure 2).

SUMMARY

Physical properties of surface water were measured and samples were collected and analyzed during 1995 from an irrigated area of the Wind River Federal Irrigation Project, Wind River Indian Reservation, Wyoming. Surface-water samples were collected from 13 sites in the Sharp Nose Draw and Mill Creek drainage areas and the Little Wind River during May; 12 samples were collected in August 1995. Sites included irrigation drains, ponds, and streams in an irrigation area underlain by seleniferous geologic material. Samples were analyzed for dissolved selenium, dissolved mercury, and other selected inorganic constituents.

Dissolved selenium concentrations in surface-water samples collected in May ranged from less than 5 to 49 µg/L; concentrations of samples collected in August were less than 5 µg/L. Although the median selenium concentration was less than 5 µg/L for both sampling periods, the mean concentration for samples collected during May was 11 µg/L compared to less than 5 µg/L for samples collected during August. Of the 13 samples collected in May, 6 samples had selenium concentrations larger than the aquatic-life chronic criterion of 5 µg/L established by the U.S. Environmental Protection Agency (USEPA). The maximum selenium concentration (49 µg/L) was detected in a sample collected in May from Sharp Nose Draw above Goose Pond Drain (site 11A). The selenium concentration in this sample exceeded the aquatic-life acute criterion of 20 µg/L established by the USEPA. The maximum concentration detected in the Mill Creek drainage area was 16 µg/L in a sample collected from Unnamed Draw to Mill Creek on Ethete Road (site 4). Selenium concentrations in all 12 samples collected during the August sampling period were less than the minimum reporting level. Goose Pond Drain (site 9A) could not be sampled in August because the site was dry. The large selenium concentrations in May were associated with large dissolved solids concentrations. Dissolution of seleniferous sulfate salts from precipitation may transport selenium and other salt-forming constituents to surface water or ground water, prior to the start of the irrigation season.

Dissolved mercury concentrations were less than the reporting level of 0.1 µg/L for all surface-water samples collected during May and August except one sample collected in May that had a concentration of 0.3 µg/L. This concentration was larger than the aquatic-life chronic criterion established by the USEPA of 0.012 µg/L, but was less than the aquatic-life acute criterion of 2.4 µg/L for mercury.

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