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Abstract

This paper details the spatial and temporal occurrence of arsenic concentrations and mass flow rates along the Jemez River and the Rio Grande in north-central New Mexico. Samples of river water, hot springs, and cold springs were collected at 25 locations during November 1994, March 1996, and June 1996. Arsenic and other trace metal analyses were performed by graphite furnace and hydride generator atomic absorption spectroscopy for acidified unfiltered samples. Concentrations along the Jemez River ranged from 2 to 300 micrograms per liter (μg/L). Seven of ten locations exceeded the current EPA arsenic drinking water standard of 10 μg/L. These seven locations were at or downstream of the Jemez Springs area where roughly 1,500 L/min of thermal water enters the river from the Valles caldera geothermal system. In the Jemez Springs area, the thermal water can be sampled directly from Soda Dam hot spring and Travertine Mound hot spring. Discharge from these hot springs flows directly into the Jemez River. From Soda Dam hot spring, the arsenic concentration was 1,770 μg/L and the mass flow rate was 0.02 kg/day. The Travertine Mound hot spring arsenic concentration was 830 μg/L, and the mass flow rate was 0.001 kg/day. The highest arsenic mass flow rate on the Jemez River was approximately 6 kg/day at a location below Soda Dam hot spring and decreased to 0.1 kg/day below the Jemez Canyon Dam. All six sampling locations along the Rio Grande between Española and Bernalillo had arsenic concentrations less than 10 μg/L. The Rio Grande showed no difference in arsenic concentrations above and below the confluence with the Jemez River. Discharge of the Rio Grande was about 30 times greater than the Jemez River. The arsenic mass flow rate of the Rio Grande during June 1996 was approximately 6 kg/day.

Introduction

Arsenic is an element of environmental concern worldwide because of its known toxicity. In the United States the Environmental Protection Agency (EPA) has reviewed the drinking water standard for arsenic beginning in the late 1990s (EPA, 2001; Wust, 2001). Since 1974 the maximum contaminant level (MCL) for arsenic in drinking water has been set 50 μg/L. An amendment to the Safe Water Drinking Act in 1996 required the EPA to review the drinking water standard for arsenic. In addition to review, the act required a proposed MCL by January 1, 2000, and implementation of the final MCL by January 2001. The review included an evaluation of: human health effects of consuming arsenic, risks associated with consumption of different concentrations of arsenic in drinking water, technology for removal of arsenic from drinking water, and occurrence and sources of arsenic in the United States. In January 2001 the EPA lowered the MCL to 10 μg/L (EPA, 2001).

In northern New Mexico, arsenic concentrations between 2,000 and 7,000 μg/L are found as a natural constituent dissolved in the 200–300°C geothermal reservoir of the Valles caldera (Fig. 1; Goff and Gardner, 1994). These high-temperature fluids circulate in caldera fill ignimbrites and precaldera rocks at depths of 500–1,500 m (1,640–4,921 ft) and drain from the caldera along the south-southwest-trending Jemez fault zone forming a classic hydrothermal outflow plume (Goff et al., 1988). The reservoir fluids mix with other ground waters and issue as hot springs primarily at Soda Dam and Jemez Springs. Discharge temperatures at these springs range from 30° to 75°C. The hot spring system at Soda Dam has created an extensive multi-tiered travertine deposit and has been episodically active for the past 1 m.y. (Goff and Shevenell, 1987). At least 1,500 L/min of hot spring discharge enters the Jemez River at the Soda Dam area (Trainer, 1984), and a similar amount enters the river at Jemez Springs. An equivalent volume of mixed geothermal fluid circulates at depth adjacent to the fault zone (Goff et al., 1988). The hot spring waters are revered for their therapeutic value and are consumed by the public in small quantities. The aquifer is tapped by wells and used for drinking and other domestic purposes.

The object of this paper is to examine the temporal and spatial changes in the chemistry of surface waters in the north-central region of New Mexico with particular attention to arsenic. Thorough documentation of the concentrations and mass flow rates of arsenic in surface waters in the Jemez Mountain region are lacking. This study focuses on arsenic because of the potential of many different anthropogenic and natural processes to have contributed to elevated arsenic levels in surface waters.

Arsenic chemistry

The stable forms of arsenic in solution are arsenate (As^{5+}) or arsenite (As^{3+}) (Hem, 1992). Unless these species are analyzed separately, chemical analyses report only the total concentration of elemental arsenic. In waters between pH 3 and 7 the dominant anion of arsenic is $H_2AsO_4^-$; between pH 7 and 11 the divalent species $HAsO_4^{2-}$ is favored (Hem, 1992). Arsenic concentrations in water decrease as a result of many inorganic processes including: adsorption or coprecipitation by hydrous iron oxide, adsorption onto aluminum hydroxide and clays, coprecipitation or combination with sulfide in reduced bottom mud, and by isomorphous substitution for phosphate in various minerals (Hem, 1992; Nagorski and Moore, 1999). Organic and biochemical mechanisms can also reduce arsenic concentrations in water. Biologically mediated methylation can transform inorganic arsenic species to organic species. This is accomplished by a sequence of five reduction reactions where arsenic acid [H_3AsO_4] transforms to trimethylarsine [$(CH_3)_3As$] (Matisoff et al., 1982; Nagorski and Moore, 1999).

Anthropogenic sources of arsenic

Several studies have reported high concentrations of arsenic in the United States, particularly in the Southwest (Welch et al., 2000). There are several factors both anthropogenic and natural that contribute to the elevated arsenic levels in the southwestern states. The most common anthropogenic sources are related to mining activities (Nagorski and Moore, 1999; Shevenell et al., 1999; Welch et al., 2000). Arsenic is concentrated in many hydrothermal ore deposits, especially those with sulfides and sulfo-salts (Boyle and Jonasson, 1973). Arsenic is used during prospecting as an indicator or path finder element for economic deposits of copper, silver, gold, zinc, cadmium, mercury, uranium, tin, lead, phosphorus, antimony, bismuth, sulfur, selenium, tellurium, molybdenum, tungsten, iron, nickel, cobalt, and platinum (Boyle and Jonasson, 1973; Nicholson, 1993). Arsenic-bearing minerals are widespread in igneous, sedimentary, and metamorphic rocks (Boyle and Jonasson, 1973; Matisoff et al., 1982; Baker
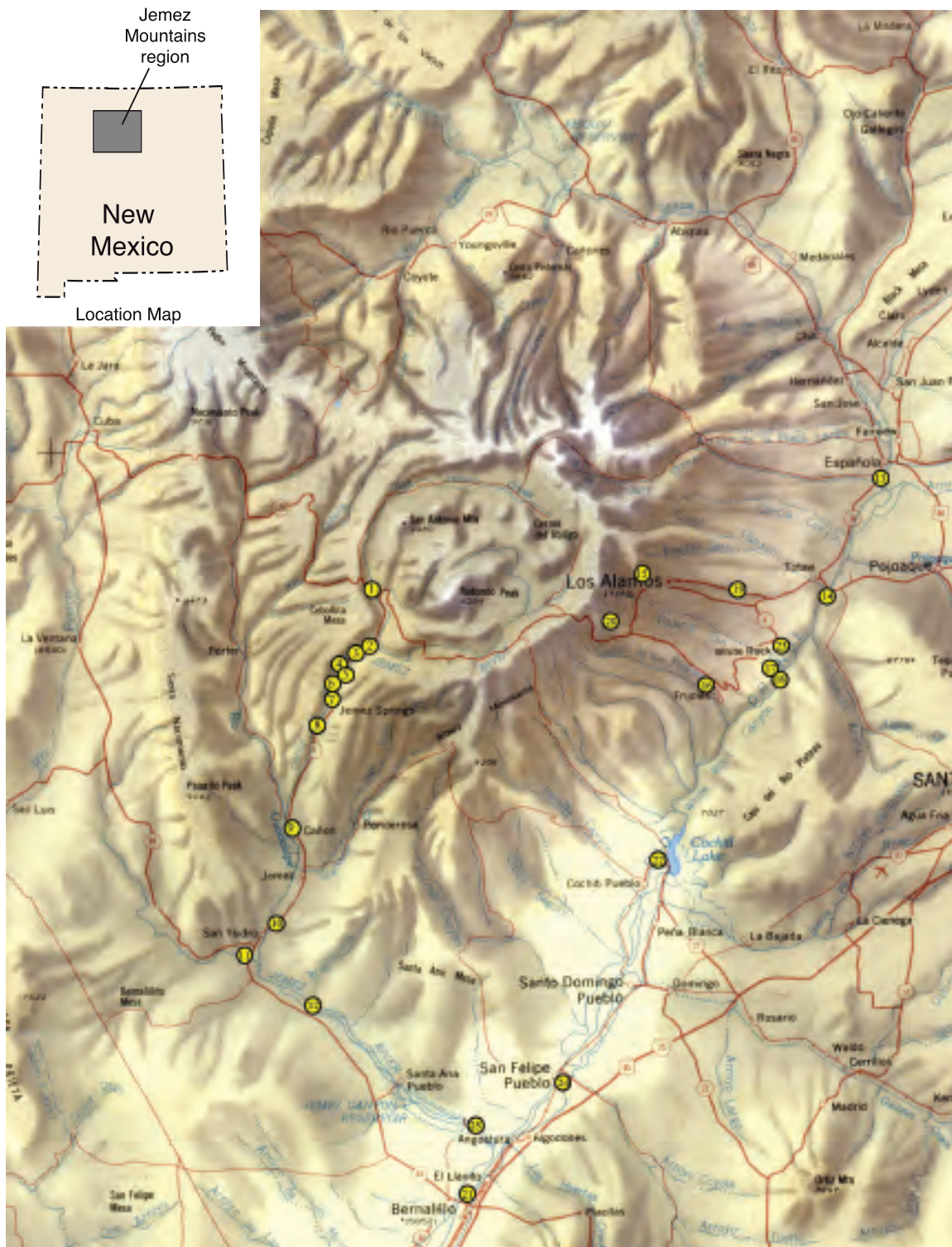
FIGURE 1—Inset map shows location of the Jemez Mountains region. Principal map shows sample localities in yellow. Base map reproduced with permission ©1988, revised 1991, Raven Maps & Images.

et al., 1998; Shevenell et al., 1999; Welch, 1999; Oremland et al., 2000; Welch et al., 2000).

Mining is the most widespread anthropogenic contributor of arsenic to the environment. Mining disaggregates the host rock and brings it to the surface where oxidation and mobilization of the principal arsenic-bearing mineral, pyrite, can occur (Boyle and Jonasson, 1973; Hem, 1992; Baker et al., 1998; Shevenell et al., 1999). Additionally, arsenic commonly exists in high concentrations in both gold and coal deposits. Other anthropogenic arsenic sources include: insecticides, herbicides, crop desiccants, wood preservatives, feed additives, pharmaceuticals, chemical weapons, riot control agents, metallurgical additives, burning of coal, and waste disposal (Aurilio et al., 1995; Welch et al., 2000; EPA, 2001).

Natural sources of arsenic

Sources of arsenic in natural waters include discharges from hot and cold springs in active volcanic terrains, and solubilization resulting from the reduction of ferric iron arsenate or arsenite and reduction to arsine or methylarsines (Clement and Faust, 1981; Hem, 1992; Nagorski and Moore, 1999). Natural releases into the atmosphere result from the venting of volcanic gases and the volatilization of arseniferous compounds by bacteria, fungi, and other microorganisms in soils, sediments, and bogs (Boyle and Jonasson, 1973; Wilson and Hawkins, 1978; Hem, 1992; Goff et al., 1998; Welch et al., 2000). Geothermal processes are also effective in making arsenic more mobile. High concentrations of arsenic are often observed in geothermal areas, particularly in the western U.S. In New Mexico high arsenic levels have been documented in the Socorro area (Dunbar et al., 1995; Welch, 1999; Brandvold, 2001) and along the Rio Grande valley (Chapin and Dunbar, 1995). The highest arsenic concentrations in New Mexico have been documented in fluids within the Valles caldera geothermal system (Goff et al., 1988; Goff and Gardner, 1994).

Study objectives

The objectives of this study are to characterize the occurrence of arsenic in surface waters in the southern Jemez Mountains of northern New Mexico. The study area can be divided into two regions; the Jemez River region and the Rio Grande region. The geology of the Jemez River catchment is primarily late Tertiary to Quaternary volcanic tuffs, domes, flows, and associated sediments. The catchment of the Rio Grande in the study area is mostly Miocene to Pliocene basin fill sediments with exposures of Precambrian basement rocks and Quaternary volcanic tuffs and lava flows. Land use in the Jemez River region includes ranching, some agriculture, very localized logging, and sparsely populated communities of less than 800 people. The Rio Grande study region is located between the communities of Española (1998 estimated population of 9,000) and Bernalillo (1998 estimated population of 7,500). Land use on this section of the river includes ranching, agriculture, municipalities, and industrial activities associated with Los Alamos National Laboratory. Both the Jemez River and the Rio Grande have dams within the study reach. To evaluate anthropogenic and natural arsenic loads, samples were collected from natural hot springs, natural cold springs, high elevation rivers, rivers below dams, rivers below municipalities, and rivers below agricultural land.

Field collection methods

Samples of surface waters were taken during three separate sampling campaigns: November 1994, March 1996, and June 1996. Samples were collected from 25 locations within Sandoval and Los Alamos Counties (Fig. 1) using standard procedures described by Trujillo et al. (1987). All samples were collected from the edge of bank or from spring outlet. At each location temperature was measured using a battery operated, digital thermometer (Fluke brand 52), and pH was measured using limited range indicator strips (ColorpHast brand nos. 9581, 9582, and 9583; appendix). Discharge on the Jemez River was measured using a Pygmy meter. On the Rio Grande discharge values were obtained at three locations where United States Geological Survey (USGS) stream gages are located. An error of 10% was assumed for Pygmy meter discharge measurements (S. Woods, pers. comm. 2003), and a 5% error was assumed for USGS stream gage discharge measurements (F. D. Byrd, pers. comm. 2003).

For trace metal analysis, samples were collected, acidified, and stored in a cooler before delivery to an analytical laboratory. A blank of acidified distilled water was submitted for quality assurance during each campaign. Trace metal concentrations were measured by atomic absorption spectroscopy using a graphite furnace, whereas chloride and sulfate concentrations were determined by ion chromatography (appendix; Trujillo et al., 1987; Goff et al., 2001). The study focused on the total available arsenic present. The results presented are all unfiltered samples and represent the total dissolved and colloidal arsenic. Arsenic mass flow rates were calculated for the Jemez River and the Rio Grande by multiplying the concentration (µg/L) by the flow rate (L/sec), then converting units to kilograms per day.

Results

Arsenic concentrations for the three sampling campaigns are listed in Table 1 by catchment and media type. Not all 25 locations were sampled each time. Changes in study scope prevented sampling each location during the three sampling campaigns.

TABLE 1—Arsenic concentrations and descriptions of samples collected. Refer to Fig. 1 for sample locations. Results are unfiltered and reported as µg/L. Locations not sampled are designated by **ns**. Values less than 10 µg/L have a 10% error. Values greater than 10 µg/L have a 5% error.

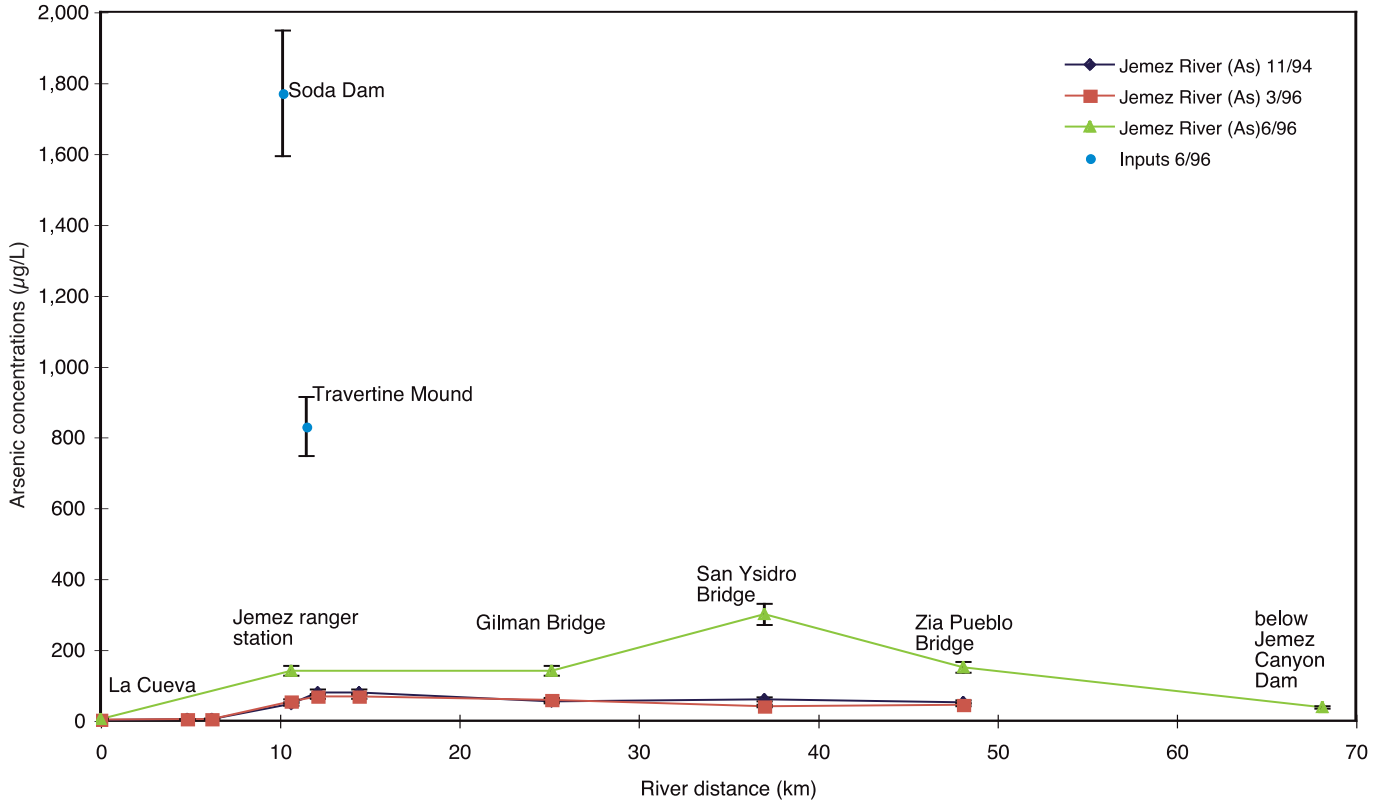| No.	Catchment	Location description	Media	11/10/94	3/13/96	6/23/96
1	Jemez	San Antonio Creek, La Cueva	Surface water	2.0	2.3	4.5
2	Jemez	Jemez River, Camp Shaver	Surface water	3.9	3.8	ns
3	Jemez	Jemez River, sulfur deposits	Surface water	3.8	4.5	ns
4	Jemez	Soda Dam hot spring	Hot spring	1,760	1,880	1,770
5	Jemez	Jemez River at ranger station	Surface water	47	54	140
6	Jemez	Travertine Mound, Jemez hot springs	Hot spring	680	890	830
7	Jemez	Jemez River 0.4 km below hot spring	Surface water	79	68	ns
8	Jemez	Jemez River 4 km below hot spring	Surface water	79	68	ns
9	Jemez	Jemez River at Gilman Bridge	Surface water	54	58	140
10	Jemez	Jemez River at San Ysidro Bridge	Surface water	60	41	300
11	Jemez	Rio Salado at San Ysidro Bridge	Surface water	4.8	3.1	ns
12	Jemez	Jemez River at Zia Pueblo Bridge	Surface water	52	45	150
25	Jemez	Jemez River below Jemez Canyon Dam	Surface water	ns	ns	37.0
13	Rio Grande	Rio Grande at Española	Surface water	2.8	3.3	1.8
14	Rio Grande	Rio Grande at Otowi Bridge	Surface water	2.8	2.6	2.3
15	Rio Grande	Los Alamos Creek, above reservoir	Surface water	0.7	0.7	ns
16	Rio Grande	Frijoles Creek at Bandelier	Surface water	0.9	1.0	ns
17	Rio Grande	Rio Grande below Pajarito Spring	Surface water	3.5	3.2	2.7
18	Rio Grande	Pajarito Spring	Spring	1.5	2.4	ns
19	Rio Grande	Los Alamos Creek, below Basalt Spring	Surface water	4.5	6.3	ns
20	Rio Grande	Armistead Spring	Spring	1.5	2.6	ns
21	Rio Grande	Rio Grande at Bernalillo	Surface water	9.3	4.2	2.5
22	Rio Grande	Rio Grande below Cochiti Dam	Surface water	2.8	3.6	2.2
23	Rio Grande	White Rock sewage treatment effluent	Surface water	ns	3.8	ns
24	Rio Grande	Rio Grande at San Felipe Pueblo	Surface water	ns	ns	2.3

FIGURE 2—Jemez River arsenic concentrations from La Cueva to below Jemez Canyon Dam. Error bars are 10% for analytical error.

Jemez River region

A total of 12 locations were sampled along a 68-km (42.3-mi) reach of the Jemez River (Fig. 1). At ten locations surface water was sampled, and at two locations thermal spring water was sampled. Figure 2 shows the arsenic concentrations for the three sampling campaigns as a function of river distance for the Jemez River. The arsenic concentration of the surface water increases between km 6 and km 10. At km 10, Soda Dam hot spring discharges into the Jemez River. Soda Dam hot spring is located at the intersection of the main trace of the Jemez fault zone and the Jemez River (Goff and Shevenell, 1987; Goff et al., 1988). All seven surface water locations downstream of this zone have arsenic concentrations greater than the current EPA drinking water standard of 10 µg/L. At the town of Jemez Springs, several seeps and small hot springs, including Travertine Mound hot spring (Fig. 3), contribute geothermal water to the Jemez River (Goff et al., 1988). By calculating a mass balance of conservative ions, Trainer (1984) estimated 1,500 L/min of geothermal water enters the river along the zone from Soda Dam to Jemez Springs. There was very little difference in arsenic concentrations between the November 1994 and March 1996 sampling periods. The June 1996 samples, however, showed higher arsenic concentrations possibly because the discharge was much less than the previous sampling events. The USGS stream gage, 08324000, located downstream of the Gilman Bridge reported discharge of 1,130 L/sec for November 10, 1994; 880 L/sec for March 13, 1996; and only 204 L/sec for June 23, 1996. Figure 4 shows the arsenic mass flow rate and discharge values for the June 1996 sample period. Discharge data for all sample locations were not available for either the November 1994 or the March 1996 sample period. The highest arsenic mass flow rate was measured at the Jemez ranger station (Fig. 5); again this location is downstream of the Soda Dam hot spring area. Downstream, below the Jemez Canyon Dam, the arsenic mass flow rate decreases to approximately 0.1 kg/day.

Rio Grande region

Arsenic concentrations were below 10 µg/L at all locations sampled on the Rio Grande. The samples showed very little difference between the three sampling events at all locations on the Rio Grande. Figure 6 shows arsenic concentrations as a function of river distance between Española and Bernalillo. Between San Felipe Pueblo and Bernalillo, the Jemez River joins the Rio Grande. The June 1996 Jemez River concentration of arsenic was approximately 40 µg/L at the farthest downstream location before joining the Rio Grande. There does not appear to be an increase in arsenic concentration downstream of the confluence of these two rivers. In June 1996 the discharge of the Rio Grande was at least 30 times greater than that of the Jemez River. The higher arsenic concentrations of the Jemez River are probably diluted by the higher discharge of the Rio Grande. Figure 7 shows the June 1996 discharge and arsenic mass flow rate of the Rio Grande. The Rio Grande mass flow rate was approximately 6 kg/day, whereas the Jemez River input was only approximately 0.1 kg/day. The June 1996 Rio Grande mass flow rate compares to the highest mass flow rate on the Jemez River. Thus, although the concentrations of arsenic are lower on the Rio Grande, the mass flow rate is the same or greater.

Discussion and conclusions

Three separate sampling campaigns were conducted to measure concentrations of arsenic in springs and surface waters in the southern Jemez Mountains region. The Rio

FIGURE 3—Travertine Mound hot spring is located in the town of Jemez Springs. Water represents a derivative fluid of the Valles caldera geothermal system. The June 1996 results reported: arsenic concentration of 830 µg/L, mass flow rate of 0.001 kg/day, temperature of 72°C, and pH of 7. Photo by Kevin Reid.

FIGURE 5—View of the Jemez River looking downstream of the Jemez ranger station. In June 1996, the surface water at this location had an arsenic concentration of 140 µg/L, mass flow rate of 5.6 kg/day, temperature of 21°C, and pH of 7.5. Photo by Kevin Reid.

Jemez River

Arsenic mass flow rate downstream of La Cueva: June 1996
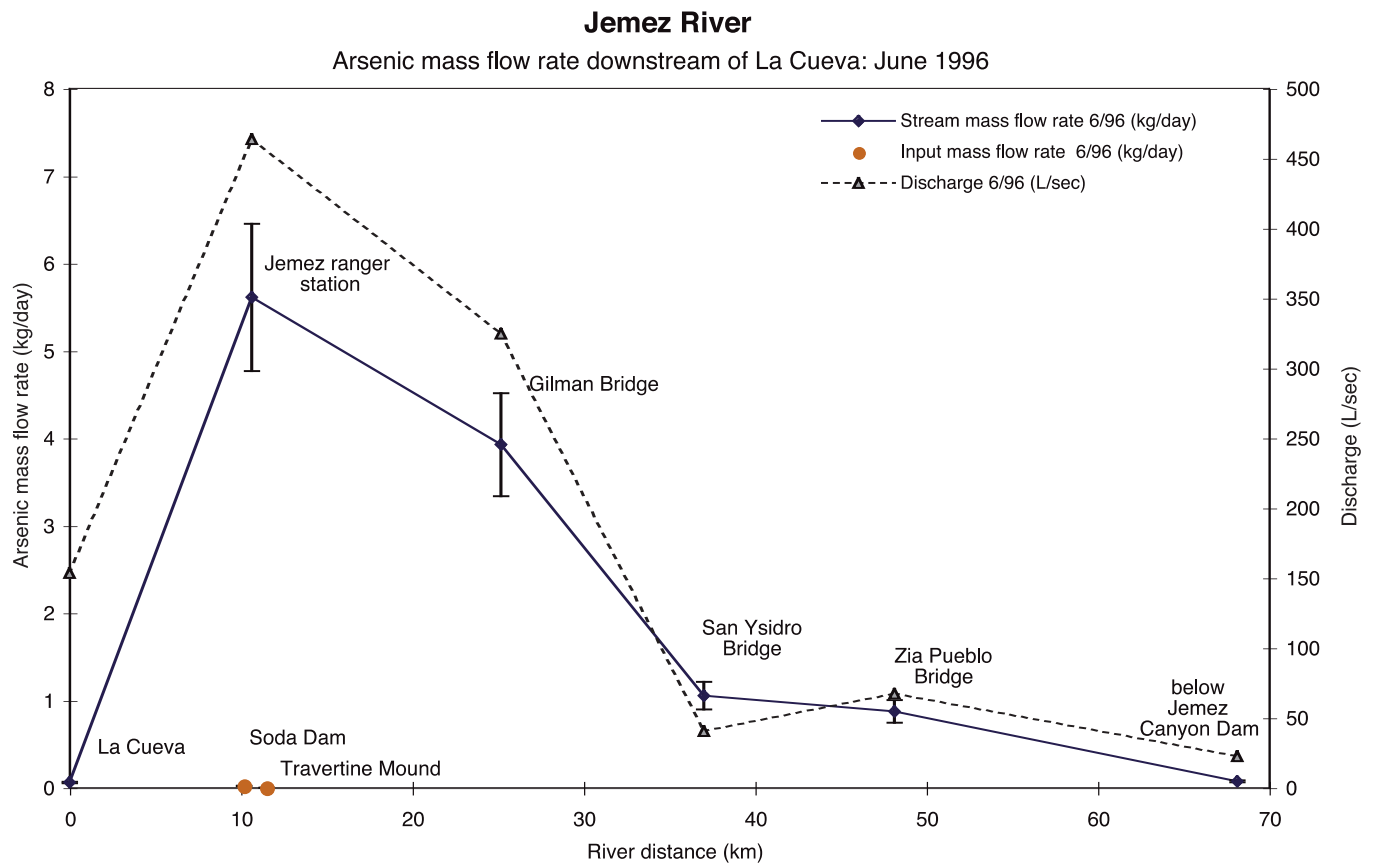
FIGURE 4—Arsenic mass flow rate of the Jemez River from La Cueva to below Jemez Canyon Dam. Error bars are 10% for analytical error. Total error is 15%.

Rio Grande
Arsenic concentrations downstream of Española: 1994, 1996

FIGURE 6—Rio Grande arsenic concentrations from Española to Bernalillo. Error bars are 10% for analytical error.

Rio Grande
Arsenic mass flow rate downstream of Española: June 1996

FIGURE 7—Rio Grande arsenic mass flow rate. Measurements taken in June 1996. Error bars represent a 5% error for discharge measurements and a 10% error for analytical measurement. Total error is 15%.

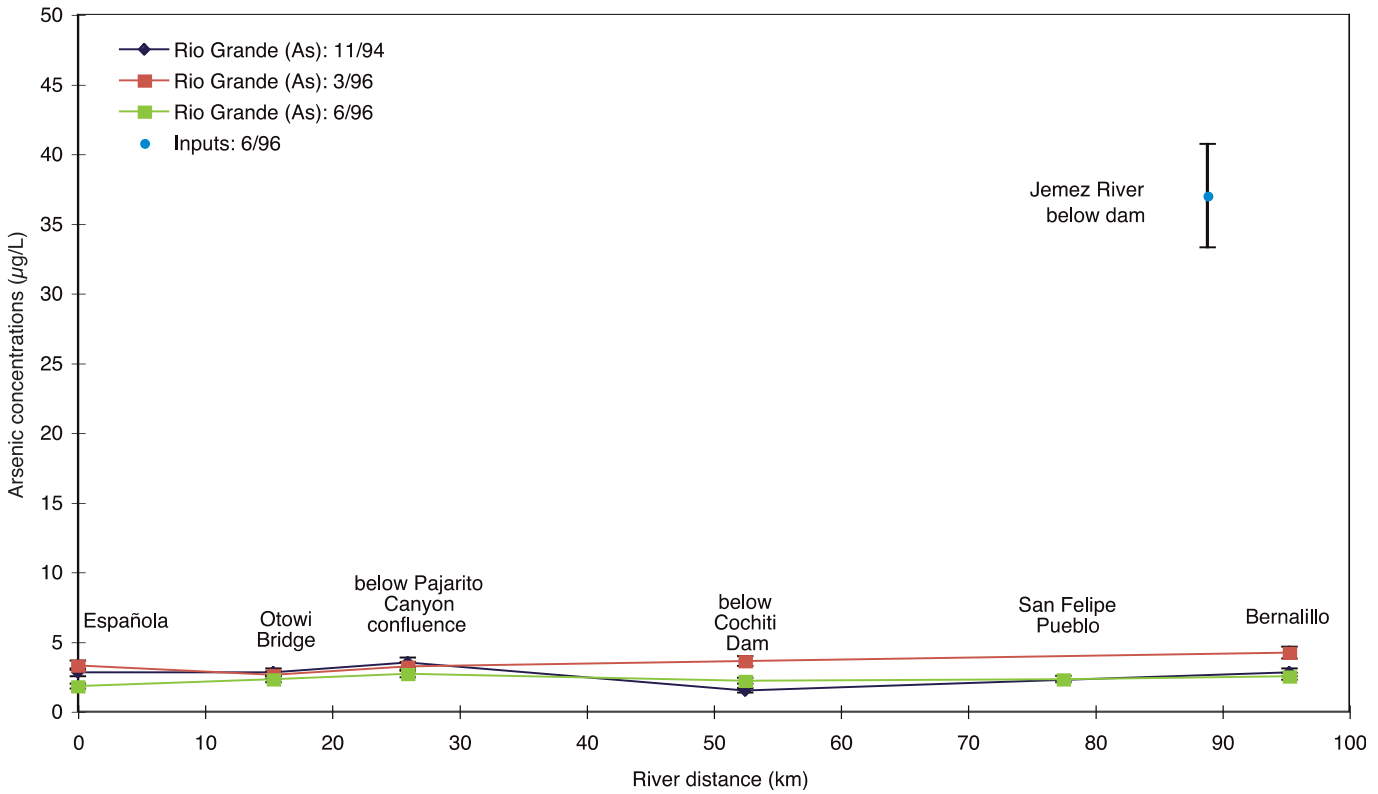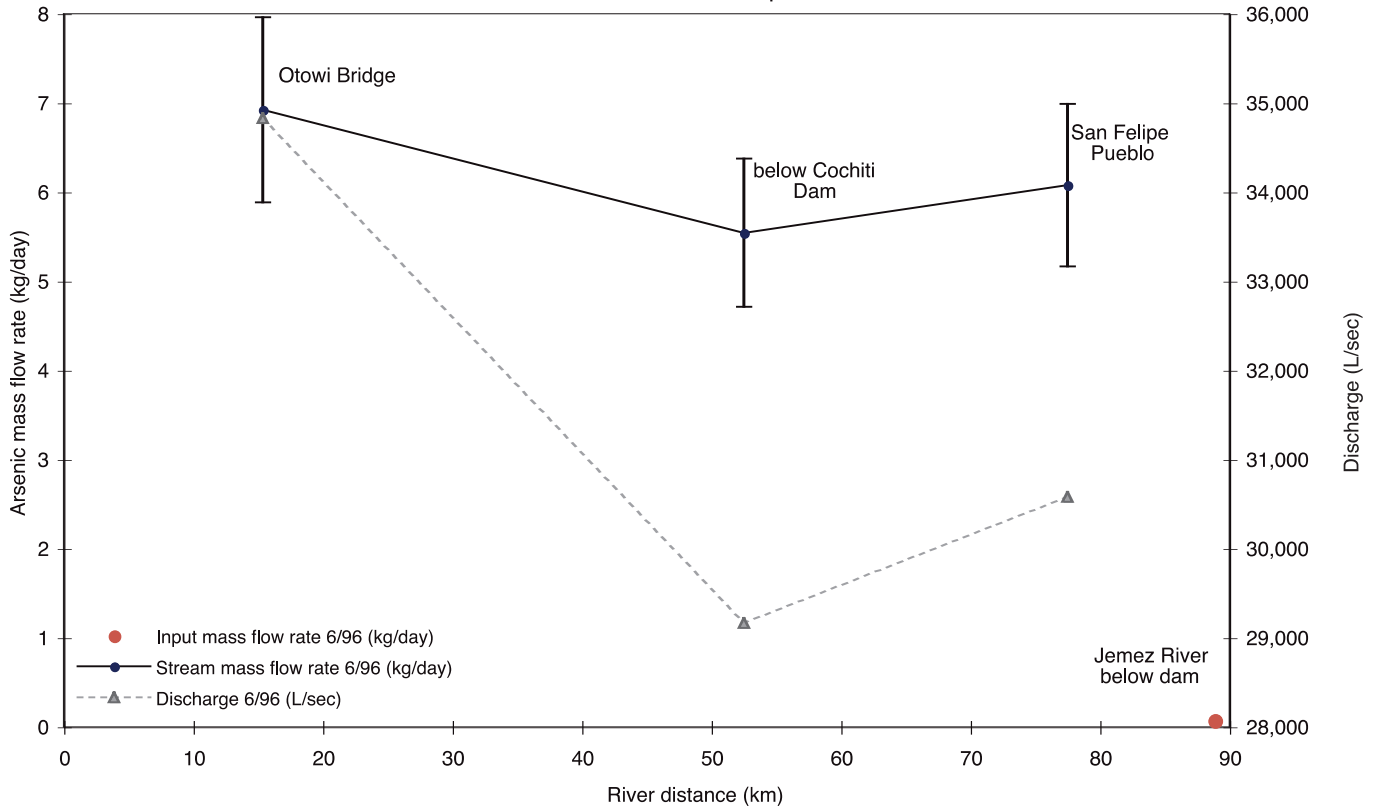Grande arsenic concentrations showed little difference among the three sampling events. The Jemez River had higher arsenic concentrations during June 1996. This could be a function of lower flows in June 1996 compared to the other sampling times. The June 23, 1996, discharge value for the USGS gaging station, 08324000, downstream from the Gilman Bridge was 204 L/sec, whereas the daily mean flow for this date is 1,060 L/sec. The arsenic contribution of geothermal waters has little seasonal variation (Trainer, 1984; Goff et al., 1988), whereas the total surface flow in June 1996 was approximately one-fifth of the daily mean flow. Under these low-flow conditions, the geothermal discharge would contribute a larger fraction of the total surface flow in the Jemez River. The highest concentrations of arsenic were found at or downstream of the town of Jemez Springs. Along this zone, deep geothermal fluids from Valles caldera enter the Jemez River. The geothermal fluids are the primary source for arsenic in the Jemez River drainage. Arsenic concentrations of 18,300 µg/L have been measured in the deep geothermal reservoir (Goff and Gardner, 1994). On the Jemez River the arsenic mass flow rates were highest at the Jemez ranger station and decreased downstream. The lowest mass flow rate was at the location below the Jemez Canyon Dam. This is a function of the low discharge and lower concentration. The lower concentration could result from adsorption, coprecipitation, or a combination of other chemical processes occurring between the Zia Pueblo location and the Jemez Canyon Dam. The various chemical and physical environments present because of the reservoir could provide the right conditions for adsorption or coprecipitation to occur. Arsenic mass flow rate on the Rio Grande was higher than the Jemez River because of the much higher discharge of the Rio Grande. Further study of both rivers would include complimentary sampling of stream sediments as well as analysis of the arsenic concentrations in ground water to help further clarify the arsenic inventory in this region.

The Jemez River is an important tributary to the Rio Grande. High concentrations of arsenic are continuously contributed to the Jemez River from geothermal waters. The results of this study do not show a noticeable change in arsenic concentrations in the Rio Grande below the Jemez River confluence. The elevated concentrations appear to be localized within the Jemez River drainage. This could be of more immediate concern for the communities along the Jemez River including Jemez Springs, Jemez Pueblo, and Zia Pueblo. These communities have fewer resources to develop treatment techniques and are located closer to the primary source of arsenic.

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Appendix

Analytical data from three sampling campaigns. All data presented are for unfiltered samples. **As** = arsenic, **Cl** = chloride, **Hg** = mercury, **Pb** = lead, **Sb** = antimony, **Se** = selenium, and **SO₄⁴⁻** = sulfate; **NA** = data not analyzed.

No. on Fig. 1	Location description	Date	Temp. (°C)	pH	As (µg/L)	Cl (µg/L)	Hg (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	SO$_4^{4-}$ (µg/L)
1	San Antonio Creek, La Cueva	11/10/94	NA	NA	2	2,500	<2	<2	0.2	<0.2	25,600
		03/13/96	6.6	6	2.3	2,890	<2	4	<0.2	<0.2	16,300
		06/23/96	21.7	7	4.5	2,090	<2	<2	0.3	<0.1	8,660
2	Jemez River, Camp Shaver	11/10/94	NA	NA	3.9	2,900	<2	<2	0.2	<0.2	15,300
		03/13/96	6.9	6	3.8	2,460	<2	<2	<0.2	<0.2	20,600
3	Jemez River sulfur deposits	11/10/94	NA	NA	3.8	3,100	<2	<2	0.1	<0.2	14,400
		03/13/96	6.7	6	4.5	2,890	<2	<2	<0.2	<0.2	13,000
4	Soda Dam hot spring	11/10/94	NA	NA	1,760	1,487,000	<2	<5	0.8	<0.2	36,200
		03/13/96	46.7	6.5	1,880	1,514,000	<2	<5	<0.2	<0.2	35,400
		06/23/96	46.6	7	1,770	1,530,000	<2	11	<0.2	<0.2	42,300
5	Jemez River at ranger station	11/10/94	NA	NA	47	51,500	<2	2	0.2	<0.2	15,700
		03/13/96	8.8	6.5	54	49,400	<2	<2	<0.2	<0.2	14,200
		06/23/96	21.4	7.5	140	114,000	<2	<2	0.5	<0.1	11,500
6	Travertine Mound, Jemez Hot Spring	11/10/94	NA	NA	680	880,000	<2	<5	<0.1	<0.2	44,800
		03/13/96	71.5	6	890	888,000	<2	<5	0.9	<0.2	39,200
		06/23/96	72.1	7	830	939,000	<2	5	1	<0.2	46,700
7	Jemez River 0.4 km below hot spring	11/10/94	NA	NA	79	59,300	<2	<2	0.1	<0.2	15,900
		03/13/96	9.8	6.5	68	61,100	<2	3	<0.2	<0.2	14,900
8	Jemez River 4 km below hot spring	11/10/94	NA	NA	79	60,900	<2	<2	0.1	<0.2	16,700
		03/13/96	10.7	7	68	63,500	<2	<2	<0.2	<0.2	15,000
9	Jemez River at Gilman Bridge	11/10/94	NA	NA	54	45,400	<2	<2	0.2	<0.2	13,400
		03/13/96	10.5	7	58	58,700	<2	2	<0.2	<0.2	14,400
		06/21/96	27.6	7	140	140,000	<2	2	0.2	<0.1	14,500
10	Jemez River at San Ysidro Bridge	11/10/94	NA	NA	60	66,000	<2	<2	0.5	<0.2	22,100
		03/13/96	11.8	7	41	74,900	<2	<2	<0.2	<0.2	21,000
		06/21/96	34	8	300	721,000	<2	6	<0.2	<0.1	182,000
11	Rio Salado at San Ysidro Bridge	11/10/94	NA	NA	4.8	2,630,000	<2	<10	1.1	<0.2	4,470,000
		03/13/96	13.1	7.5	3.1	2,943,000	<2	<10	<0.2	<0.2	4,890,000
12	Jemez River at Zia Pueblo Bridge	11/10/94	NA	NA	52	107,000	<2	3	1.9	<0.2	77,600
		03/13/96	10.5	6.5	45	105,000	<2	2	<0.2	<0.2	64,200
		06/21/96	30.7	8	150	900,000	<2	8	<0.2	<0.1	801,000
13	Rio Grande at Española	11/08/94	NA	NA	2.8	6,800	<2	<2	<0.1	<0.2	54,800
		03/12/96	7.8	6.5	3.3	4,710	<2	<2	<0.2	<0.2	45,800
		06/08/96	18	7.5	1.8	2,580	<2	<2	<0.2	<0.1	64,200
14	Rio Grande at Otowi Bridge	11/08/94	NA	NA	2.8	7,200	<2	<2	0.1	<0.2	53,400
		03/12/96	8.2	6.5	2.6	6,750	<2	2	<0.2	<0.2	43,600
		06/08/96	18.9	7	2.3	4,430	<2	<2	<0.2	0.1	61,700
15	Los Alamos Creek, above reservoir	03/11/96	4.6	6.5	0.7	3,140	<2	<2	<0.2	<0.2	3,040
		11/08/94	NA	NA	0.7	5,000	<2	<2	<0.1	<0.2	23,900
16	Frijoles Creek at Bandelier	11/08/94	NA	NA	0.9	4,200	<2	<2	<0.1	<0.2	4,300
		03/11/96	8.9	6	1	1,690	<2	<2	<0.2	<0.2	2,400
17	Rio Grande below Pajarito Spring	11/09/94	NA	NA	3.5	6,900	<2	<2	0.1	<0.2	52,200
		03/11/96	12.1	7	3.2	5,600	<2	2	<0.2	<0.2	43,900
		06/08/96	19.7	7.5	2.7	2,700	<2	<2	<0.2	<0.1	62,500
18	Pajarito Spring	11/09/94	NA	NA	1.5	5,000	<2	2	<0.1	<0.2	7,900
		03/11/96	21.8	7	2.4	3,620	<2	<2	<0.2	<0.2	5,850
19	Los Alamos Creek, below Basalt Spring	11/14/94	NA	NA	4.5	25,600	<2	6	0.2	<0.2	13,200
		03/12/96	8	6.5	6.3	35,100	<2	<2	<0.2	<0.2	25,500
20	Armistead Spring	11/14/94	NA	NA	1.5	<2,000	<2	2	0.4	<0.2	6,200
		03/14/96	7	6	2.6	140	<2	2	<0.2	<0.2	5,170
21	Rio Grande at Bernalillo	11/08/94	NA	NA	9.3	25,300	<2	2	0.2	<0.2	101,000
		03/13/96	7	6.5	4.2	8,530	<2	<2	<0.2	<0.2	46,600
		06/09/96	21.3	7	2.5	3,870	<2	<2	0.2	<0.1	66,000
22	Rio Grande below Cochiti Dam	11/08/94	NA	NA	2.8	5,500	<2	<2	0.1	<0.2	61,100
		03/13/96	7.2	6.5	3.6	4,900	<2	<2	<0.2	<0.2	43,100
		06/09/96	18	6.5	2.2	4,210	<2	<2	<0.2	0.1	63,100
23	White Rock sewage treatment effluent	03/12/96	14.9	6	3.8	32,200	<2	2	<0.2	<0.2	29,500
24	Rio Grande at San Felipe Pueblo	06/09/96	20.7	7	2.3	3,880	<2	<2	0.4	0.2	65,300
25	Jemez River below Jemez Canyon Dam	06/21/96	23.5	7.5	37	118,000	1	<2	<0.2	<0.1	157,000