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Arsenic in ground water in the Socorro Basin, New Mexico

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Abstract

The presence of high concentrations of arsenic in the Socorro Basin ground water is well known, but the distribution of arsenic in the basin has not been investigated. The object of this study was to investigate the levels and distribution of arsenic in ground water in the Socorro Basin and the relationship, if any, of arsenic to other ground-water parameters. The data are presented as collected and with little interpretation. A total of 74 ground-water samples were collected and analyzed. The wells sampled extended from the Sevilleta Wildlife Refuge headquarters, just north of the Socorro Basin, to the Bosque del Apache Wildlife Refuge, on the south. Arsenic distribution ranged from less than 2 µg/L to 43 µg/L. The wells north of the City of Socorro contained low arsenic (<2–10 µg/L) with only one exception. High arsenic levels (30 µg/L or greater) occur in three separate areas: (1) the thermal springs located at the southwest corner of Socorro City limits, (2) three wells located 2–3 mi south of San Antonio, and (3) the thermal well at the Bosque del Apache Wildlife Refuge. Eight wells have intermediate arsenic levels of 15–30 µg/L. In a study of the Albuquerque Basin, arsenic concentration correlated with many geochemical parameters: temperature, depth, fluoride, sodium, chloride, silica, and alkalinity. In this study there was only a slight negative correlation with hardness. The water varied in general composition within the basin from the springs with low sodium, low hardness, and low total dissolved solids (TDS) to wells with high sodium, low hardness, high TDS to wells with low sodium, high hardness, and high TDS.

Introduction

Arsenic in ground water is of current interest in New Mexico for several reasons: (1) the United States Environmental Protection Agency (US EPA) has proposed lowering the maximum contaminant level (MCL) for arsenic in drinking water from 50 µg/L (micrograms per liter) or 50 ppb (parts per billion) to 10 µg/L or 10 ppb (US EPA, 2000), (2) arsenic occurs naturally in ground water at levels of 5–40 µg/L in many parts of the state, and (3) ground water is used as a source of drinking water for approximately 80% of New Mexicans. Under the 1996 amendments to the Safe Drinking Water Act, Congress required that the EPA propose a new standard by January 2000, and finalize the rule by January 1, 2001. Congress recently announced that EPA may take up to June 30, 2001, to finalize the rule. In a report commissioned by the EPA, the National Research Council (NRC, 1999) concluded that the Federal Government has underestimated the risk posed by arsenic in drinking water and could be putting large numbers of Americans at risk for bladder and lung cancer. EPA proposed the MCL of 5 µg/L on May 24, 2000, and then asked the interested parties to submit comments on the costs vs. the benefits of alternative standards. EPA finalized an MCL of 10 µg/L on January 16, 2001, without waiting for the June 30 deadline.

Arsenic not only occurs above the proposed 5 µg/L limit in drinking-water supplies in Socorro but ranges as high as 40 µg/L (R. Sanchez, pers. comm. 1993). Removing arsenic from drinking-water supplies will be expensive. For example, the City of Albuquerque estimated that if the MCL is lowered to 10 µg/L, 80% of the city's wells would be above the MCL and the initial cost of treatment would be about $150 million (Soussan, 1999). Paying the bill would require a water- and sewer-rate increase of about 38% or $10 a month.

The presence of arsenic in the public drinking-water sources in Socorro has been well documented (R. Sanchez, pers. comm. 1993, 1995, 1997; Chapin and Dunbar, 1995), but the distribution of arsenic in the Socorro Basin has not been investigated. The work reported here was begun to define arsenic levels and distribution in ground water and the relationship, if any, of arsenic to other ground-water quality parameters.

A number of geochemical factors have been found to be associated with arsenic in the ground water in the Albuquerque area (CH2M Hill, 1990). Total and dissolved arsenic correlated positively with temperature ($r = 0.5–0.8$), fluoride ($r = 0.6–0.8$), silica ($r = 0.7–0.9$), sodium ($r = 0.7$), chloride ($r = 0.7$), and specific conductance ($r = 0.4 – 0.7$). Where depth measurements were available there was a slight correlation with arsenic ($r = 0.32$).

High concentrations of arsenic in ground water are generally associated with one of four geochemical environments (Welch et al., 1988): (1) basin-fill deposits of alluvial lacustrine origin (produced by fresh-water lakes) particularly in semi-arid areas, (2) volcanic deposits, (3) geothermal systems, and (4) uranium and gold mining areas. The Socorro area has two of these environments, volcanic deposits and geothermal systems.

Background

The Socorro Basin is located in central New Mexico along the Rio Grande from San Acacia to San Marcial (Fig. 1). The basin is within the Rio Grande rift, at the edge of an extensive volcanic field. Seismic data and heat-flow measurements indicate that there is magma in the Earth's crust in the immediate vicinity of Socorro, both at mid-crustal levels (~20 km [~12 mi] depth) and possibly at upper crustal levels as shallow as 5 km (3 mi) depth (Sanford, 1983). The basin is part of the Rio Grande drainage in which the ground water flows generally from north to south beneath the river. The

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COVER—Photo of Bosque del Apache National Wildlife Refuge by Rebecca Titus.

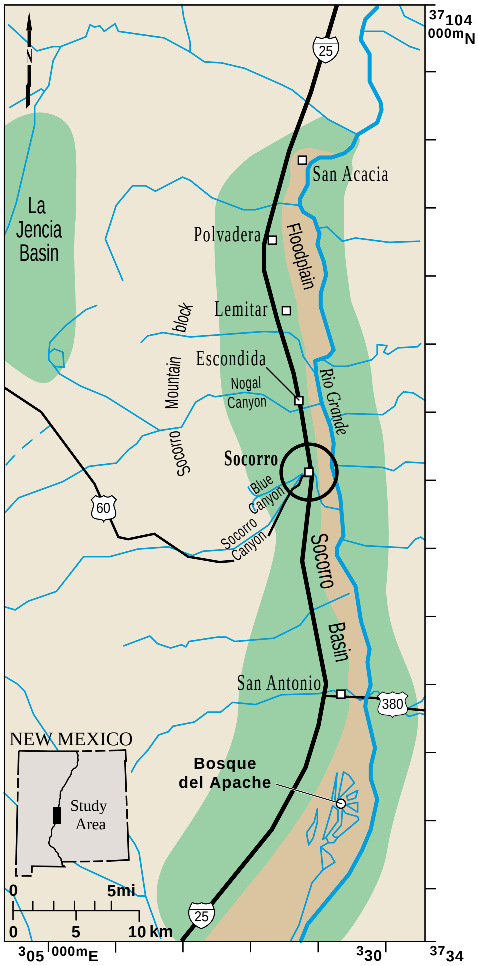

FIGURE 1—Socorro ground-water basin.

ground water spreads out in the shallow alluvium on either side of the river. The Socorro Mountain block west of Socorro (Fig. 1) separates the Socorro Basin from La Jencia Basin. Ground water recharges in or near the Magdalena Mountains and flows, approximately, from southwest to northeast in the La Jencia Basin subsurface (W. J. Stone, umpubl. maps, 1977). Some ground water flows through the Socorro Mountain block into the Socorro Basin, perhaps preferentially through more permeable fractured zones such as Socorro and Nogal Canyons (W. J. Stone, umpubl. maps, 1977; Anderholm, 1983). Some of the water flowing through the Socorro Mountain block rises along the major fault zone separating the Socorro Mountain block from the Socorro Basin and issues forth as warm springs (32° C), which are sources of municipal water that contain 40 µg/L arsenic. Barroll and Reiter (1990) proposed that some of the ground-water flow is blocked by a 1,000-ft- (305-m-) thick deposit of playa clays, which forces the water to flow through arsenic-rich volcanic rocks beneath the La Jencia Basin where the water becomes heated and some arsenic is solubilized. In a study done by Holmes (1963), tritium data indicated that recharge to Socorro Springs through La Jencia Basin and Snake Ranch Flats has an average storage time of 4.3 yrs and a flow rate of less than 35 ft/day. This suggests that Socorro Springs water has too short a storage time to be able to flow down, under, and back up a 1,000-ft-thick deposit of playa clays. Yet the water is heated and contacts rocks that contain high arsenic.

Stone (unpubl. maps, 1977) prepared maps from ground-water data available in various New Mexico Bureau of Mines and Mineral Resources circulars. The maps cover the area from Magdalena to just across the Rio Grande east of Socorro and from a few miles north of Polvadera to a few miles south of Socorro. Based on these maps, Stone and Foster (1977), in an open-file report on the hydrogeology of a landfill area west of Escondida, concluded that two flow systems operate on the west side of the Rio Grande valley, one next to the mountain front (in which the flow is easterly) and one in the lower floodplain areas (in which the flow is southerly). The resultant flow direction in the zone where the two systems merge is southeasterly. The water chemistry of the two flow systems differs: ground waters next to the mountain front are fresh (TDS much less than 1,000 ppm), whereas ground waters on the lower floodplain are slightly saline (TDS in excess of 1,000 ppm). Locally, opposite favorable places on the mountain front, ground waters in the lower floodplain are anomalously fresh owing to dilution by fresh water from the mountain flow system.

Barroll and Reiter (1995) in their investigation of the hydrogeothermal setting of the Bosque del Apache Wildlife Refuge proposed a broad, southward upflow of deep ground water in this area. The thermal well in the area, which produces warm, poor-quality water from apparently shallow depths, appeared to be a localized phenomenon. They suggested that this warm water comes from a deeper ground-water zone and rises along a high-angle fault or through discontinuities in the clay layers of the alluvial aquifer. Water-level data indicated that ground water flows from the west toward the Rio Grande and south along the river.

Methods

In addition to the city water-supply sources, there are many private wells inside the city limits that are used mostly for watering of yards and gardens. Private wells outside the city limits are used for irrigation, stock watering, and domestic supply. A total of 72 wells and 2 springs were sampled and analyzed over a 2-yr period from 1998 through 2000. The wells sampled extended from the Sevilleta Wildlife Refuge just beyond the north end of the Socorro Basin to the Bosque del Apache Wildlife Refuge at the south end. No effort was made to sample all the wells. Well locations were taken from drillers logs and from quadrangle maps and should not be taken as exact but only approximate. The same is true for well-depth information, which was taken from drillers logs or homeowners' records. Approximate well locations are plotted in Figure 2. Twenty-three wells are located within the Socorro City limits, four wells are from the Lemitar–Polvadera rural water system, one well is from the San Acacia rural water system, and one well is from the San Antonio rural water system. All the wells with the exception of four are on the west side of the river.

Wells were allowed to pump for approximately 10 min to assure that standing water had been removed and that fresh water was sampled. Samples were taken in clean polypropylene 1L bottles that were rinsed with a portion of the sample immediately before filling. The samples were returned to the lab where conductivity, pH, and alkalinity were determined immediately on the unfiltered sample. A 100 mL portion was acidified to a pH of 2 with ultra high purity nitric acid. Total recoverable metals were determined on this portion by flame atomic absorption spectrophotometry (FAA) or graphite furnace atomic absorption spectrophotometry (GFAA), depending on the concentration level. Iron and manganese were first scanned by FAA, and if their concentrations were lower than 0.05 and 0.03 mg/L respectively, then a determination by GFAA was done. If the concentrations were higher than the above concentrations, the analyses were done by FAA. Arsenic was determined by GFAA using a nickel nitrate modifier. Another portion of the sample was filtered through 0.22-micron filter paper and was used for the determination of chloride, sulfate, nitrate, and fluoride by ion chromatography (IC) using conductivity detection. Calcium, magnesium, sodium, potassium, lithium, strontium, silica, and zinc were determined by FAA.

Standard quality-control procedures were followed. Duplicate samples were included in each batch and between-batch run. If a cation-anion equivalents balance of ± 3% was not obtained, the sample was reanalyzed. For trace-metal determinations a certified reference sample, National Institute of Standards and Testing (NIST) #1643d, was included in each batch. To measure reproducibility at high arsenic concentration range, a Socorro Springs sample was included in each batch. Hardness (as $CaCO_3$) was calculated from calcium and magnesium concentrations. Total dissolved solids (TDS) were calculated from the total cations and anions.

Results

Physical and chemical parameters are presented in three tables. Table 1 lists well ownership, location, and other physical

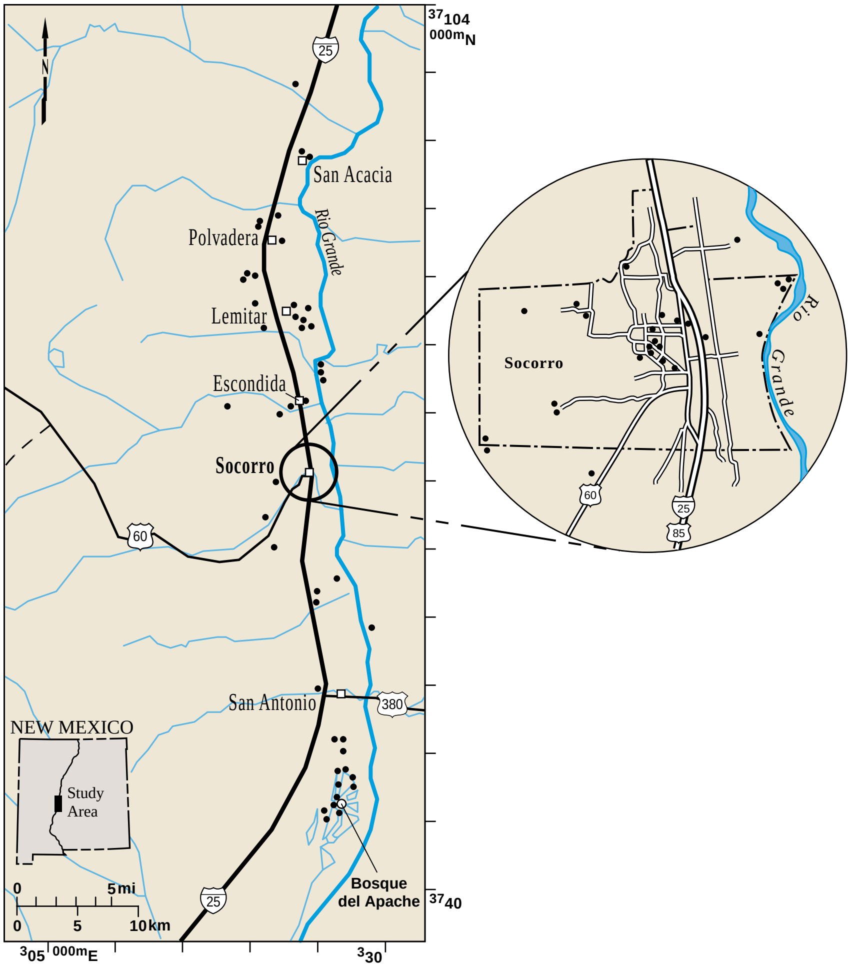

FIGURE 2—Well locations.

parameters. Wells are numbered from north to south with the northernmost well numbered **1**. Well locations are presented in Universal Transverse Mercator (UTM). UTM coordinates (meters) measure east and north from two perpendicular reference baselines. Socorro Basin is located in zone 13. Table 2 lists the major and minor constituents, and Table 3 lists the trace elements.

Because the accuracy and precision of the arsenic analyses are critical to this paper, they are presented in Table 4. The detection limit for arsenic was 1 µg/L. Accuracy and precision data for the other trace metals was comparable but is not presented here.

Depth varied from surface (springs) to 500 ft. Overall, wells south and west of the city were deeper, whereas wells close to the river were shallow, reflecting the water-table levels. TDS ranged from 260 mg/L in the springs to 3,350 mg/L in the Bosque thermal well. The water also varied in composition from the springs with low sodium, low hardness, and low TDS to wells with high sodium, low hardness, and high TDS to wells with low sodium, high hardness, and high TDS.

Generally speaking, the trends were the same as noted by Stone and Foster (1977); ground waters next to the mountain front have TDS less than 1,000 ppm, and ground waters on the lower floodplain have TDS greater than 1,000 ppm. There were some notable exceptions; the Bauer well (**#32**), located almost at the river, had a TDS of 650 ppm, whereas the Torres Lab well, west of Escondida (**#34**), and the Austin well, on Socorro's west side (**#47**), had TDS of 1,440 ppm and 1,800 ppm respectively. All four of the wells located along the east side of the river (**#19**, **#20**, **#21**, and **#60**) had TDS values of less than 750 ppm.

Arsenic distribution ranged from less than 2 to 43 µg/L. The wells north of Socorro contained low arsenic in the range of <2–10 µg/L with the exception of an anomalously high value of 17 µg/L in one irrigation well (**#15**). Wells containing 10 µg/L or greater are plotted in Figure 3. High arsenic levels (30 µg/L or greater) occur in three separate areas: (1) the thermal springs in Socorro and the Blue Canyon well (**#52**, **#53**, and **#46**); (2) three wells located approximately 3 mi south of San Antonio (**#62**, **#63**, and **#64**); and (3) the thermal well at the Bosque del Apache Wildlife Refuge (**#72**). Eight wells have an intermediate As range of 15–30 µg/L. One is a relatively deep well (500 ft) located downgradient of the thermal springs (Industrial well, **#54**), and the other is a shallower well (200 ft) located in the center of town (School of Mines well, **#40**). These two wells are city drinking-water supply wells. The wells surrounding the School of Mines well are relatively shallow (50–120 ft) and contain arsenic in the range of 2–17 µg/L. The well closest to the School of Mines well, the Jones well (**#41**), is also the shallowest (50 ft) and has the least amount of arsenic (2 µg/L). Moving toward the river, in general, the wells are shallow and contain 10 µg/L As or less. Two irrigation wells located north of San Antonio (**#58** and **#59**) contain 14 and 18 µg/L respectively.

The Albuquerque Basin study (CH2M Hill, 1990) looked at water quality records from over 5,000 sampling events extending from 1968 to 1989. The database was divided into three subsets: (1) analyses containing both dissolved and total arsenic, (2) total arsenic, and (3) dissolved arsenic. The study found that both dissolved and total arsenic were strongly correlated with the same parameters. Fluoride ($r = 0.8–0.9$), temperature ($r = 0.8$), and silica ($r = 0.7–0.9$) were the most highly correlated. These parameters were closely followed by sodium, chloride, and specific conductance ($r = 0.7$ each). Dissolved arsenic was correlated with fluoride ($r = 0.42$) and temperature ($r = 0.40$) and negatively correlated with hardness ($r = –0.3$). Total arsenic was correlated with fluoride ($r = 0.6$), longitude ($r = 0.6$), alkalinity ($r = 0.59$), temperature ($r = 0.51$), and specific conductance ($r = 0.39$). In the Socorro Basin study, total recoverable arsenic was determined, which is similar to total arsenic in the Albuquerque Basin study in that samples were not filtered before acidification and determination. In the Socorro Basin study, the only correlation found was a slight negative correlation with hardness ($r = –0.36$). Temperature, which correlated with total arsenic in the Albuquerque study, was not measured in the Socorro study.

Summary

There are three distinct areas of high arsenic concentration in the Socorro Basin: (1) the area of the thermal springs on the southwest side of Socorro (40 µg/L), (2) south of San Antonio (33–43 µg/L), and (3) the Bosque del Apache area (39 µg/L). There are areas of intermediate arsenic levels located close to the high areas (17–25 µg/L), and there is one area of intermediate arsenic levels located north of San Antonio. Mixing of high arsenic water with low arsenic water as it flows toward the river probably causes the intermediate arsenic levels. The wells with intermediate levels appear to be downgradient of the high arsenic areas. Of the 72 wells and 2 springs sampled, seven had arsenic levels greater than 30 µg/L, nine had levels

TABLE 1—Well description, location, owner, sampling date, and physical parameters.

No.	Description	UTM-E	UTM-N	Date	Elevation (ft)	Well depth (ft)	Pump level (ft)	Owner
1	Sevilleta—VSA—La Joya	327000	3802400	03/08/99	4,950	100	60	USF&W
2	San Acacia water supply	325360	3791875	08/28/98	4,650	70	40	San Acacia
3	Rayl well—San Acacia	324975	3791875	06/30/98	4,630	60		Tina Rayl
4	Lemitar–Polvadera well #1	322175	3786450	08/04/98	4,735	250	225	Lemitar–Polvadera
5	Lemitar–Polvadera well #2	322150	3786600	08/04/98	4,735	330	201	Lemitar–Polvadera
6	Leavitt well	324100	3787825	07/15/99	4,651	20		Vernon Leavitt
7	Van Landingham well	322200	3785075	09/14/98	4,700	240	200	L. Van Landingham
8	Kelly—Lemitar—irrigation	322050	3785050	09/16/98	4,745	240		Wilma Kelly
9	Perry well—Polvadera area	322540	3785075	05/18/98	4,700	168	120	Jodi Perry
10	Dunbar irrigation well—Lemitar	325075	3781800	05/21/98	4,630	26	26	Nelia Dunbar
11	Barclay well—Lemitar	323475	3786700	04/14/99	4,650	125		Rick Barclay
12	Popp—irrigation well, sandpoint—Lemitar	323975	3781500	05/20/98	4,640	15		Carl Popp
13	Lemitar–Polvadera well #3	322475	3781575	08/04/98	4,750	260	230	Lemitar–Polvadera
14	Kloss well #3—sandpoint	325200	3780710	08/31/98	4,630	25		Dan Kloss
15	Kloss well #2—irrigation	325400	3780175	08/31/98	4,650	100	60	Dan Kloss
16	Kloss well #1—irrigation	325375	3780075	08/31/98	4,630	60	40	Dan Kloss
17	Pullen well	325800	3780950	08/31/98	4,620	100	75	Jim Pullen
18	Lemitar–Polvadera well #4	323600	3778000	08/04/98	4,730	250		Lemitar–Polvadera
19	Watts well—E of river at Escondida	326720	3777125	03/04/99	4,620	85		Judy Watts
20	Hall well—E of river at Escondida	326850	3777400	05/28/98	4,620	72	25	Tim Hall
21	Eveleth well—E of river at Escondida	326775	3777025	05/29/98	4,620	70	60	Bob Eveleth
22	Eagle Picher well	324199	3774727	04/22/98	4,691	225	190	City of Socorro
23	Dorr well—Escondida	325050	3775075	05/18/98	4,600	55	15	Bob Dorr
24	Miller well—Florida	324825	3774180	05/28/98	4,634	89	68	Greg Miller
25	Saavedra well—Florida	324850	3773650	08/31/98	4,617	95	60	Saavedra
26	Love well—sandpoint—Florida	324650	3773575	05/26/98	4,628	39		David Love
27	Smoake irrigation well	325475	3773250	09/17/98	4,600	85		J. A. Smoake
28	6th Street monitoring well—Doc Holiday Lane	325500	3771600	05/10/99	4,600	8		City of Socorro
29	Preston well—406 Melody Loop	325700	3771450	08/06/98	4,600	60		Phil Preston
30	Beers well—NE Socorro	326550	3771575	02/26/99	4,600	130	124	Duane Beers
31	McPhaul well	326350	3772800	10/12/99	4,601	60		James McPhaul
32	Bauer well	326950	3772650	05/29/98	4,590	80		Paul Bauer
33	Bridges well	326425	3772475	06/01/98	4,590	120		Jeffery Bridges
34	Torres Lab well—NW Socorro	319800	3774375	02/14/99	5,050	360		NMIMT
35	Olson well—Socorro	323957	3772203	04/22/98	4,690	97	62	City of Socorro
36	East Sedillo Park well	325150	3771250	10/12/00	4,592	115	70	City of Socorro
37	West Sedillo Park well	324800	3771425	10/12/00	4,595	110	70	City of Socorro
38	Bushman well—Tech Campus	323793	3771184	05/07/99	4,635	145	130	NMIMT
39	Mason well—405 College Ave.	324975	3770990	06/09/98	4,600	91	30	Ken Mason
40	School of Mines well—Socorro	324916	3770597	04/22/98	4,650	197	115	City of Socorro
41	Jones well—402 School of Mines Rd.	324900	3770400	03/25/99	4,650	50	47	D. Jones
42	Bezpalko well—305 Lopez Place	325000	3770250	03/08/99	4,650	77		Olga Bezpalko
43	Chapin well—507 School of Mines Rd.	324760	3770475	06/24/98	4,650	105		Charles Chapin
44	Lattman well	323246	3771126	05/07/99	4,700	210		NMIMT
45	Holmes well	323685	3771269	05/07/99	4,655	140		NMIMT
46	Blue Canyon—thermal well	320000	3768800	05/04/99	5,200	60		NMIMT
47	Austin well—700 Neel	324430	3770440	05/15/98	4,620	80	30	George Austin
48	Chamberlin well—117 Stallion Circle	324300	3770330	08/06/98	4,635	120	95	Richard Chamberlin
49	Eaton House well—403 Eaton Ave.	324780	3769500	08/06/98	4,630	60	50	Tom Harper
50	Miler well—Blue Canyon Rd.	321220	3769320	04/23/99	5,200	465	198	Leon Miler
51	Gilson well—W of Socorro	322850	3769150	08/06/98	4,700	260	200	Bruce Gilson
52	Socorro Springs—Socorro	321370	3768440	04/22/98	4,947			City of Socorro
53	Sedillo Springs—Socorro	321378	3768455	04/22/98	4,934			City of Socorro
54	Industrial well—Socorro	322985	3767640	04/22/98	4,906	505	260	City of Socorro
55	Dicaperl well	321100	3765850	05/28/98	5,300	500	300	Dicaperl
56	MCA well near Gun Club Range	321900	3758575	05/21/98	5,000	560	480	Gary Perry
57	Weiss well	327175	3762875	11/08/98	4,570	100	60	Bill Weiss
58	Glen Perry well—8 mi S of Socorro	327050	3757550	05/21/98	4,675	100		Glen Perry
59	Gary Perry well—8 mi S of Socorro	327100	3757050	05/21/98	4,700	120	80	Gary Perry
60	Kendall well—E of river at Bosquecito	328925	3760930	05/20/98	4,570	75	15	Glenn Kendall
61	San Antonio water supply	325150	3758100	06/02/98	4,700	210	190	City of San Antonio
62	Sanchez well—2 mi S of San Antonio	326800	3751200	05/20/98	4,560	45		Greg Sanchez
63	Verploegh well—San Antonio	326650	3752675	05/20/98	4,560	100	60	Curtis Verploegh
64	Cather well—San Antonio	326600	3752675	08/11/98	4,850	100	70	Steve Cather
65	Bosque del Apache well #2	327749	3749285	08/21/98	4,522	125	73	USF&W
66	Bosque del Apache well #4	328684	3747379	08/21/98	4,522	114	63	USF&W
67	Bosque del Apache well #5	328675	3745975	08/21/98	4,520	115	80	USF&W
68	Bosque del Apache well #7	326400	3749160	08/21/98	4,530	150	78	USF&W
69	Bosque del Apache well #8	327650	3747562	08/21/98	4,520	142	70	USF&W
70	Bosque del Apache well #10	327675	3745885	08/21/98	4,525	142	60	USF&W
71	Bosque del Apache well #11	327800	3743325	08/21/98	4,515	170	72	USF&W
72	Bosque del Apache well #14	326200	3742344	08/21/98	4,520	252		USF&W
73	Bosque del Apache well #20	324841	3741965	08/21/98	4,550	80		USF&W
74	Bosque del Apache well #19	324875	3741750	08/26/98	4,520	80		USF&W

TABLE 2—Major and minor constituents. Values in ppm except pH and conductivity (µS).

No.	pH	Conductivity	TDS	Hardness	HCO_3	Cl	SO_4	NO_3	F	Na	K	Mg	Ca	SiO_2
1	7.4	2,600	1,880	340	185	600	500	2.0	1.10	515	7.4	39	72	51
2	7.0	1,500	1,110	515	485	180	310	2.4	<0.20	189	9.0	28	160	60
3	7.2	630	450	180	210	35	100	0.27	0.38	69	2.8	20	40	78
4	7.6	780	660	300	215	87	200	9.7	<0.20	92	5.2	24	80	56
5	7.3	1,200	1,020	400	210	170	335	30	<0.20	164	5.4	32	107	71
6	7.4	960	710	300	350	53	195	0.35	0.56	113	4.8	22	86	59
7	7.5	870	660	450	340	90	140	0.72	<0.20	42	5.8	32	128	58
8	7.7	820	700	440	230	74	220	19	<0.20	45	4.4	28	129	62
9	7.3	2,100	1,460	475	320	195	530	23	<0.20	300	7.7	37	129	79
10	7.1	1,600	1,210	480	550	90	390	10	0.21	212	7.9	33	138	60,
11	7.6	2,500	1480	475	360	310	450	5.6	<0.20	310	9.2	25	148	51
12	7.2	1,300	980	370	520	67	270	0.36	0.42	175	7.6	30	99	73
13	7.9	400	320	135	130	28	60	1.2	0.37	32	4.8	10	37	86
14	7.1	740	600	270	300	48	140	6.5	0.44	84	6.0	15	83	62
15	7.2	1,700	1,410	670	460	160	490	<0.20	<0.20	214	8.8	33	213	71
16	7.3	1,400	1,100	560	310	190	345	0.29	<0.20	127	8.2	27	179	66
17	7.5	650	570	220	245	53	145	<0.20	0.29	86	5.2	12	69	75
18	7.7	720	530	230	205	68	150	<0.20	0.62	88	5.4	17	64	39
19	8.2	920	560	255	255	23	185	<0.20	0.35	74	4.9	14	79	53
20	7.5	980	790	430	255	59	310	0.25	<0.20	73	6.0	26	128	57
21	7.5	580	470	240	200	32	140	0.45	<0.20	52	4.6	11	79	52
22	7.5	600	470	215	220	51	110	0.83	0.10	62	3.4	9	71	60
23	7.7	1,100	800	390	235	73	230	4.4	<0.20	90	5.5	31	104	74
24	7.3	470	350	175	165	30	80	1.1	0.29	35	3.5	11	51	60
25	7.3	470	360	160	160	30	80	2.2	0.29	40	3.6	9	48	68
26	7.5	440	330	150	130	30	75	1.4	0.33	35	4.0	8	48	60
27	7.2	1,600	1,340	710	575	120	420	<0.20	<0.20	172	9.1	35	226	77
28	6.9	810	510	340	460	22	230	0.8	<0.20	34	6.3	21	101	66
29	7.4	1,500	1,310	640	330	200	455	9.9	<0.20	159	9.6	28	211	71
30	8.3	1,500	1,030	525	535	85	285	<0.20	<0.20	141	7.4	26	167	56
31	7.6	1,400	960	415	590	60	275	0.9	0.10	170	8.6	25	125	69
32	7.5	700	650	405	240	55	225	<0.20	<0.20	41	5.8	19	131	51
33	7.4	970	810	515	280	81	295	<0.20	0.21	48	6.0	24	167	45
34	7.9	1,800	1,440	370	220	51	710	13	1.7	295	7.3	31	98	118
35	7.3	600	530	255	300	40	100	3.0	0.24	69	2.8	12	82	67
36	7.5	620	380	230	210	34	115	<0.20	0.44	37	3.7	9.6	77	11
37	7.6	435	230	135	140	19	62	<0.20	0.52	30	2.9	7.3	42	13
38	7.4	1,000	800	430	350	51	260	3.0	0.23	99	3.1	21	137	56
39	7.4	620	560	250	190	52	175	<0.20	0.23	80	3.6	9	85	60
40	7.5	880	650	295	260	75	170	0.54	0.10	98	4.7	11	100	62
41	8.0	1,500	980	365	200	115	365	12	0.56	156	7.2	22	110	92
42	7.4	920	920	370	350	96	275	7.5	0.36	140	6.5	17	120	81
43	7.6	1,200	950	265	295	79	338	<0.20	0.23	213	6.2	10	89	67
44	7.4	740	510	240	190	34	162	4.5	0.34	62	2.3	11	77	58
45	7.4	750	480	305	235	33	124	2.3	0.31	30	2.0	12	102	56
46	7.8	550	250	70	150	19	43	0.62	0.91	57	2.9	4	20	30
47	7.6	2,200	1,800	155	415	250	627	12	<0.20	550	3.5	9	48	95
48	7.4	1,100	990	580	260	110	370	11	<0.20	73	4.3	28	186	77
49	7.2	1,400	1,060	465	380	145	255	45	<0.20	156	7.5	26	143	96
50	6.9	700	450	145	255	24	66	3.2	0.80	81	4.4	9	43	90
51	7.8	420	350	95	140	14	73	4.8	0.61	53	3.7	4	32	92
52	7.7	360	260	70	175	5	26	2.2	0.60	53	2.8	4	21	53
53	7.7	350	260	68	180	5	24	2.2	0.60	54	2.7	4	20	53
54	7.5	970	700	210	270	145	72	2.6	0.71	130	10	12	63	125
55	7.7	600	540	200	230	30	123	9.0	0.37	73	5.4	12	60	109
56	7.7	630	450	200	145	90	70	6.2	0.30	55	5.0	8	67	73
57	7.1	560	400	220	120	32	145	<0.20	<0.20	29	3.5	12	68	53
58	7.5	1,100	860	335	310	145	223	0.61	<0.20	144	7.2	20	101	63
59	7.4	590	470	170	195	58	89	1.1	0.51	72	5.1	8	54	83
60	7.8	440	330	160	180	22	65	0.42	0.28	37	3.2	9	50	56
61	7.4	600	480	130	225	63	55	2.0	0.57	96	5.2	6	41	96
62	7.6	640	500	145	215	59	93	2.7	0.54	97	4.2	9	44	86
63	7.0	430	290	97	130	20	50	0.33	0.49	37	4.3	5	30	77
64	7.6	490	390	130	190	31	73	2.4	0.20	61	4.1	8	39	77
65	7.5	1,300	1,050	460	305	200	293	<0.20	<0.20	157	7.3	26	142	71
66	7.0	530	450	115	185	26	120	<0.20	<0.20	84	11	10	29	81
67	7.8	750	640	51	220	46	190	<0.20	<0.20	167	8.6	4	14	98
68	7.4	1,400	1,160	490	490	115	333	<0.20	<0.20	196	8.4	27	152	86
69	7.8	520	410	190	155	42	107	<0.20	<0.20	41	5.4	11	58	68
70	7.7	1,600	1,340	585	375	175	447	<0.20	<0.20	190	12	41	166	92
71	7.5	1,100	950	345	370	110	273	<0.20	<0.20	169	10	22	102	83
72	7.2	4,100	3,350	450	280	1000	564	373	<0.20	900	34	40	114	175
73	7.8	870	700	145	240	95	164	6.7	2.80	166	4.9	6	48	88
74	7.7	510	410	78	180	43	62	4.2	2.30	88	3.7	3	26	88

TABLE 3—Trace constituents. Values in ppm. Varying significant figures in the iron (Fe) and manganese (Mn) columns are due to rescanning samples with Fe and Mn concentrations lower than 0.05 and 0.03 mg/L respectively using graphite furnace atomic absorption spectrophotometry (GFAA). Higher concentrations of Fe and Mn were determined by flame atomic absorption spectrophotometry (FAA).

No.	Al	As	Cd	Cr	Co	Cu	Fe	Li	Pb	Mn	Se	Sr	Zn
1	<0.005	0.001	<0.001	<0.001	<0.001	<0.005	0.028	0.33	<0.005	<0.005		2.9	0.06
2	0.006	0.003	<0.001	<0.001	<0.001	<0.005	0.003	0.11	<0.005	0.48	<0.005	2.7	<0.03
3		0.001	<0.001	<0.001	<0.001	<0.005	0.60		<0.005	0.24	<0.005		<0.02
4	<0.005	0.003	<0.001	<0.001	<0.001	0.076	0.026	0.08	<0.005	0.056	<0.005	1.8	0.06
5	0.011	0.005	<0.001	0.004	<0.001	0.038	0.013	0.14	<0.005	<0.005	<0.005	2.9	0.04
6	0.021	0.011	<0.005	<0.002		<0.005	<0.005	0.09	<0.005	1.700	<0.005	2.4	0.13
7	<0.005	0.001	<0.001	<0.001	<0.001	0.026	0.042	0.06	<0.005	1.1	<0.005	2.8	<0.03
8	0.005	0.001	<0.001	0.002	<0.001	0.015	0.18	0.07	<0.005	0.017	<0.005	2.3	0.02
9	<0.005	0.001	<0.001	<0.001	<0.001	0.080	0.06		<0.005	<0.004	0.006		0.23
10	<1.0	0.001	<0.001	<0.001	<0.001	<0.005	0.19	0.15	<0.005	3.0	<0.005	1.8	0.05
11	<0.005	0.001	<0.005	0.003	<0.001	0.070	0.005	0.12	<0.005	1.2	<0.005	2.2	0.05
12	<0.005	0.001	<0.001	<0.001	<0.001	0.030	2.3	0.06	<0.005	1.6	<0.005	1.5	0.03
13	0.007	0.005	<0.001	<0.001	<0.001	0.052	0.066	0.05	<0.005	0.003	<0.005	0.74	0.04
14	<0.005	0.006	<0.001	<0.001	<0.001	0.045	<0.005	0.07	<0.005	0.04	<0.005	1.6	<0.03
15	0.006	0.017	<0.001	<0.001	<0.001	0.028	0.80	0.11	<0.005	1.4	<0.005	3.6	<0.03
16	0.012	0.003	<0.001	<0.001	<0.001	0.051	0.60	0.08	<0.005	1.6	<0.005	2.7	<0.03
17	0.005	0.001	<0.001	<0.001	<0.001	0.041	0.24	0.05	<0.005	0.89	<0.005	1.0	<0.03
18	<0.005	0.005	<0.001	<0.001	<0.001	0.021	0.003	0.07	<0.005	0.045	<0.005	1.5	1.4
19	<0.005	0.003	<0.001	<0.001	<0.001	0.056	0.10	0.06	<0.005	0.48	<0.005	0.80	0.13
20	0.017	0.010	<0.001	<0.001	<0.001	<0.005	<0.005	0.03	<0.005	1.5	<0.005	1.5	<0.03
21	0.006	0.001	<0.001	<0.001	<0.001	0.031	0.033	0.04	<0.005	0.08	<0.005	0.80	<0.03
22	0.008	0.008	<0.001	<0.001	<0.001	<0.005	0.077		<0.005	0.073	<0.005	0.20	0.02
23	<0.005	0.006	<0.001	<0.001	<0.001	0.540	0.033	0.06	<0.005	<0.004	<0.005	1.5	0.05
24	<0.005	0.005	<0.001	<0.001	<0.001	0.012	0.008	0.04	<0.005	<0.004	<0.005	0.60	<0.03
25	<0.005	0.007	<0.001	<0.001	<0.001	0.041	0.008	0.03	<0.005	<0.005	<0.005	0.62	<0.03
26	<0.005	0.006	<0.001	<0.001	<0.001	0.020	0.70	0.04	<0.005	<0.005	<0.005	0.54	0.09
27	0.014	0.010	<0.001	<0.001	<0.001	0.071	0.98	0.08	<0.005	1.7	<0.005	3.5	0.05
28	0.073	0.001	<0.001	0.005	<0.001	0.024	4.7	0.03	<0.005	4.8	<0.005	0.97	0.05
29	<0.005	0.003	<0.001	<0.001	<0.001	0.019	0.93	0.08	<0.005	2.0	<0.005	3.0	0.09
30	<0.005	0.001	<0.001	<0.001	<0.001	0.017	0.20	0.10	<0.005	0.99	<0.005	1.2	<0.02
31	0.042	0.001	<0.001		<0.001	0.037	0.55	0.10	<0.005	1.3	<0.005	2.77	0.03
32	<0.005	0.003	<0.001	<0.001	<0.001	0.003	0.11		<0.005	1.6			<0.03
33	<0.005	0.001	<0.001	<0.001	<0.001	0.003	0.11		<0.005	0.35	<0.005		<0.03
34	0.023	0.004	<0.001	0.004	<0.001	0.030	0.53	0.25	<0.005	0.008	<0.005	4.4	0.03
35	0.014	0.006	<0.001	<0.001	<0.001	0.006	0.003		<0.005	0.003	<0.005	0.70	0.02
36		0.020	<0.001				0.49	0.07	<0.005	0.29			
37		0.017	<0.001				0.23	0.06	<0.005	0.18			
38	0.011	0.006	<0.001	<0.001	<0.001	0.056	0.24	0.05	0.014	0.08	<0.005	1.1	<0.03
39	<0.005	0.017	<0.001	<0.001	<0.001	0.017	0.21		<0.005	0.35	<0.005		<0.03
40	0.010	0.024	<0.001	<0.001	<0.001	0.014	0.064		<0.005	0.26	<0.005	1.80	0.02
41	<0.005	0.002	<0.001	0.002	<0.001	0.016	0.020	0.11	<0.005	0.77	<0.005	1.5	0.02
42	<0.005	0.008	<0.001	<0.001	<0.001	0.010	0.024	0.08	<0.005	1.7	<0.005	1.3	0.05
43	<0.005	0.019	<0.001	<0.001	<0.001	0.009	0.20		<0.005	0.7	<0.005		<0.02
44	0.011	0.003	<0.001	0.001	<0.001	0.028	0.032	0.03	<0.005	<0.005	<0.005	0.46	<0.03
45	<0.005	0.009	<0.001	<0.001	<0.001	0.033	0.016	0.04	<0.005	0.015	<0.005	0.42	<0.03
46	0.032	0.030	<0.001	0.002	<0.001	0.031	0.32	0.05	<0.005	0.018	<0.005	0.38	0.16
47	<0.005	0.008	<0.001	<0.001	<0.001	0.006	0.010	0.09	<0.005	<0.004	<0.005	2.2	<0.03
48	<0.005	0.010	<0.001	<0.001	<0.001	0.034	0.007	0.04	<0.005	0.008	<0.005	3.1	<0.03
49	<0.005	0.013	<0.001	<0.001	<0.001	0.029	0.008	0.09	<0.005	0.007	<0.005	2.9	<0.03
50	0.140	0.003	<0.001	<0.001	<0.001	0.011	0.029	0.07	<0.005	<0.003	<0.005	0.90	0.06
51	<0.005	0.006	<0.001	<0.001	<0.001	0.017	0.003	0.02	<0.005	<0.005	<0.005	0.68	0.05
52	<0.005	0.040	<0.001	<0.001	<0.001	0.003	0.003		<0.005	0.003	<0.005	0.78	0.02
53	<0.005	0.040	<0.001	<0.001	<0.001	0.003	0.003		<0.005	0.003	<0.005	0.78	0.02
54	0.041	0.022	<0.001	<0.001	<0.001	0.003	0.10		<0.005	0.007	<0.005	3.2	0.02
55	<0.005	0.001	<0.001	<0.001	<0.001	0.021	<0.005	0.06	<0.005	<0.004	<0.005	1.9	0.07
56	<0.005	0.007	<0.001	<0.001	<0.001	0.028	0.006	0.04	<0.005	0.023	<0.005	1.2	0.11
57	0.009	0.001	<0.001	<0.001	<0.001	0.011	0.11	0.03	<0.005	0.56	<0.005	0.92	<0.03
58	<0.005	0.014	<0.001	<0.001	<0.001	0.014	0.059	0.05	<0.005	1.7	<0.005	1.7	<0.03
59	<0.005	0.018	<0.001	<0.001	<0.001	0.020	0.006	0.04	<0.005	<0.005	<0.005	0.68	<0.03
60	<0.005	0.001	<0.001	<0.001	<0.001	0.026	0.078	0.04	<0.005	0.12	<0.005	0.40	<0.03
61	<0.005	0.013	<0.001	<0.001	<0.001	0.034	<0.005		<0.005	<0.004	0.006		0.04
62	<0.005	0.033	<0.001	<0.001	<0.001	0.039	0.10	0.05	<0.005	<0.004	<0.005	0.65	0.54
63	<0.005	0.038	<0.001	<0.001	<0.001	0.070	0.025	0.04	0.009	<0.004	<0.005	0.43	<0.03
64	<0.005	0.043	<0.001	<0.001	<0.001	0.020	<0.005	0.03	<0.005	<0.005	<0.005	0.80	<0.03
65	0.057	0.001	<0.001	<0.001	<0.001	0.003	0.63	0.12	<0.005	0.81	<0.005	2.7	<0.03
66	0.047	0.002	<0.001	<0.001	<0.001	0.015	0.036	0.09	<0.005	0.13	<0.005	0.94	<0.03
67	0.012	0.006	<0.001	<0.001	<0.001	0.025	0.33	0.21	<0.005	0.028	<0.005	0.50	<0.03
68	0.021	0.001	<0.001	<0.001	<0.001	0.003	2.2	0.13	<0.005	0.91	<0.005	3.0	<0.03
69	0.019	0.001	<0.001	<0.001	<0.001	0.003	0.25	0.05	<0.005	0.30	<0.005	1.3	<0.03
70	0.008	0.001	<0.001	<0.001	<0.001	0.018	0.42	0.12	<0.005	0.74	<0.005	5.3	<0.08
71	0.025	0.003	<0.001	<0.001	<0.001	0.039	0.64	0.12	<0.005	0.54	<0.005	2.7	0.08
72	0.006	0.039	<0.001	<0.001	<0.001	0.015	1.2	0.93	<0.005	0.22	<0.005	5.7	<0.03
73	0.055	0.026	<0.001	<0.001	<0.001	0.045	0.080	0.09	<0.005	0.013	<0.005	1.3	<0.03
74	0.006	0.015	<0.001	0.003	<0.001	0.038	0.008	0.05	<0.005	0.009	<0.005	0.62	<0.03

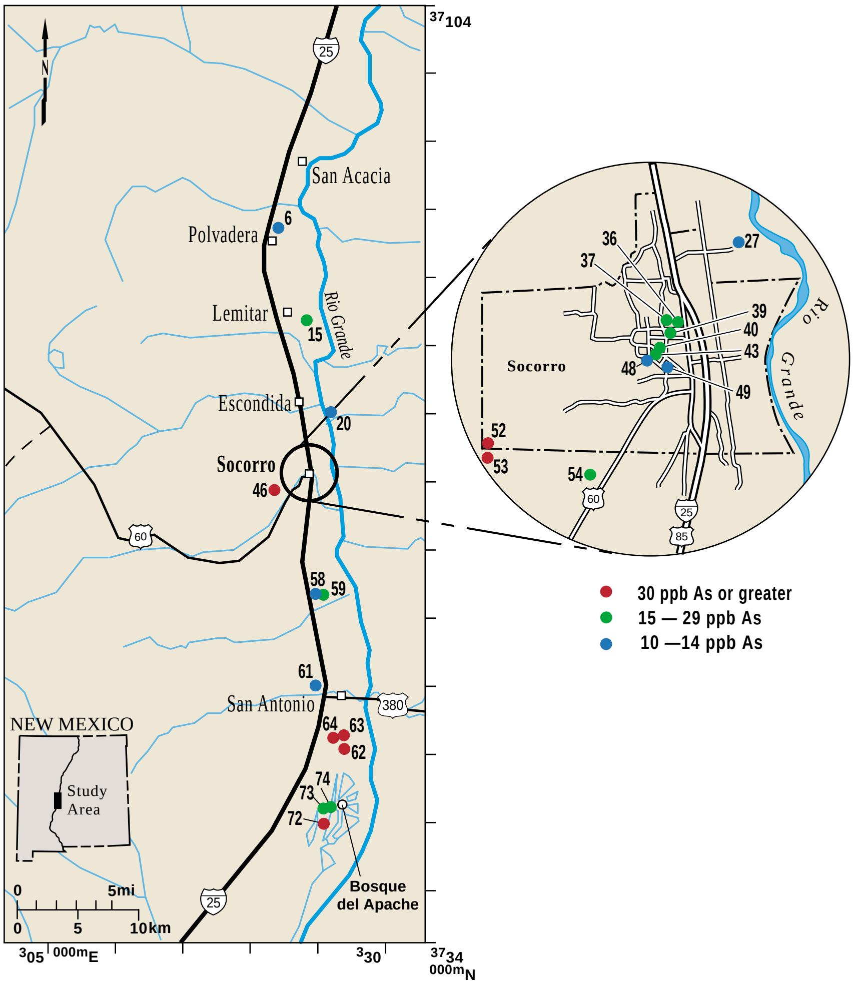

FIGURE 3—Wells containing arsenic in concentrations of 10 ppb or greater.

between 15 and 29 µg/L, six had levels between 10 and 14 µg/L, and 17 had levels between 5 and 9 µg/L. A total of 22 wells had arsenic levels at or above the new MCL of 10 µg/L. Four of the City of Socorro drinking-water sources had arsenic levels greater than 10 µg/L and would need arsenic removal treatment to meet an MCL of 10. The San Antonio drinking-water source contained 13 µg/L. The San Acacia and Lemitar drinking-water supplies contained 5 µg/L or less.

In the Albuquerque ground-water study, arsenic correlated positively with temperature, fluoride, sodium, chloride, silica, and alkalinity and correlated negatively with hardness. The only correlation noted in the Socorro Basin was a slight negative correlation with hardness.

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TABLE 4—Quality control for arsenic analyses.

NIST 1643d (1/10 dilution)	**Socorro Springs**
Certified value = 5.6 µg/L	
Average obtained (8 runs) = 5.51 ± 0.66	Average value obtained (8 runs) = 40.6 ± 2.01

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