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Water-Chemistry Data for Selected Hot Springs, Geysers, and Streams in Yellowstone National Park, Wyoming, 2001-2002

Open-File Report 2004-1316

U.S. Department of the Interior
U.S. Geological Survey

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By R. Blaine McCleskey, James W. Ball, D. Kirk Nordstrom, JoAnn M. Holloway, and Howard E. Taylor

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Front Cover Photography: View taken in 2001 of Sulphur Spring, Crater Hills, Yellowstone National Park.

Back Cover Photography: View taken in 2001 of Sulphur Spring, Crater Hills, Yellowstone National Park.

U.S. Department of the Interior
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U.S. Geological Survey, Boulder, Colorado 2004
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Explanation of Symbols and Abbreviations

---	not analyzed, measured, or calculated
<	less than
°C	degrees Celsius
C.I.	charge imbalance
CVAFS	cold-vapor atomic fluorescence spectrometry
DIW	deionized water
DO	dissolved oxygen
DOC	dissolved organic carbon
EMF	electromotive force
Eh	redox potential
F_s	pseudosigma
FA	filtered-acidified
FU	filtered-unacidified
FIAS	flow injection analysis system
GFAAS	graphite furnace atomic absorption spectrometry
GW	ground water
HDPE	high-density polyethylene
HGAAS	hydride generation atomic absorption spectrometry
IC	ion chromatography
ICP-OES	inductively coupled plasma-optical emission spectrometry
ID	identification
ISE	ion-selective electrode
km	kilometers
m	meters
M	moles per liter
mm	millimeter
meq/L	milliequivalents per liter
mM	millimoles per liter
mg/L	milligrams per liter
mV	millivolts
MS	mass spectrometry
MPV	most probable value
µg/L	micrograms per liter
µL	microliter
µm	micrometer
µS/cm	microsiemens per centimeter
n	number of analyses
N	equivalents per liter
ng/L	nanograms per liter
nm	nanometer
PE	polyethylene
RSD	relative standard deviation
s	standard deviation
SC	specific conductance
SLAP	standard light Antarctic precipitation
SRWS	standard reference water sample
THGA	transversely heated graphite atomizer
TISAB	total ionic strength adjustment buffer
TOC	total organic carbon
UV	ultra-violet
VSMOW	Vienna standard mean ocean water
v/v	volume per volume
w/v	weight per volume

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
micrometer (μm)	0.00003937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
cubic meter (m^3)	264.2	gallon (gal)
liter (L)	61.02	cubic inch (in^3)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32

Coordinate information is referenced to the North American Datum 27 – Continental United States (NAD27-CONUS)

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L), micrograms per liter (μg/L), nanograms per liter (ng/L), or millimolar (mM).

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ABSTRACT

Water analyses are reported for one-hundred-twenty-one samples collected from hot springs and their overflow drainages, the Gibbon River, and one ambient-temperature acid stream in Yellowstone National Park (YNP) during 2001-2002. Twenty-five analyses are reported for samples collected during May 2001, fifty analyses are reported for samples collected during September 2001, eleven analyses are reported for samples collected during October 2001, and thirty-five analyses are reported for samples collected during June and July 2002. Water samples were collected and analyzed for major and trace constituents from nine areas of YNP including Norris Geyser Basin, Nymph Lake and Roadside Springs, Lower Geyser Basin, Washburn Springs, Calcite Springs, Crater Hills, Mammoth Hot Springs, West Thumb Geyser Basin, and Brimstone Basin. These water samples were collected and analyzed as part of research investigations in YNP on arsenic redox distribution in hot springs and overflow drainages, the occurrence and distribution of dissolved mercury, and sulfur redox speciation. Most samples were analyzed for major cations and anions, trace metals, and iron, arsenic, nitrogen, and sulfur redox species. Only mercury concentration, pH, and specific conductance were determined for samples collected in October 2001 as they were collected during a reconnaissance field trip. Analyses were performed at the sampling site, in an onsite mobile laboratory, or later in a U.S. Geological Survey laboratory, depending on stability of the constituent and whether it could be preserved effectively.

Water samples were filtered and preserved onsite. Water temperature, specific conductance, pH, Eh, and dissolved hydrogen sulfide were measured onsite at the time of sampling. Alkalinity and acidity were determined by titration, usually within a few days of sample collection. Concentrations of thiosulfate (S_2O_3) and polythionate (S_nO_6) were determined as soon as possible (generally minutes to hours after sample collection) by ion chromatography in an onsite mobile laboratory vehicle. Total dissolved iron and ferrous iron concentrations often were measured onsite in the mobile laboratory.

Concentrations of aluminum, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, selenium, silica, sodium, strontium, vanadium, and zinc were determined by inductively coupled plasma-optical emission spectrometry. Trace concentrations of antimony, cadmium, chromium, cobalt, copper, lead, and selenium were determined by Zeeman-corrected graphite-furnace atomic-absorption spectrometry. Concentrations of total arsenic and arsenite were determined by hydride-generation atomic-absorption spectrometry using a flow-injection analysis system. Concentrations of total mercury were determined by cold-vapor atomic fluorescence spectrometry. Concentrations of bromide, chloride, nitrate, and sulfate were determined by ion chromatography. Concentrations of ferrous and total iron were determined by the FerroZine colorimetric method. Concentrations of nitrite were determined by colorimetry or chemiluminescence. Concentrations of ammonia were determined by ion chromatography, with reanalysis by colorimetry when separation of sodium and ammonia peaks was poor. Dissolved organic carbon concentrations were determined by the wet persulfate oxidation method.

INTRODUCTION

Investigations into the water chemistry of hot springs, geysers, streams, and rivers in Yellowstone National Park (YNP) have been conducted by the U.S. Geological Survey (USGS), dating back to 1888. A table of publications describing these investigations can be found in Ball and others (2002). Waters at YNP have pH values ranging from less than 1 to 10, temperatures from ambient to about 93°C (boiling at YNP's altitude), and high concentrations of alkalinity, arsenic, hydrogen sulfide, silica, and sulfate relative to many natural waters. Numerous redox reactions and mineral-precipitation reactions occur. In addition to being a valuable natural resource and tourist attraction, active geothermal areas such as those in YNP provide insight into formation of mineral deposits, microbiological processes in extreme environments, and water-rock interactions.

Purpose and Scope

The purpose of this report is to: (1) provide water-quality data from numerous sample sites in YNP; (2) describe methods used to collect and analyze the samples; (3) describe quality-control procedures; and (4) supplement interpretive reports. The samples were collected during four field trips to YNP during May, September, and October 2001 and June and July 2002. The primary purpose of the May and September 2001 and June 2002 field trips was to study the geochemical processes involving redox species of arsenic, iron, nitrogen, and sulfur in mineral springs and geothermal waters. Several papers have been published describing earlier phases of this project and of related collaborative research efforts (Ball and others, 1998a; 1998b; 2001; 2002; Xu and Schoonen, 1995; Xu and others, 1996; 1998; 2000). The evolution and chemical composition of several newly developed hydrothermal features of the Ragged Hills Area of Norris Geyser Basin also were studied. The occurrence and distribution of total dissolved mercury in geothermal waters was studied during the October 2001 and June 2002 field trips.

During 2001-2002, one-hundred-twenty-one water samples were collected from nine areas of YNP (fig. 1): Norris Geyser Basin, Nymph Lake and Roadside Springs including Bijah Spring and Frying Pan Spring, Lower Geyser Basin, Washburn Springs, Calcite Spring (near Tower Junction), Crater Hills, Mammoth Hot Springs, West Thumb Geyser Basin, and Brimstone Basin. Many of the analyses in this report contain the most complete data available for aqueous chemistry of YNP geothermal waters. Constituents analyzed include calcium (Ca), magnesium (Mg), strontium (Sr), barium (Ba), sodium (Na), potassium (K), lithium (Li), sulfate (SO_4), thiosulfate (S_2O_3), polythionate (S_nO_6), hydrogen sulfide (H_2S), alkalinity (HCO_3), acidity, fluoride (F), chloride (Cl), bromide (Br), nitrate (NO_3), nitrite (NO_2), ammonium (NH_4), silica (SiO_2), boron (B), aluminum (Al), iron total (Fe(T)), ferrous iron (Fe(II)), manganese (Mn), copper (Cu), zinc (Zn), cadmium (Cd), chromium (Cr), cobalt (Co), mercury (Hg), nickel (Ni), lead (Pb), beryllium (Be), vanadium (V), molybdenum (Mo), antimony (Sb), selenium (Se), arsenic total (As(T)), arsenite (As(III)), dissolved organic carbon (DOC), and isotopes of hydrogen (δD) and oxygen ($\delta^{18}O$).

Acknowledgments

We extend our appreciation to the staff of Yellowstone National Park for permission to collect water samples and for their assistance on numerous occasions. In particular, we extend our thanks to Christi Hendrix, Katie Duffy, Wes Miles, Brian Thorpe, John Tebby, Bill Wise, and all of the Ranger staff at Norris Geyser Basin for escorting us and educating us about the many thermal features of Norris. We thank Steve Miller of the Yellowstone Spatial Analysis Center for assistance on numerous occasions with identifying and precisely locating Yellowstone Park thermal features. We also would like to extend our appreciation to Maria-Elvira Hernandez-Garcia and Sara LoVetere for their assistance with the 2001 sampling trips. We are especially thankful to John Varley, Director of the Center for Natural Resources at YNP, for his continued encouragement of our work.

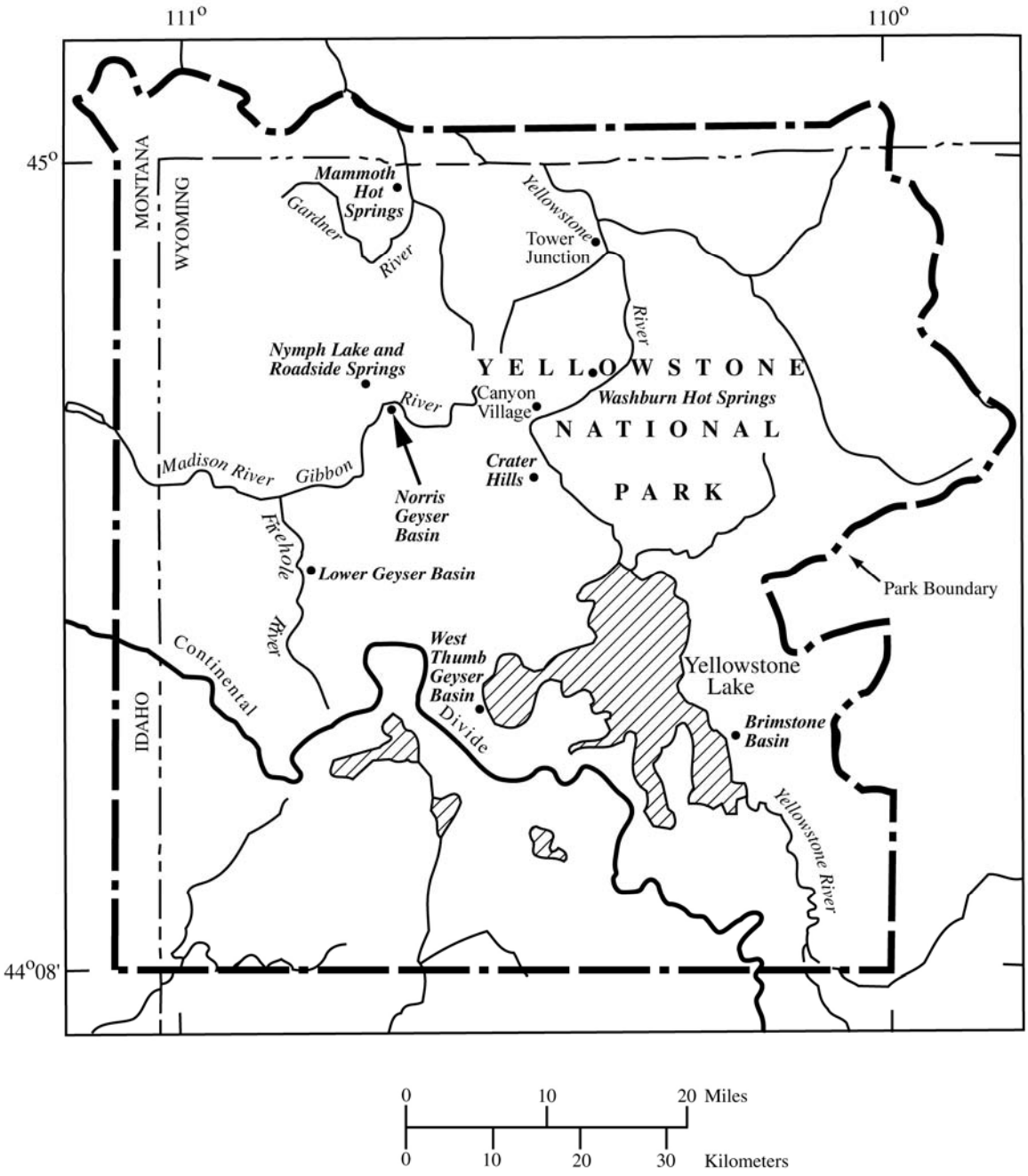


Figure 1. Location of sampling areas in Yellowstone National Park, Wyoming.

METHODS OF SAMPLE COLLECTION, PRESERVATION, AND ANALYSIS

Sample Collection and Preservation

Samples were collected from streams, tributaries, and overflow channels as close to the center of flow as possible and in areas that appeared to be well mixed. For hot springs and geysers, samples were collected as close to the discharge source as possible. Extreme care was taken to safely collect water samples from the larger geothermal sites, to protect fragile hot spring mineral formations, and to minimize changes in temperature, pH, and water chemistry during sampling. Samples were collected from the middle of large pools and geysers by positioning the sample tubing intake using a thermally insulated stainless steel container as a flotation device attached to the end of an extendable aluminum pole. At more easily accessible sites, the tubing intake was positioned in the source or channel by hand. A Teflon block attached to the end of the sampling tubing was used as a weight to keep the sample tubing in place (see photo 2 in the appendix). Grab samples also were collected from the source using the stainless-steel container or a syringe with Teflon tubing.

Samples were collected and filtered onsite by either or both of the following two techniques. The first technique involved pumping the water directly from the source with a battery-operated peristaltic pump fitted with medical-grade silicone tubing through a 142-mm diameter all-plastic filter holder (Kennedy and others, 1976) containing a 0.1-µm pore-size mixed-cellulose-ester filter membrane. The second technique consisted of filling a 60-mL syringe at the source or with source water collected in the stainless-steel container and immediately forcing the water through a 25-mm disposable filter having a mixed-cellulose-ester membrane with a pore size of 0.2 or 0.45 µm.

Sample splits were collected for analyses of inorganic constituents, redox species, hydrogen and oxygen isotopes, and dissolved organic carbon (DOC). Container preparation and storage and stabilization methods for filtered samples are summarized in table 1. Samples for the determination of major cations and trace metals (As, Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, SiO_2, Sr, V, and Zn), major anions (Br, Cl, F, NO_3, and SO_4), alkalinity (as HCO_3), acidity, density, NH_4, NO_2, DOC , and water isotopes (δD and $\delta^{18}O$) were filtered and then stabilizing reagents, if needed, were added. Sample bottles were pre-rinsed with filtered water prior to sample collection. Stabilizing reagents for intermediate sulfur species were put into the sample bottle before the sample was collected; therefore, these bottles were not pre-rinsed. All sample splits were chilled as soon as practical after sample collection.

To prevent over-estimation of S_2O_3 concentrations, S(-II) oxidation was minimized by adding zinc chloride ($ZnCl_2$). This technique caused zinc sulfide (ZnS) to precipitate. Polythionate (S_nO_6) was converted to thiocyanate (SCN) by the addition of potassium cyanide (KCN) to that sample split (Moses and others, 1984). For hot springs and geysers, a sample split for the determination of dissolved SiO_2 was diluted onsite 1 to 9 with distilled water to prevent precipitation of SiO_2 as the sample cooled. Samples for the determination of DOC were filtered through a 142-mm diameter all-plastic plate filter containing a 0.1-µm mixed-cellulose-ester filter membrane and collected in a glass bottle that was baked at 600°C. At least 1 L of sample was passed through the all-plastic plate filter assembly before a DOC sample was collected. An equipment blank processed in the field yielded a DOC value similar to DOC measured in double-distilled water from our laboratory storage container. Samples for δD and $\delta^{18}O$ (water isotopes) determinations were filtered when the water filtered easily, otherwise water isotope samples were unfiltered.

Table 1. Container preparation and stabilization methods for filtered samples

[HCl, hydrochloric acid; HNO_3, nitric acid; H_2SO_4, sulfuric acid; KCN, potassium cyanide; $K_2Cr_2O_7$, potassium dichromate; M, moles per liter; mL, milliliters; N, equivalents per liter; NaOH, sodium hydroxide; v/v, volume per volume; w/v, weight per volume; $ZnCl_2$, zinc chloride; °C, degrees Celsius; %, percent]

Sample type(s)	Storage container and preparation	Stabilization treatment in addition to refrigeration (4°C)
Major cations and trace metals (Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, SiO_2, Sr, V, and Zn)	Polyethylene bottles, soaked in 5% HCl and rinsed 3 times with distilled water	1% (v/v) concentrated redistilled HNO_3 added, samples were not chilled
Total Mercury (Hg(T))	Borosilicate glass bottles, soaked with 5 % HNO_3 and rinsed 3 times with deionized water	5 mL of concentrated redistilled HNO_3 (added in the field) + 0.04% w/v $K_2Cr_2O_7$ per 125 mL of sample (added in the laboratory)
Iron and arsenic redox species (Fe(T), Fe(II), As(T), and As(III))	Opaque polyethylene bottles, soaked in 5% HCl and rinsed 3 times with distilled water	1% (v/v) redistilled 6 N HCl added
Major anions (Br, Cl, F, and SO_4), alkalinity as HCO_3, acidity, and density	Polyethylene bottles filled with distilled water and allowed to stand for 24 hours, then rinsed 3 times with distilled water	None
Ammonium (NH_4)	Same as major cations and trace metals	1% (v/v) 1:9 H_2SO_4 added
Nitrite (NO_2)	Same as anions	None
Silica (SiO_2)	Same as major anions, alkalinity, and density	Immediately diluted 1:9 with distilled water
Thiosulfate and polythionate (S_2O_3, S_nO_6)	30-mL polyethylene bottle	1.7% (v/v) 0.6 M $ZnCl_2$ plus 1% (v/v) 1 M NaOH added to precipitate S(-II), 1.7% (v/v) 1 M KCN also added to S_nO_6 bottle
Dissolved organic carbon (DOC)	Amber glass bottle baked at 600°C	None
Water Isotopes (δD and $\delta^{18}O$)	60-mL glass bottle	None (unfiltered sample collected when filtration was not possible)

Analytical Measurements

Analytical methods, typical relative standard deviations, detection limits, equipment used, pertinent references, and comments are described briefly in table 2. Detection limits were equal to 3 times the sample standard deviation (s) of several dozen measurements of the constituent in a blank solution analyzed as a sample. Relative standard deviation for each analytical method is determined from the measurement of an analyte concentration at least ten times the detection limit. Quality assurance and quality control methods and results are presented in Appendix 1. Methods, general conditions, and variants from standard procedures are discussed in the following sections.

The purity of all reagents were equal to the reagent-grade standards of the American Chemical Society or higher. Double-distilled or de-ionized water and re-distilled or trace metal grade acids were used in all preparations. Samples were diluted as necessary to bring the analyte concentration within the optimal range of the method. Each sample was analyzed at least twice for each dilution and for all constituents.

Field Measurements

Temperature, specific conductance, pH, EMF, DO, and H_2S were measured onsite. Measurements of EMF and pH were made on unfiltered sample water pumped from the source through an acrylic plastic flow-through cell to minimize sample contact with air. The flow-through cell contained a combination redox electrode, a pH electrode with integral thermistor, and test tubes containing buffer solutions for calibration of the pH electrode. All components were thermally equilibrated with the sample water before obtaining measurements. The redox potential (Eh) was calculated from the EMF value obtained at the temperature in the flow-through cell. Where possible, temperature, specific conductance, and DO measurements were made by immersing probes directly into the source as close to the sampling point as possible. Otherwise, probes were immersed into an unfiltered sample collected in a stainless steel insulated container, or into the flow-through cell. The DO probe does not function properly at temperatures greater than 55°C; therefore, DO was determined by the Winkler titration method for waters greater than 55°C.

A mobile laboratory truck containing an ion chromatograph, ultraviolet-visible spectrophotometer, autotitrator, and reagent-grade water system was set up as close to each sampling site as feasible so that unstable intermediate sulfur oxyanion species could be determined as soon as possible after sample collection. Iron redox species also were determined in the mobile laboratory to guide sampling strategies. Alkalinity and acidity titrations were performed before oxidation and hydrolysis reactions changed the sample composition.

pH Measurements

Field measurement of pH in geothermal waters is challenging because of high temperatures, complex sample matrices often supersaturated with CO_2, and surging water resulting from gas discharge. We have found that many pH electrodes perform poorly in near-boiling water and some fail after only a few immersions. Thus, electrodes rated for boiling or near-boiling water temperatures were used. At each site, the flow-through cell, temperature probe, electrode, and calibration buffers were equilibrated to sample temperature prior to calibration and measurement. The system was calibrated using at least two bracketing standard buffers (chosen from among 1.68, 2.00, 4.01, 7.00, or 10.00) corrected to their values at the sample temperature. After calibration, the pH electrode was placed in the sample water in the flow-through cell and monitored until no change in temperature (± 0.1°C) or pH (± 0.01 standard unit) was detected for at least 30 seconds. Following sample measurement, the electrode was immersed in the standard buffer of pH closest to that of the sample and allowed to equilibrate. The entire calibration and measurement process was repeated as many times as necessary until the measured value for the buffer differed by no more than 0.05 standard units from its certified pH at the measured temperature.

Hydrogen Sulfide Determinations

Dissolved H_2S concentration was measured onsite using a battery-operated, portable ultraviolet-visible spectrophotometer and the methylene blue method (equivalent to Standard Method 4500-S^{2-} D for waste water; APHA, 1985). Dissolved H_2S can be unstable and de-gas and oxidize rapidly, therefore, samples were either collected directly from the outflow of a thoroughly equilibrated 142-mm plastic filtration apparatus containing a 0.1-µm membrane filter or drawn into a plastic syringe and forced through a syringe-mounted 0.2-µm or 0.45-µm membrane filter. Samples were filtered directly into a measuring cuvette and color reagents were added immediately. After waiting for color development, the sample absorbance and the temperature of the solution were measured. Figure 2 shows the temperature dependence of the H_2S-methylene blue color complex. A temperature correction was applied to the measurement using the following equation:

$$H_2S_c = H_2S_m/(-0.0141T + 1.71) \quad (1)$$

where H_2S_c is the corrected concentration, H_2S_m is the measured concentration, and T is the temperature in degrees Celsius.

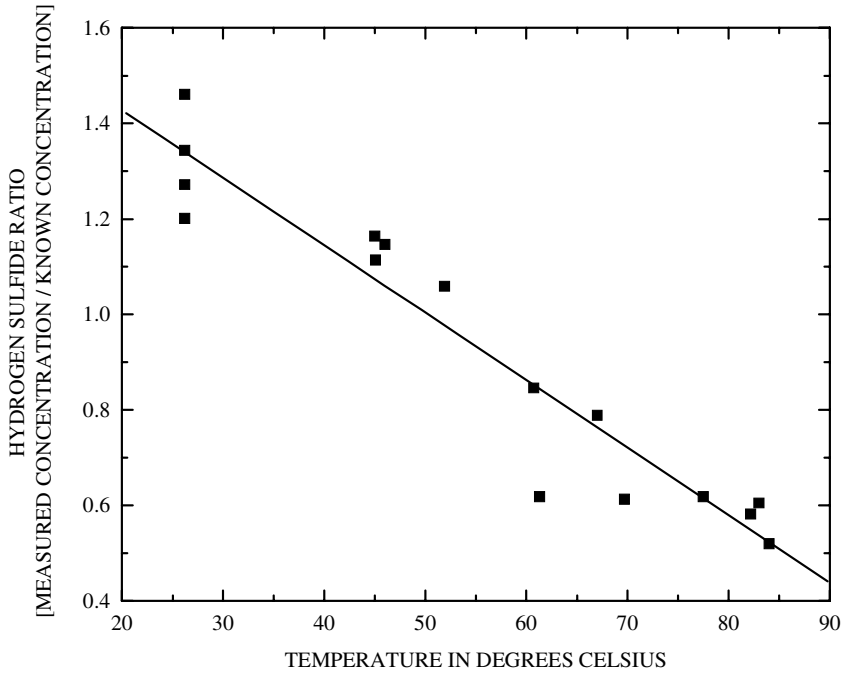


Figure 2. Temperature dependence of hydrogen sulfide measurement using the methylene blue method.

Table 2. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references

[cm, centimeter; CVAFS, cold vapor atomic fluorescence spectrometry; GFAAS, graphite furnace atomic absorption spectrometry; HGAAS, hydride generation atomic absorption spectrometry; IC, ion chromatography; ICP-OES, inductively coupled plasma-optical emission spectrometry; ISE, ion-selective electrode; µg/L, micrograms per liter; mg/L, milligrams per liter; mM, millimolar; mN, millinormal; MS, mass spectrometry; ng/L, nanograms per liter; nm, nanometer; RSD, relative standard deviation; SC, specific conductance; SLAP, standard light Antarctic precipitation; TISAB, total ionic strength adjustment buffer; TOC, total organic carbon; VSMOW, Vienna standard mean ocean water; %, percent]

Constituent	Instrumental Technique	Typical RSD[1], *detection limit (mg/L)*	Equipment Used	Comments and Reference(s)
pH	Potentiometry	0.02 pH units[2]	Beckman 265 pH meter with Orion Ross combination electrode or Orion Research model 1230 multi-parameter meter with pH triode or Orion Ross combination electrode	Two- or three-buffer calibration at sample temperature using 1.68, 2.00, 4.01, 7.00, and 10.00 pH buffers
Specific Conductance (SC)	Conductometry	0.5%	Orion Research model 1230 multi-parameter meter with conductivity electrode	Automatic temperature correction, calibration with 0.0100 N KCl
Eh	Potentiometry	10%	Orion Research model 96-78-00 combination redox electrode	Electrode checked using ZoBell's solution (ZoBell, 1946; Nordstrom, 1977)
Dissolved oxygen (DO)	Titration or Potentiometry	1%	Burette and Erlenmeyer flask or Orion Research model 1230 multi-parameter meter with dissolved oxygen probe	Winkler Titration using manganous sulfate, alkaline iodide-azide, sulfamic acid, starch indicator, phenyl arsine oxide (APHA, 1971). Probe used only at temperatures less than 45°C.
Calcium (Ca)	ICP-OES	2%, *0.1*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 315.887 nm, view: radial
Magnesium (Mg)	ICP-OES	2%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 280.270 nm, view: axial
Sodium (Na)	ICP-OES	2%, *0.1*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 589.592 nm, view: radial
Potassium (K)	ICP-OES	3%, *0.04*	Leeman Labs Direct Reading Echelle[3]	1,000 mg/L Cs ionization buffer, analytical wavelength: 766.490 nm, view: axial
Strontium (Sr)	ICP-OES	2%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 421.611 nm, view: axial
Barium (Ba)	ICP-OES	2%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 455.403 nm, view: axial

Table 2. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references — Continued

Constituent	Instrumental Technique	Typical RSD[1], *detection limit (mg/L)*	Equipment Used	Comments and Reference(s)
Lithium (Li)	ICP-OES	2%, *0.003*	Leeman Labs Direct Reading Echelle[3]	1,000 mg/L Cs ionization buffer, analytical wavelength: 670.784 nm, view: axial
Sulfate (SO_4)	IC	3%, *1.0*	Dionex model 2010i ion chromatograph with AG4A guard and AS4A separator columns and Anion Self-Regenerating Suppressor	0.018 M $NaHCO_3$ + 0.017 M Na_2CO_3 eluent (Brinton and others, 1995)
Thiosulfate (S_2O_3)	IC	3%, *0.3*	Dionex model 2010i ion chromatograph with two AG4A guard columns and Anion Self-Regenerating Suppressor	0.028 M $NaHCO_3$ + 0.022 M Na_2CO_3 eluent (Moses and others, 1984)
Polythionate (S_nO_6)	IC	3%, *0.3*	Dionex model 2010i ion chromatograph with two AG4A guard columns and Anion Self-Regenerating Suppressor	0.028 M $NaHCO_3$ + 0.022 M Na_2CO_3 eluent (Moses and others, 1984)
Hydrogen sulfide (H_2S)	Colorimetry	3%, *0.002*	Hach model DR-2000 ultraviolet - visible spectrometer and Hach method # 8131 reagents	Methylene Blue Method based on APHA (1985)
Alkalinity (as HCO_3)	Titration	2%, *1.0*	Orion Research model 960/940 autotitrator, potentiometric detection, end-point determined by the first derivative technique	(Barringer and Johnsson, 1989; Fishman and Friedman, 1989)
Acidity	Titration	2%, *0.4 mM*	Orion Research model 960/940 autotitrator, potentiometric detection	(Barringer and Johnsson, 1989; Fishman and Friedman, 1989)
Fluoride (F)	ISE	3%, *0.1*	Orion Research model 96-09 combination F-electrode	Sample mixed 1:1 with TISAB (Barnard and Nordstrom, 1980)
Chloride (Cl)	IC	3%, *0.05*	Dionex model 2010i ion chromatograph with AG4A guard and AS4A separator columns and Anion Self-Regenerating Suppressor	0.018 M $NaHCO_3$ + 0.017 M Na_2CO_3 eluent (Brinton and others, 1995)
Bromide (Br)	IC	3%, *0.1*	Dionex model 2010i ion chromatograph with AG4A guard and AS4A separator columns and Anion Self-Regenerating Suppressor	0.018 M $NaHCO_3$ + 0.017 M Na_2CO_3 eluent (Brinton and others, 1995)

Table 2. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references — Continued

Constituent	Instrumental Technique	Typical RSD[1], *detection limit (mg/L)*	Equipment Used	Comments and Reference(s)
Nitrate (NO_3)	IC	3%, *0.1*	Dionex model 2010i ion chromatograph with AG4A guard and AS4A separator columns and Anion Self-Regenerating Suppressor	0.018 M $NaHCO_3$ + 0.017 M Na_2CO_3 eluent (Brinton and others, 1995)
Nitrite (NO_2)	Colorimetry (2001); Chemiluminescence (2002)	3%, *0.01;* *2% 0.0003*	Hewlett-Packard model 8452A diode array spectrometer with 1 and 5 cm cells; Sievers 280 NO Analyzer	(Antweiler and others, 1996; Venkataraman and others, 2000)
Ammonium (NH_4)	Colorimetry; IC	3%, *0.04*; *2%, 0.3*	Alpkem model RFA-300 flow injection analyzer; Dionex model DX-300 ion chromatograph with CS12A column	22 mN H_2SO_4 eluent (Solorzano, 1969; Antweiler and others, 1996)
Silica (SiO_2)	ICP-OES	2%, *0.05*	Leeman Labs Direct Reading Echelle[3]	Sample diluted 1:10 in field, analytical wavelength: 251.611 nm, view: axial
Boron (B)	ICP-OES	2%, *0.01*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 249.678 nm, view: axial
Aluminum (Al)	ICP-OES	2%, *0.07*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 308.215 nm, view: axial
Total iron (Fe(T))	Colorimetry	2%, *0.002*	Hewlett-Packard model 8452A diode array spectrometer with 1 and 5 cm cells	FerroZine method (Stookey, 1970; To and others, 1999)
Ferrous iron (Fe(II))	Colorimetry	2%, *0.002*	Hewlett-Packard model 8452A diode array spectrometer with 1 and 5 cm cells	FerroZine method (Stookey, 1970; To and others, 1999)
Manganese (Mn)	ICP-OES	3%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 257.610 nm, view: axial
Copper (Cu)	GFAAS	3%, *0.0005*	Perkin-Elmer model 4110ZL	Analytical wavelength: 324.8 nm, modifier: 5µg Pd + 3µg $Mg(NO_3)_2$, atomization temperature: 2,000°C
Zinc (Zn)	ICP-OES	2%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 206.200 nm, view: radial

Table 2. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references — Continued

Constituent	Instrumental Technique	Typical RSD[1], *detection limit (mg/L)*	Equipment Used	Comments and Reference(s)
Cadmium (Cd)	GFAAS	5%, *0.0001*	Perkin-Elmer model 4110ZL	Analytical wavelength: 228.8 nm, modifier: 50µg PO_4 + 3µg $Mg(NO_3)_2$, atomization temperature: 1,500°C
Chromium (Cr)	GFAAS	~5%, *0.0005*	Perkin-Elmer model 4110ZL	Analytical wavelength: 357.9 nm, modifier: 15µg $Mg(NO_3)$, atomization temperature: 2,300°C
Cobalt (Co)	GFAAS	~5%, 0.0007	Perkin-Elmer model 4110ZL	Analytical wavelength: 242.5 nm, modifier: 15µg Mg(NO3)2, atomization temperature: 2,400°C
Total mercury (Hg(T))	CVAFS	2%, 0.4 ng/L	PS Analytical, model Galahad, direct cold-vapor atomic fluorescence spectrometry	Taylor and others (1997), Roth and others (2001)
Nickel (Ni)	ICP-OES	2%, *0.002*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 231.604 nm, view: axial
Lead (Pb)	GFAAS	5%, *0.0008*	Perkin-Elmer model 4110ZL	Analytical wavelength: 283.3 nm, modifier: 50µg PO_4 + 3µg $Mg(NO_3)_2$, atomization temperature: 1,600°C
Beryllium (Be)	ICP-OES	2%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 313.042 nm, view: axial
Vanadium (V)	ICP-OES	3%, *0.002*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 292.401 nm, view: axial
Molybdenum (Mo)	ICP-OES	3%, *0.007*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 277.540 nm, view: axial
Antimony (Sb)	GFAAS	5%, *0.001*	Perkin-Elmer model 4110ZL	Analytical wavelength: 217.6 nm, modifier: 5µg Pd + 3µg $Mg(NO_3)_2$, atomization temperature: 1,900°C
Selenium (Se)	GFAAS	5%, *0.001*	Perkin-Elmer model 4110ZL	Analytical wavelength: 196.0 nm, modifier: 5µg Pd + 3µg $Mg(NO_3)_2$, atomization temperature: 2,100°C

Table 2. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references — Continued

Constituent	Instrumental Technique	Typical RSD[1], *detection limit (mg/L)*	Equipment Used	Comments and Reference(s)
Selenium (Se)	GFAAS	5%, *0.001*	Perkin-Elmer model 4110ZL	Analytical wavelength: 196.0 nm, modifier: 5µg Pd + 3µg $Mg(NO_3)_2$, atomization temperature: 2,100°C
Arsenic total (As(T))	HGAAS	2%, *0.0001*	Perkin-Elmer AAnalyst 300 atomic absorption spectrometer with a FIAS-100 flow injection analysis system, quartz cell, and furnace	Pre-reduction of As(V) using KI + ascorbic acid + HCl (McCleskey and others, 2003)
Arsenite (As(III))	HGAAS	5%, *0.0005*	Perkin-Elmer AAnalyst 300 atomic absorption spectrometer with a FIAS-100 flow injection analysis system, quartz cell, and furnace	(McCleskey and others, 2003)
Deuterium (δD)	MS	1 per mil[2]	V.G. Micromass model 602 mass spectrometer	Standardization against VSMOW (δD = 0 per mil) and SLAP (δD = -428 per mil) (Coplen and others, 1991)
Oxygen ($\delta^{18}O$)	MS	0.1 per mil[2]	DuPont model 21-491 mass spectrometer	Standardization against VSMOW ($\delta^{18}O$ = 0 per mil) and SLAP ($\delta^{18}O$ = -55.5 per mil) (Epstein and Mayeda, 1953)
Dissolved organic carbon (DOC)	TOC Analyzer	2%, *0.1*	Oceanography International Model 700 TOC Analyzer	Wet oxidation method (Aiken, 1992)

[1]relative standard deviation expressed in percent (standard deviation ÷ mean × 100)

[2]these values are expressions of precision or range, rather than RSD

[3]dual view, sequential multielement, inductively coupled plasma spectrometer. Hildebrand grid nebulizer and glass Scott spray chamber

Major-Cation and Trace-Metal Determinations

Concentrations of major cations and trace metals were determined using inductively coupled plasma-optical emission spectrometry (ICP-OES). Major cation concentrations were determined using the radial view while the axial view was used for trace-metal determinations. A cesium chloride (CsCl) ionization buffer was added to the samples for ICP-OES measurement of lithium and potassium concentrations. Analytical wavelengths and plasma viewing orientations are specified in table 2.

Concentrations of Sb, Cd, Cr, Co, Cu, Pb, and Se were measured using graphite furnace atomic absorption spectrometry (GFAAS) with a transversely heated graphite atomizer (THGA) and Zeeman-effect background correction. The wavelength, atomization temperature, and matrix modifiers used are listed in table 2.

Hydride generation atomic absorption spectrometry was used to measure dissolved As(T) and dissolved As(III) concentrations in HCl-acidified samples. A flow-injection analysis system (FIAS) was used to generate arsine (McCleskey and others, 2003). Dissolved Fe(T) and Fe(II) concentrations were determined in samples preserved with HCl using a modification of the FerroZine colorimetric method (Stookey, 1970; To and others, 1999).

Major-Anion Determinations

Concentrations of SO_4, Cl, and Br were determined using ion chromatography (IC) (Brinton and others, 1995). Fluoride concentrations were determined using an ion-selective electrode (ISE) and mixing samples one to one with a total ionic strength adjustment buffer (TISAB) (Barnard and Nordstrom, 1980). Alkalinity (as HCO_3) was determined by automated titration using standardized H_2SO_4 (Barringer and Johnsson, 1989).

Nutrient and Dissolved Organic Carbon Determinations

Ammonium concentrations were determined using an IC with 50 mN H_2SO_4 eluent. Samples containing elevated Na concentrations often yielded poor peak resolution requiring secondary analyses by spectrophotometry. Ammonium concentrations measured using IC were compared with values from the same sample analyzed by spectrophotometry to ensure equivalent results. Nitrite concentrations were determined by colorimetry (Antweiler and others, 1996) for the samples collected in May 2001 and by chemiluminescence (Venkataraman and others, 2000) for all other samples. For the chemiluminescence NO_2 determination, a 1 percent solution of KI in glacial acetic acid was used to convert NO_2 to NO. The NO produced in this step reacted with ozone to form an excited state of NO_2* proportional to the amount of NO in the sample, and was quantified using a chemiluminescence detector.

Dissolved organic carbon concentrations were measured using the wet oxidation method (Aiken, 1992) with Oceanography International Model 700 TOC Analyzer. Potassium biphthalate was used to calibrate the instrument, and sodium benzoate was used as a different organic carbon source to check the calibration. Analyses of an inorganic carbon, $NaHCO_3$, alongside the samples provided a daily verification that the acid valve was functioning properly.

Water Isotope Determinations

Hydrogen isotope ratios were determined using a hydrogen equilibration technique (Coplen and others, 1991; Revesz and Coplen, 2003a). Oxygen isotope ratios were determined using the CO_2 equilibration technique of Epstein and Mayeda (1953), which has been automated by Revesz and Coplen (2003b). The isotopic concentration is reported in "delta notation," which compares the isotope ratio of a sample to that of a reference standard. For the example of $^{18}O/^{16}O$ ratios, delta notation is:

$$\delta^{18}O‰ = \frac{\left(^{18}O/_{16}O\right)_{sample} - \left(^{18}O/_{16}O\right)_{standard}}{\left(^{18}O/_{16}O\right)_{standard}} \times 1000 \quad (2)$$

where ‰ is per mil, which is equivalent to parts per thousand.

Oxygen and hydrogen isotopic results are reported relative to the VSMOW (Vienna Standard Mean Ocean Water) standard and normalized (Coplen, 1994) on scales such that the oxygen and hydrogen isotopic values of SLAP (Standard Light Antarctic Precipitation) are -55.5 per mil and -428 per mil, respectively.

Acidity Determinations

Total acidity was determined by titrating samples having pH less than 5 to pH greater than 7 using an autotitrator and standardized sodium hydroxide (NaOH) solution. The NaOH titrant (0.01 to 0.05 M) was standardized daily by titrating a known quantity of potassium hydrogen phthalate. The autotitrator was programmed for 50- to 100-µL constant-volume additions or constant change in millivolts (mV), typically 10 mV per addition. Equivalence points were determined using a modified Gran's function (Barringer and Johnsson, 1989):

$$F_{acid} = (v_0 + v_{NaOH}) \times 10^{-pH} \quad (3)$$

where F_{acid} is the Gran function, v_0 is the sample volume and v_{NaOH} is the volume of NaOH titrant added.

The portion of the titration curve for total acidity will lie in the basic region where free hydrogen ion (H^+) is negligible compared to hydroxide (OH^-). Therefore, OH^- may be substituted for H^+, or 10^{-pOH} for 10^{-pH} in equation (3) (Barringer and Johnsson, 1996). The most important reactions contributing to total acidity are sulfate hydrolysis, iron oxidation and hydrolysis, and aluminum hydrolysis (Ball and others, 2002). Free H^+ was derived by subtracting the hydrogen ions produced by hydrolysis of sulfate, iron, and aluminum from the total acidity. The bisulfate concentration was estimated using an interactive version (PHREEQCI, Charlton and others, 1997) of the geochemical modeling code PHREEQC (Parkhurst and Appelo, 1999) in conjunction with the WATEQ4F (Ball and Nordstrom, 1991) database. Sample pH from the acidity titration was calculated by combining the H^+ activity coefficient determined by PHREEQCI with the free H^+ molality and computing the common logarithm of the resulting activity. Total acidity and free H^+ are expressed in millimoles per liter (mM).

Revised pH Measurements

Accurate measurement of pH is of primary importance for interpretation of aqueous chemical speciation. The hydrogen ion (H^+) is usually the major cation in geothermal waters with pH less than 2.5 (Ball and others, 2002), is important in controlling geochemical reactions, and is critical in calculating the speciated charge imbalance (C.I.). For the subset of 47 samples with pH less than 5, table 3 shows the determination of pH using 4 different techniques: (1) pH measured in the field, (2) pH measured in the laboratory, (3) pH calculated using free H^+ from the acidity titration and the activity coefficient calculated using PHREEQCI (acidity pH), and (4) pH calculated by using the H^+ concentration to adjust the speciated C.I. to zero. The pH calculated by using the H^+ concentration to adjust the speciated C.I. to zero was used only as a reference in this report because it relies on measurements of several parameters. Comparison of pH values from the four sources aided in the selection of the most accurate estimates of pH values.

A flow-chart showing the pH selection process is shown in figure 3. Field pH was considered to be the most accurate because pH measurements made in the laboratory may be biased from temperature changes and hydrolysis reactions and pH obtained from acidity is affected by uncertainties in measured iron, aluminum, and sulfate concentrations. Field pH was selected for all samples with a pH greater than 5. For samples with pH less than 5, field pH was selected unless the sample had a C.I. greater than 5 percent. For samples with a C.I. (using field pH) greater than 5 percent, laboratory pH was selected if the C.I. (using laboratory pH) was less than 5 percent. For samples with pH greater than 3 and field and laboratory pH that both produced C.I. greater than 5 percent, the pH that produced the lowest C.I. was selected. For samples with pH less than 3 and having field pH and laboratory pH that both yielded C.I.s greater than 5 percent, pH from the free H^+ calculated from the acidity titration was selected if the C.I. (using acidity pH) was less than 5 percent. For samples with a pH less than 3 and having field, laboratory, and acidity pHs that produced C.I.s greater than 5 percent, the pH that yielded the lowest C.I. or an average of two or more of the pH values was selected.

Laboratory pH was selected for samples 01WA102, 01WA112, 01WA113, 01WA118, 01WA120, 01WA123, 01WA125, 01WA129, 01WA132, 01WA133, and 02WA125. Acidity pH was selected for sample 01WA130. The average of field pH and acidity pH was used for sample 02WA148. Field pH was selected for the remaining 104 samples. Values of pH listed in table 3 as “selected” are the values found in the tables of chemical data (tables 5-10) along with the C.I. using the selected pH.

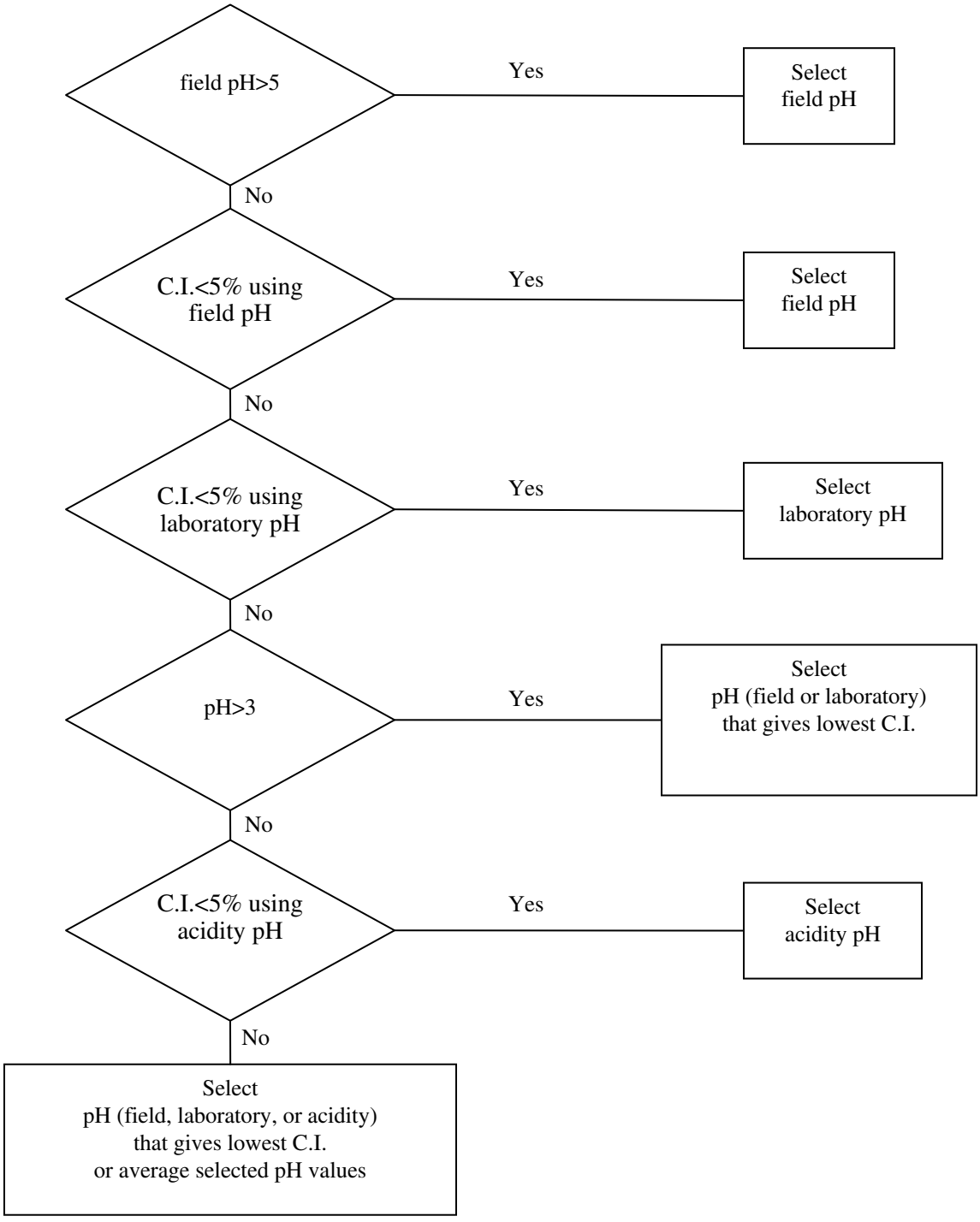


Figure 3. Flow-chart showing the sample pH selection process.

[C.I., charge imbalance]

Table 3. Sample pH measured in the field and laboratory and calculated from acidity titration and speciated charge imbalance, for samples with a pH less than 5

[Selected, selected pH value after evaluation of four methods to determine pH; ---, not measured]

	pH, in standard units				
Sample	Measured in the field	Measured in the laboratory	Calculated from acidity titration	Calculated from charge imbalance	Selected
01WA102	3.72	3.65	3.54	3.18	3.65
01WA103	2.93	2.87	2.86	2.89	2.93
01WA104	2.99	2.88	2.86	2.94	2.99
01WA105	4.32	3.89	3.26	7.75	4.32
01WA106	3.73	3.54	3.42	5.73	3.73
01WA107	3.46	3.37	3.28	3.06	3.46
01WA108	2.76	2.69	2.72	2.73	2.76
01WA109	2.39	2.34	2.35	2.38	2.39
01WA112	3.47	3.37	2.92	2.48	3.37
01WA113	3.72	3.49	3.10	2.53	3.49
01WA118	3.71	3.35	3.35	3.16	3.35
01WA120	2.89	2.81	2.83	2.77	2.81
01WA121	2.83	2.83	2.89	2.78	2.83
01WA122	2.88	2.84	2.91	2.81	2.88
01WA123	2.93	2.81	2.85	2.80	2.81
01WA125	4.01	3.90	3.71	3.36	3.90
01WA126	4.24	4.03	3.57	3.36	4.24
01WA127	3.35	3.16	3.63	2.97	3.35
01WA129	3.30	3.14	3.16	2.88	3.14
01WA130	3.00	2.99	2.97	2.74	2.97
01WA131	2.87	2.81	2.85	2.82	2.87
01WA132	3.13	2.98	3.04	2.80	2.98
01WA133	3.15	3.07	3.13	2.84	3.07
01WA134	2.66	2.61	2.69	2.60	2.66
01WA136	2.81	2.74	2.88	2.80	2.81
01WA139	4.89	5.34	4.19	3.33	4.89
01WA140	3.67	3.60	3.48	3.66	3.67
01WA141	4.36	4.15	4.60	3.51	4.36
01WA147	2.06	2.08	2.04	2.03	2.06
01WA148	2.72	2.84	2.68	2.78	2.72
01WA149	1.72	1.75	1.73	1.72	1.72
01WA150	2.10	2.07	2.09	2.07	2.10
01WA171	2.58	2.64	2.63	2.54	2.58
02WA125	4.76	3.34	---	3.54	3.34
02WA126	3.32	3.29	3.06	3.51	3.32

Table 3. Sample pH measured in the field and laboratory and calculated from acidity titration and speciated charge imbalance, for samples with a pH less than 5 — Continued

[Selected, selected pH value after evaluation of four methods to determine pH; ---, not measured]

	pH, in standard units				
Sample	Measured in the field	Measured in the laboratory	Calculated from acidity	Calculated from charge imbalance	Selected
02WA127	2.36	2.32	2.37	2.36	2.36
02WA128	3.83	3.63	3.60	8.03	3.83
02WA129	3.05	2.96	2.94	3.51	3.05
02WA130	3.61	3.47	3.48	3.55	3.61
02WA131	2.54	2.50	2.56	2.60	2.54
02WA132	3.24	3.13	3.21	3.20	3.24
02WA133	3.28	3.28	3.03	3.79	3.28
02WA134	4.32	4.04	3.20	6.18	4.32
02WA137	2.93	2.88	2.90	2.96	2.93
02WA138	2.93	2.87	2.77	2.92	2.93
02WA148	2.09	1.98	2.15	2.16	2.11

SAMPLE LOCATIONS AND CROSS-REFERENCE INFORMATION

Many geothermal features are within meters of each other, thus it is critical that sample sites be accurately located and described. Every effort was made to include detailed maps (figs. 4-16), verbal descriptions, accurate latitude and longitude measurements (table 4), and photographs (Appendix 2) of all the sample sites for which analytical results are reported. In table 4, samples are grouped by area (Norris Geyser Basin: One Hundred Spring Plain area, Back Basin, Ragged Hills area; Nymph Lake / Roadside Springs; Lower Geyser Basin; Washburn Hot Springs; Calcite Spring Area; Crater Hills; Mammoth Hot Springs; West Thumb Geyser Basin; and Brimstone Basin) and each sample has cross reference information for maps with sample locations, chemical data tables, and numbered photographs which are found in Appendix 2.

Sample locations are shown on the following maps: Norris Geyser Basin (figs. 4-7), Nymph Creek Springs, Nymph Creek, and the thermal features in the Roadside Springs area including Bijah Spring and Frying Pan Spring (fig. 8), Lower Geyser Basin (figs. 9 and 10), Washburn Springs (fig. 11), Mammoth Hot Springs (fig. 12), West Thumb Geyser Basin (fig. 13), Crater Hills (fig. 14), near Calcite Spring (fig. 15), and Alluvium Creek and its tributaries at Brimstone Basin (fig. 16). Official names are taken from Whittlesey (1988). Several features, especially newly formed features in the Ragged Hills area of Norris Geyser Basin, do not have official names. Names assigned to features by the authors are in quotations marks in tables 4-10.

In the tables, “source” samples were collected at the origin of the spring, and “overflow channel” samples were collected at various distances downstream from the source. Series of samples were collected in the overflow channels from Nymph Creek (transects A, C, D, G), Washburn Springs Inkpot #1 (transect B), Octopus Spring (transect E), Mushroom Spring (transect F), and Ojo Caliente Spring (transects H and I). Latitudes and longitudes for sample locations were acquired using a portable global positioning system (GPS, Garmin III+) and coordinate information is referenced to the NAD27 datum.

Table 4. Detailed sample site descriptions, locations, and map, photograph, and chemical data table reference

[---, not measured or not photographed; cm, centimeters; m, meters]

Name and/or Site Description	Sample code number	Latitude	Longitude	Map[1] (figure)	Chemical data (table)	Photograph (appendix 2)
Norris Geyser Basin (One Hundred Spring Plain area)						
Cinder Pool	01WA105	44°43'57.2"	110°42'35.6"	4, 5	5	5, 24
Cinder Pool (side of pool)	01WA105S	44°43'57.2"	110°42'35.6"	4, 5	5	5, 24
Cinder Pool	01WA126	44°43'57.2"	110°42'35.6"	4, 5	5	5, 24
Cinder Pool	02WA134	44°43'57.2"	110°42'35.6"	4, 5	5	5, 24
Cinder Pool (side of pool)	02WA134S	44°43'57.2"	110°42'35.6"	4, 5	5	5, 24
Tantalus Creek at weir	01WA130	44°44'2.8"	110°42'54.6"	4, 5	5	27
Unnamed small sulfur pool	01WA176	44°44'34.0"	110°42'58.8"	4, 5	5	---
Unnamed mud pot	01WA169	44°44'21.3"	110°42'37.0"	4, 5	5	47
Unnamed mud pot	02WA125	44°44'21.3"	110°42'37.0"	4, 5	5	47
Unnamed large pond 220 m west of 02WA125	02WA126	44°44'22.4"	110°42'46.8"	4, 5	5	48
Unnamed hot springs outflow along north bank of Gibbon River	01WA170	44°44'18.2"	110°42'48.6"	4, 5	5	---
Unnamed shallow hot springs 130 m north-west of Cinder pool	01WA109	44°44'0.9"	110°42'37.7"	4, 5	5	9
Norris Geyser Basin (Back Basin area)						
Bathtub Spring	01WA127	44°43'35.3"	110°42'15.4"	4, 6	5	25
"Black Gassy Spring"	01WA138	44°43'36.6"	110°42'30.7"	4, 6	5	32
Black Pit	02WA142	44°43'20.4"	110°42'4.8"	4, 6	5	57
Cistern Spring	01WA119	44°43'23.4"	110°42'14.8"	4, 6	5	19
Cistern Spring	01WA128	44°43'23.4"	110°42'14.8"	4, 6	5	19
Cistern Spring	02WA141	44°43'23.4"	110°42'14.8"	4, 6	5	19
Hydrophane Spring	01WA141	44°43'12.9"	110°42'31.4"	4, 6	5	35
Orpiment Spring	01WA139	44°43'26.6"	110°42'35.5"	4, 6	5	33
Perpetual Spouter	01WA135	44°43'35.7"	110°42'32.7"	4, 6	5	29, 30
Pork Chop Geyser	01WA137	44°43'19.9"	110°42'29.3"	4, 6	5	31
Pork Chop Geyser	02WA136	44°43'19.9"	110°42'29.3"	4, 6	5	31
Recess Spring	01WA140	44°43'22.0"	110°42'35.9"	4, 6	5	34
Rediscovered Geyser	02WA144	44°43'38.3"	110°42'20.9"	4, 6	5	58
Steamboat Geyser	01WA142	44°43'24.8"	110°42'11.2"	4, 6	5	36
Vixen Geyser	01WA129	44°43'22.4"	110°42'25.0"	4, 6	5	26
Unnamed acid spring next to Perpetual Spouter	01WA136	44°43'35.5"	110°42'33.1"	4, 6	5	30
Norris Geyser Basin (Ragged Hills area)						
Crystal Spring	02WA135	44°43'43.5"	110°42'40.1"	4, 7	5	53
"Lifeboat Spring"	01WA108	44°43'39.4"	110°42'51.5"	4, 7	5	8
"Lifeboat Spring"	02WA129	44°43'39.4"	110°42'51.5"	4, 7	5	8
"Persnickety Geyser"	01WA106	44°43'40.1"	110°42'49.9"	4, 7	5	6
Mixing area between "Persnickety Geyser" and "Titanic Spring"	01WA106/107	---	---	4, 7	5	6, 7
"Persnickety Geyser"	01WA132	44°43'40.1"	110°42'49.9"	4, 7	5	6
"Persnickety Geyser"	02WA128	44°43'40.1"	110°42'49.9"	4, 7	5	6
"Titanic Spring"	01WA107	44°43'39.6"	110°42'50.7"	4, 7	5	7
"Titanic Spring"	01WA131	44°43'39.4"	110°42'50.9"	4, 7	5	7
"Titanic Spring"	02WA130	44°43'39.4"	110°42'50.9"	4, 7	5	7
"Verde Crater"	02WA127	44°43'46.6"	110°42'53.6"	4, 7	5	49
Unnamed small spouter in The Gap, cemented shelf coated with red crust, yellow-gray clay material surrounds vent	02WA132	44°43'42.0"	110°42'46.5"	4, 7	5	51
Unnamed spring in The Gap downslope of explosive red crater in hillside coated with white clay	01WA134	44°43'41.9"	110°42'48.2"	4, 7	5	28
Unnamed spring in The Gap downslope of explosive red crater in hillside white clay	02WA131	44°43'41.9"	110°42'48.2"	4, 7	5	28, 50
Unnamed 15 cm diameter pool with bright yellow precipitate, ~6 m west of creek, Ragged Hills	02WA133	44°43'45.3"	110°42'41.4"	4, 7	5	52
Unnamed spring in The Gap, most active with fumaroles	01WA133	44°43'41.4"	110°42'49.2"	4, 7	5	28
"Sperm Spring"	01WA175	44°44'28.7"	110°43'3.1"	4, 5	5	---
Gibbon River - at highway 89 bridge, near Norris Geyser Basin	01WA178	44°44'16.2"	110°41'54.0"	4	5	---
Gibbon River - downstream from Norris Geyser Basin	01WA177	44°43'3.6"	110°43'25.0"	4	5	---

Table 4. Detailed sample site descriptions, locations, and map, photograph, and chemical data table reference — Continued

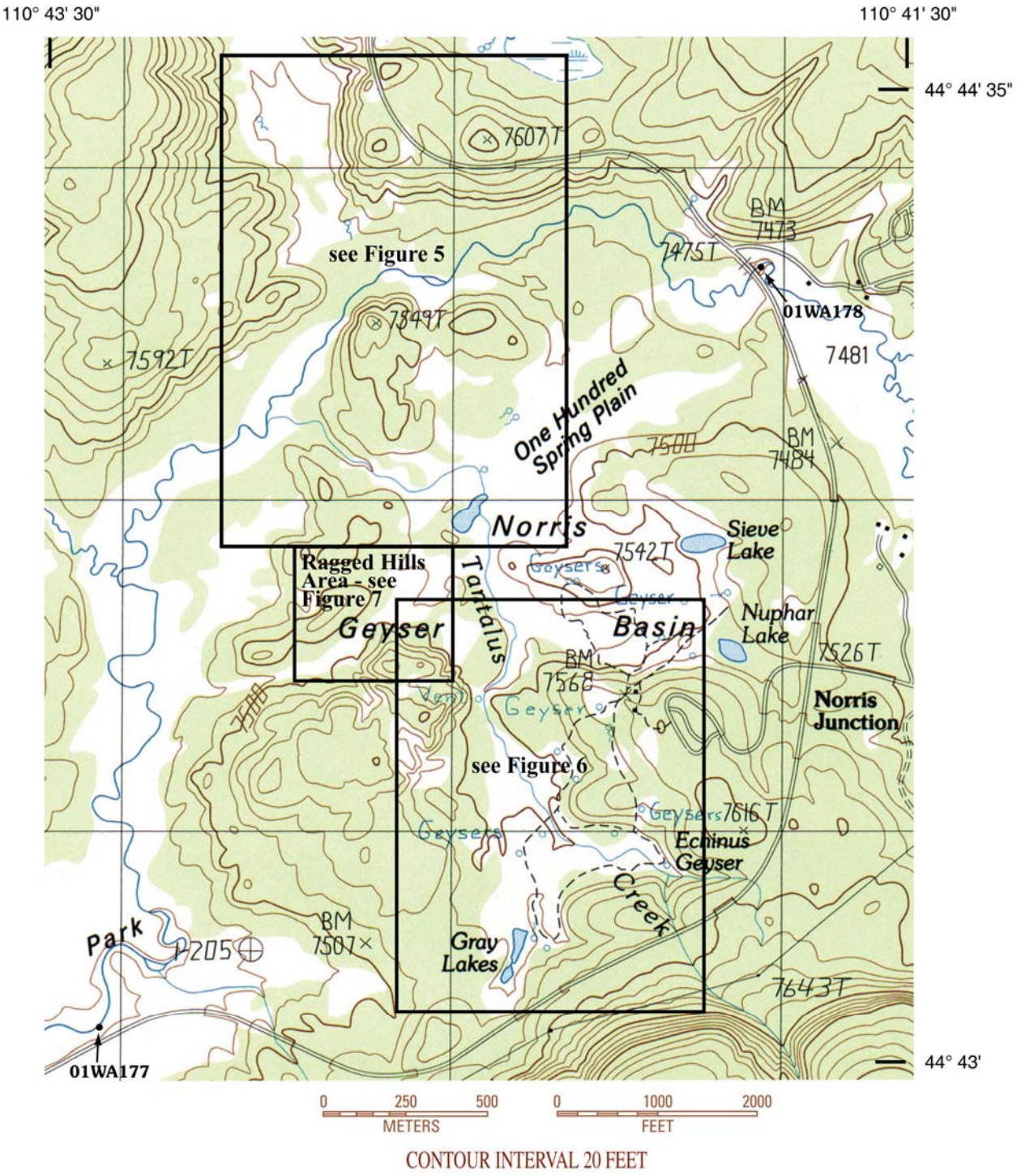
Name and/or Site Description	Sample code number	Latitude	Longitude	Map[1] (figure)	Chemical data (table)	Photograph (appendix 2)
Nymph Lake / Roadside Springs						
Bijah Spring - large hot pool between Roadside Springs and Twin Lakes along Norris-Mammoth road	02WA140	44°45'40.4"	110°43'48.5"	8	6	56
Frying Pan Spring	01WA164	44°45'8.4"	110°43'21.3"	8	6	---
Nymph Creek Spring - main vent source	01WA103 / transect A	44°45'10.9"	110°43'26.5"	8	6	3
Nymph Creek - 4.9 m from source	01WA103 A / transect A	---	---	8	6	---
Nymph Creek - 10.7 m feet from source	01WA103 B / transect A	---	---	8	6	---
Nymph Creek - 19.5 m from source	01WA103 C / transect A	---		8	6	---
Nymph Creek - 32 m from source	01WA104 / transect A	44°45'10.0"	110°43'27.1"	8	6	4
Nymph Creek - secondary source, vent on north bank of creek, 6 m downstream of main fissure	01WA122 / transect C	44°45'10.7"	110°43'27.1"	8	6	22
Nymph Creek - 3.4 m from secondary source	01WA121B / transect C	---	---	8	6	---
Nymph Creek - 4.9 m from secondary source	01WA121A / transect C	---	---	8	6	---
Nymph Creek - 7.0 m from secondary source	01WA121 / transect C	44°45'10.8"	110°43'26.9"	8	6	21
Nymph Creek - 12.8 m from secondary source	01WA120A / transect C	---	---	8	6	---
Nymph Creek - 22 m from secondary source	01WA120 / transect C	44°45'10.2"	110°43'27.4"	8	6	20
Nymph Creek - secondary source, vent on north bank of creek, 6 m downstream from main fissure	01WA123E / transect D	44°45'10.7"	110°43'27.1"	8	6	---
Nymph Creek - 3.4 m from secondary source	01WA123D / transect D	---	---	8	6	---
Nymph Creek - 4.9 m from secondary source	01WA123C / transect D	---	---	8	6	---
Nymph Creek - 7.0 m from secondary source	01WA123B / transect D	44°45'10.8"	110°43'26.9"	8	6	---
Nymph Creek - 12.8 m from secondary source	01WA123A / transect D	---	---	8	6	---
Nymph Creek - 22 m from secondary source	01WA123 / transect D	44°45'10.2"	110°43'27.4"	8	6	23
Nymph Creek - source	02WA138 / transect G	44°45'11.3"	110°43'23.7"	8	6	54
Nymph Creek - 1.6 m from source	02WA137D / transect G	---	---	8	6	54
Nymph Creek - 2.4 m from source	02WA137C / transect G	---	---	8	6	54
Nymph Creek - 3.4 m from source	02WA137B / transect G	---	---	8	6	54
Nymph Creek - 4.5 m from source	02WA137A / transect G	44°45'11.3"	110°43'23.6"	8	6	54
Nymph Creek - source	01WA165	44°45'11.1"	110°43'26.6"	8	6	---
Nymph Lake - at shore	01WA168	44°45'8.9"	110°43'32.3"	8	6	---
Roadside Spring (east)	01WA102	44°45'12.8"	110°43'29.5"	8	6	2
Roadside Spring (east)	01WA125	44°45'12.8"	110°43'29.5"	8	6	2
Roadside Spring (east)	01WA166	44°45'12.8"	110°43'29.5"	8	6	2
Roadside Spring (west, center of pool)	01WA101	44°45'12.7"	110°43'30.9"	8	6	1
Roadside Spring (west, side of pool)	01WA101S	44°45'12.7"	110°43'30.9"	8	6	1
Roadside Spring (west)	01WA124	44°45'12.7"	110°43'30.9"	8	6	1
Roadside Spring (west)	01WA167	44°45'12.7"	110°43'30.9"	8	6	1
Unnamed spring east of two more prominent Roadside Springs	02WA139	44°45'13.0"	110°43'26.3"	8	6	55
Lower Geyser Basin						
Azure Spring	02WA146	44°33'39.7"	110°49'55.9"	9	7	60
Bath Spring	02WA147	44°33'37.6"	110°49'59.0"	9	7	61
Mushroom Spring - center of pool	01WA146	44°32'19.3"	110°47'52.7"	10	7	40
Mushroom Spring - edge of pool	01WA146B / transect F	---	---	10	7	---
Mushroom Spring - 8.5m downdrainage of pool	01WA146C / transect F	---	---	10	7	---
Octopus Spring	01WA145	44°32'3.0"	110°47'52.6"	10	7	39
Octopus Spring - edge of pool	01WA145A / transect E	---	---	10	7	39
Octopus Spring - 9.4 m from edge of pool	01WA145B / transect E	---	---	10	7	39
Octopus Spring - 16.2 m from edge of pool	01WA145C / transect E	---	---	10	7	---
Octopus Spring - 23.5 m from edge of pool	01WA145D / transect E	---	---	10	7	---
Octopus Spring - 37.8 m from edge of pool	01WA145E / transect E	---	---	10	7	---
Ojo Caliente Spring	02WA145	44°33'46.1"	110°50'16.9"	9	7	59
Ojo Caliente Spring - edge of pool	02WA145A1 / transect H/I	44°33'46.1"	110°50'16.9"	9	7	---
Ojo Caliente Spring - 6.6 m from edge of pool, drainage A	02WA145A2 / transect H	---	---	9	7	---
Ojo Caliente Spring - 13 m from edge of pool, drainage A	02WA145A3 / transect H	---	---	9	7	---
Ojo Caliente Spring - 18.1 m from edge of pool, drainage A	02WA145A4 / transect H	---	---	9	7	---
Ojo Caliente Spring - 24 m from edge of pool, drainage A	02WA145A5 / transect H	---	---	9	7	---
Ojo Caliente Spring - 6.9 m from edge of pool, drainage B	02WA145B1 / transect I	---	---	9	7	---
Ojo Caliente Spring - 13.7 m from edge of pool, drainage B	02WA145B2 / transect I	---	---	9	7	---
Ojo Caliente Spring - 20.5 m from edge of pool, drainage B	02WA145B3 / transect I	---	---	9	7	---

Table 4. Detailed sample site descriptions, locations, and map, photograph, and chemical data table reference – Continued

Name and/or Site Description	Sample code number	Latitude	Longitude	Map[1] (figure)	Chemical data (table)	Photograph (appendix 2)
Washburn Hot Springs						
Washburn Hot Springs - Inkpot #1, lower most large pool, first one encountered on trail from Canyou Village area	01WA110 / transect B	44°45'52.8"	110°25'48.9"	11	8	10, 11, 18
Washburn Hot Springs - Inkpot #1 Drainage (high), 5m from Inkpot #1	01WA117 / transect B	44°45'52.5"	110°25'48.8"	11	8	17, 18
Washburn Hot Springs - Inkpot #1 Drainage (middle), 20m from Inkpot #1	01WA116 / transect B	44°45'52.2"	110°25'48.8"	11	8	16
Washburn Hot Springs - Inkpot #1 Drainage (low), 2m upstream from Sulfur Creek	01WA115 / transect B	44°45'49.2"	110°25'51.5"	11	8	15
Sulphur Creek below confluence with drainage from Washburn Springs Inkpot #1	01WA114	44°45'48.6"	110°25'51.3"	11	8	14
Washburn Hot Springs - Inkpot #2, blacker than #1 almost a mud pot	01WA111	44°45'52.9"	110°25'48.7"	11	8	11, 18
Washburn Hot Springs - Inkpot #3, immediately downslope of several fumaroles and vigorously surging small pools and vents	01WA118	44°45'53.2"	110°25'48.1"	11	8	11, 18
Calcite Spring Area						
Unnamed spring, downstream from Calcite Spring, Grand Canyon of the Yellowstone near Tower Junction	02WA148	44°54'23.3"	110°23'38.4"	15	9	62, 63
Crater Hills						
Unnamed light green flowing pool south of Sulphur Spring	01WA112	44°39'16.7"	110°28'54.8"	14	9	12
Sulphur Spring	01WA113	44°39'16.7"	110°28'54.8"	14	9	13
Mammoth Hot Springs						
Canary Spring	01WA143	44°58'1.1"	110°42'20.3"	12	9	37
Canary Springs - near base of travertine terrace above wetland area	01WA144	44°58'1.9"	110°42'14.1"	12	9	38
West Thumb Geyser Basin						
Lakeshore Geyser	01WA173	44°25'0.5"	110°34'11.7"	13	9	45
Unnamed pool	01WA174	44°25'0.0"	110°34'18.4"	13	9	46
Seismograph Pool	01WA172	44°24'57.0"	110°34'15.6"	13	9	44
Brimstone Basin						
Alluvium Creek - below main confluence of north branch above lower sulfur mounds confluence	01WA147	44°23'10.7"	110°13'0.6"	16	10	41
Alluvium Creek - right branch above main confluence of north branch above lower sulfur mounds confluence	01WA148	44°23'10.3"	110°13'0.3"	16	10	41
Alluvium Creek, acid high-conductance left branch above main confluence of north branch above lower sulfur mounds confluence	01WA149	44°23'10.3"	110°13'0.3"	16	10	41
Alluvium Creek - about 500m below big bend just above where surface flow disappears	01WA150	44°23'25.2"	110°13'51.1"	16	10	42
Alluvium Creek - downstream from Thorofare Trail just below where surface flow reappears	01WA171	44°23'9.9"	110°14'8.4"	16	10	43

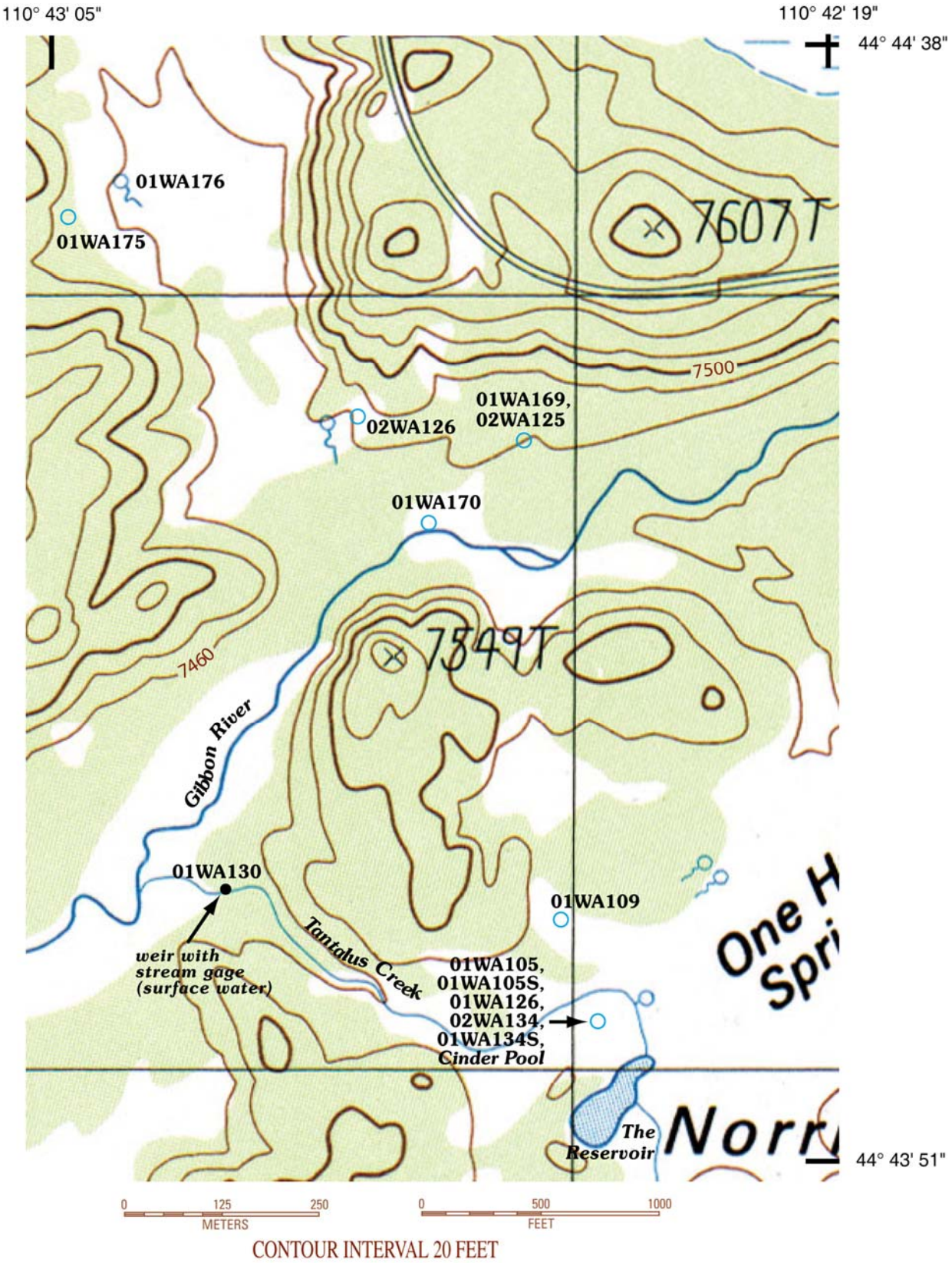
[1]Not all samples codes are shown on maps

Explanation of coordinate data: North American Datum 27-Continental United States (NAD27-CONUS), compatible with USGS topographic maps.



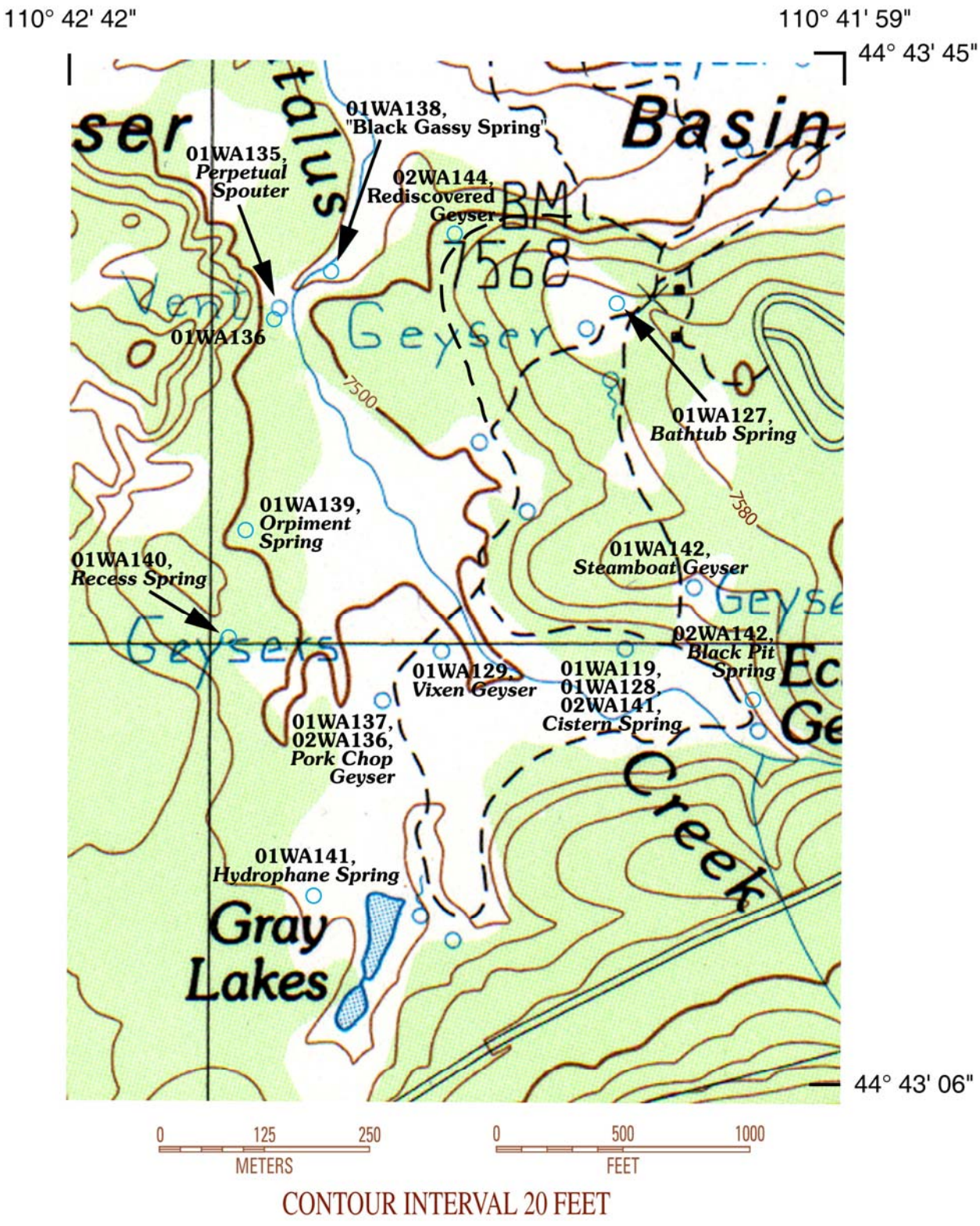
Base from U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 4. Sampling locations for hot springs, geysers, and surface waters at Norris Geyser Basin, Yellowstone National Park, Wyoming.



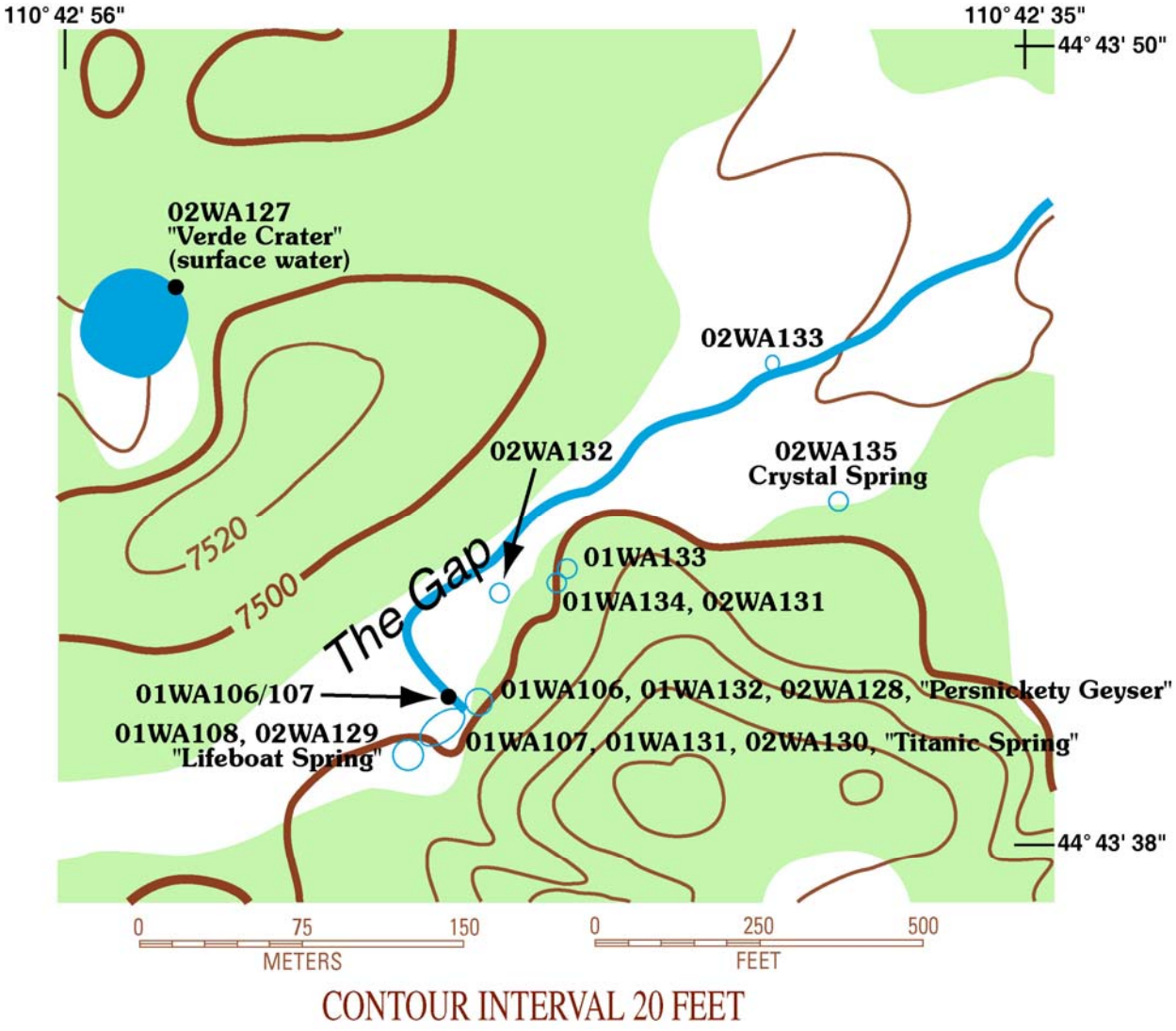
Base from U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 5. Sampling locations with sample code numbers for thermal features and one surface-water sample in the One Hundred Spring Plain area of Norris Geyser Basin, Yellowstone National Park, Wyoming (see figure 4).



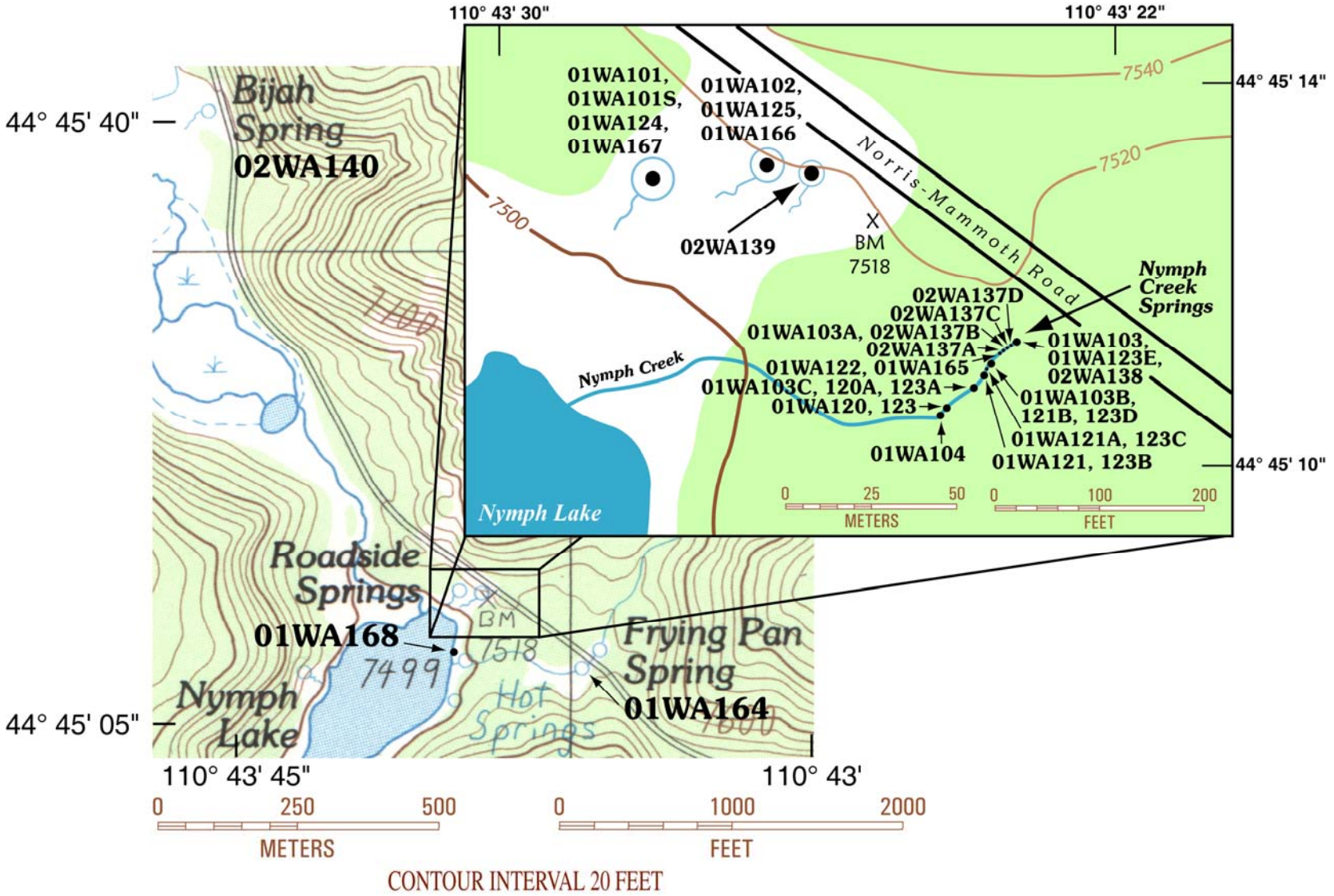
Base from U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 6. Sampling locations with sample code numbers for hot springs and geysers in the Back Basin area of Norris Geyser Basin, Yellowstone National Park, Wyoming (see figure 4).



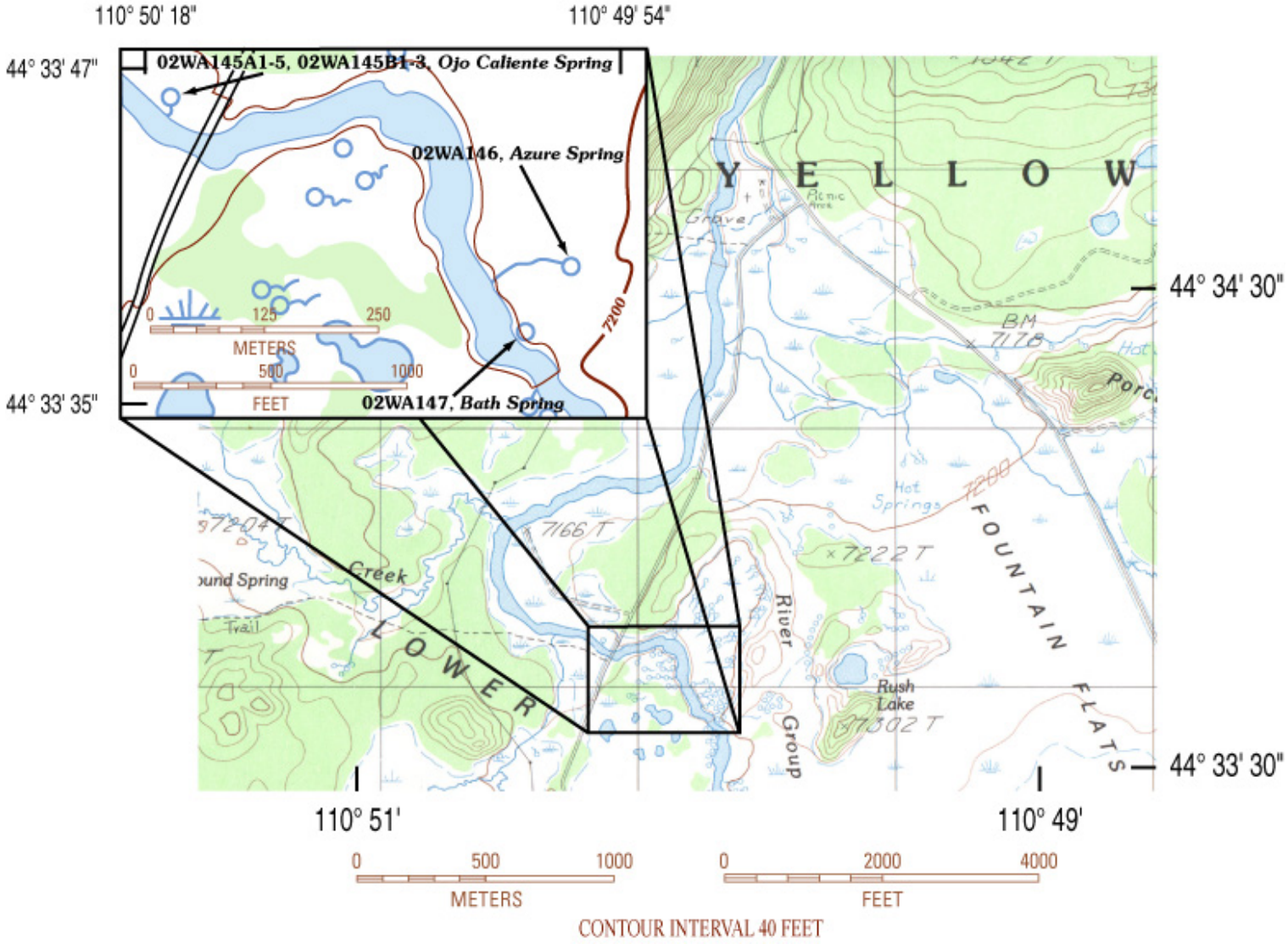
Sketch based on U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 7. Sampling locations with sample code numbers for hot springs and one surface water sample in the Ragged Hills area of Norris Geyser Basin, Yellowstone National Park, Wyoming (see figure 4).



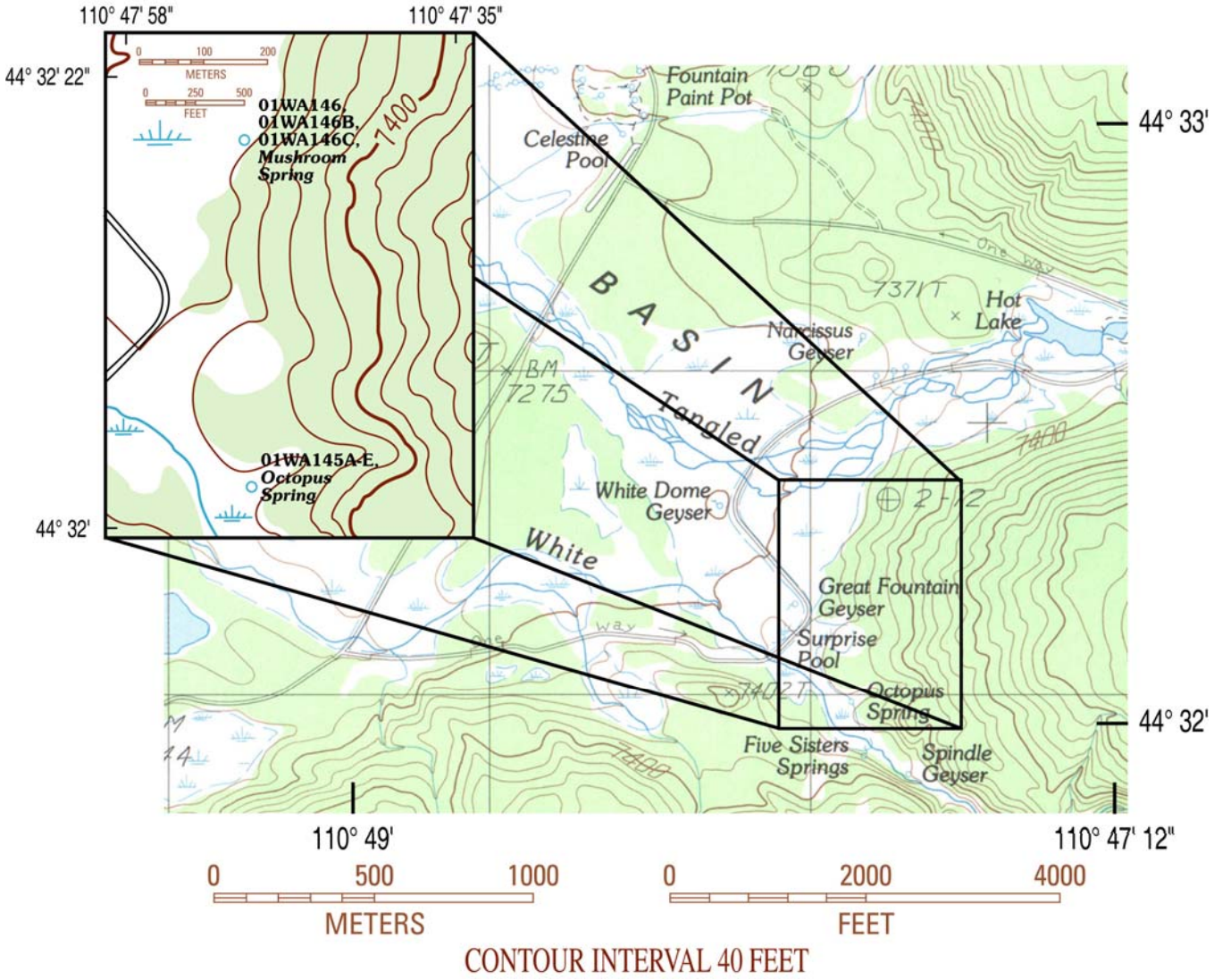
Sketch based on U.S. Geological Survey Obsidian Cliff quadrangle, 1:24,000 (1986)

Figure 8. Sampling locations with sample code numbers for Nymph Lake and Roadside Springs area, Bijah Spring, and Frying Pan Spring, Yellowstone Park, Wyoming.



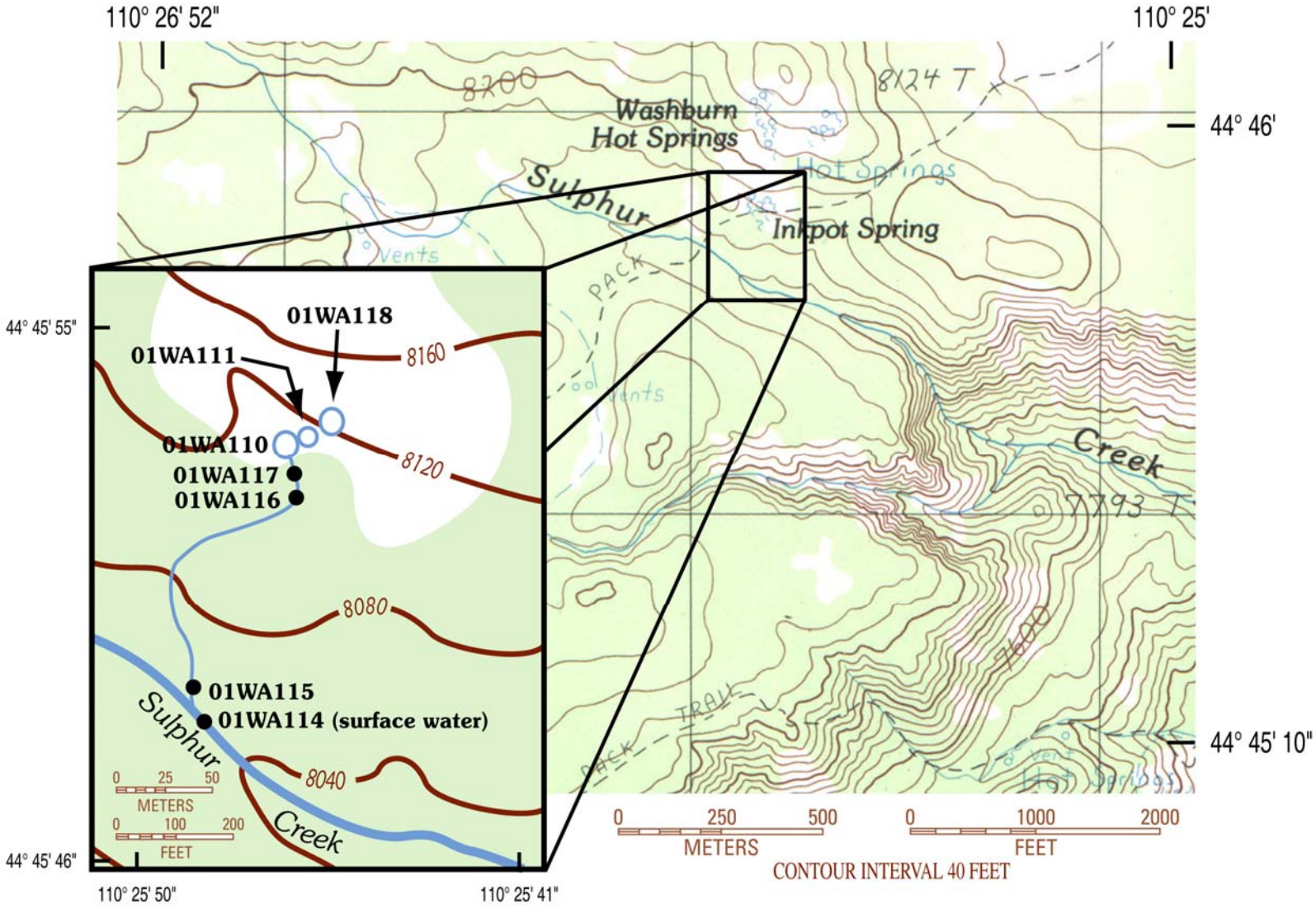
Base from U.S. Geological Survey Lower Geyser Basin Quadrangle, 1:24,000 (1986)

Figure 9. Sampling locations with sample code numbers for Ojo Caliente Spring, Azure Spring, and Bath Spring, Lower Geyser Basin, Yellowstone Park, Wyoming.



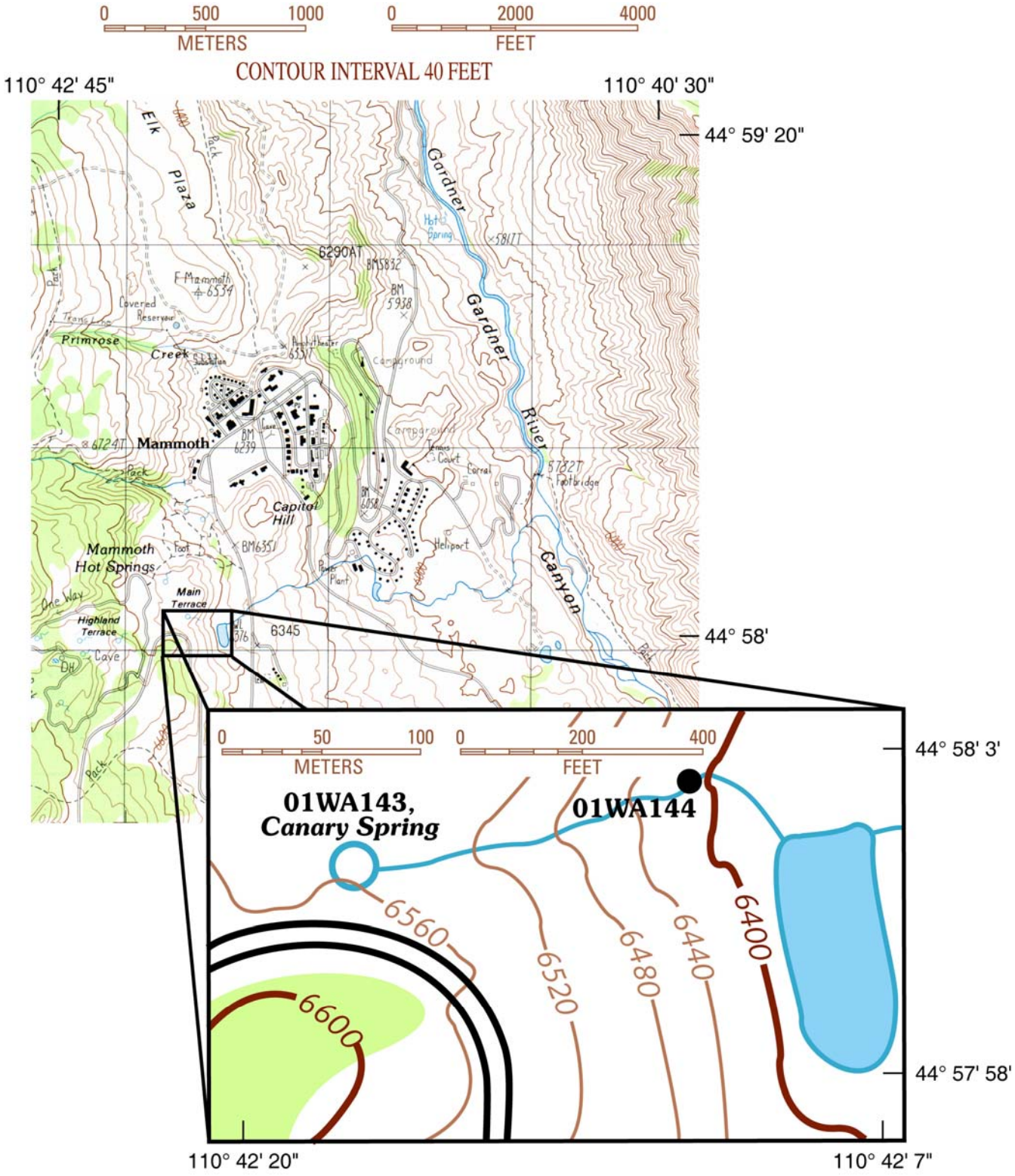
Base from U.S. Geological Survey Lower Geyser Basin Quadrangle, 1:24,000 (1986)

Figure 10. Sampling locations with sample code numbers for Octopus Spring and Mushroom Spring, Lower Geyser Basin, Yellowstone Park, Wyoming.



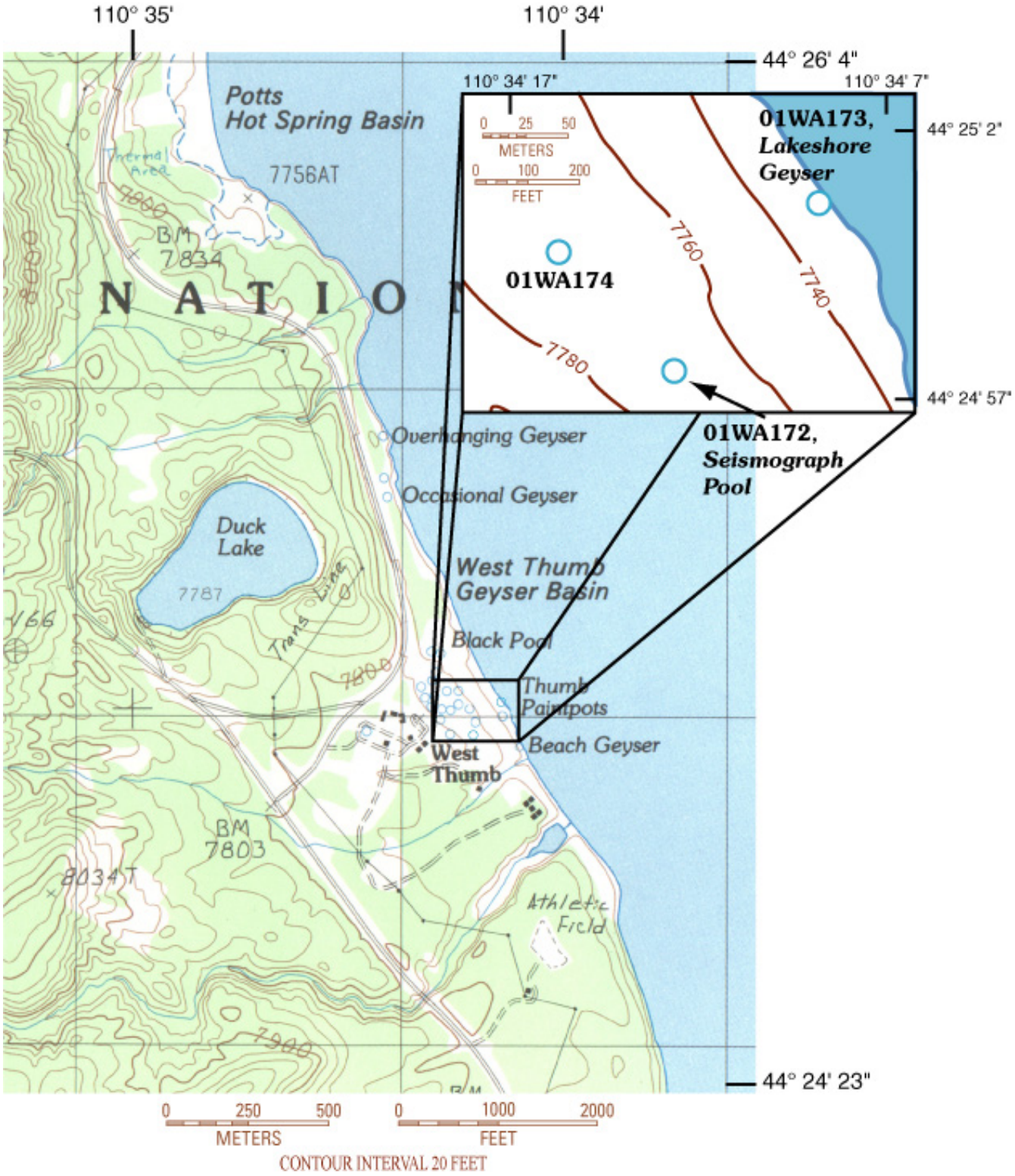
Base from U.S. Geological Survey Mount Washburn Quadrangle, 1:24,000 (1986)

Figure 11. Sampling locations with sample code numbers for Washburn Hot Springs, Inkpot overflow channel, and Sulphur Creek, Yellowstone Park, Wyoming.



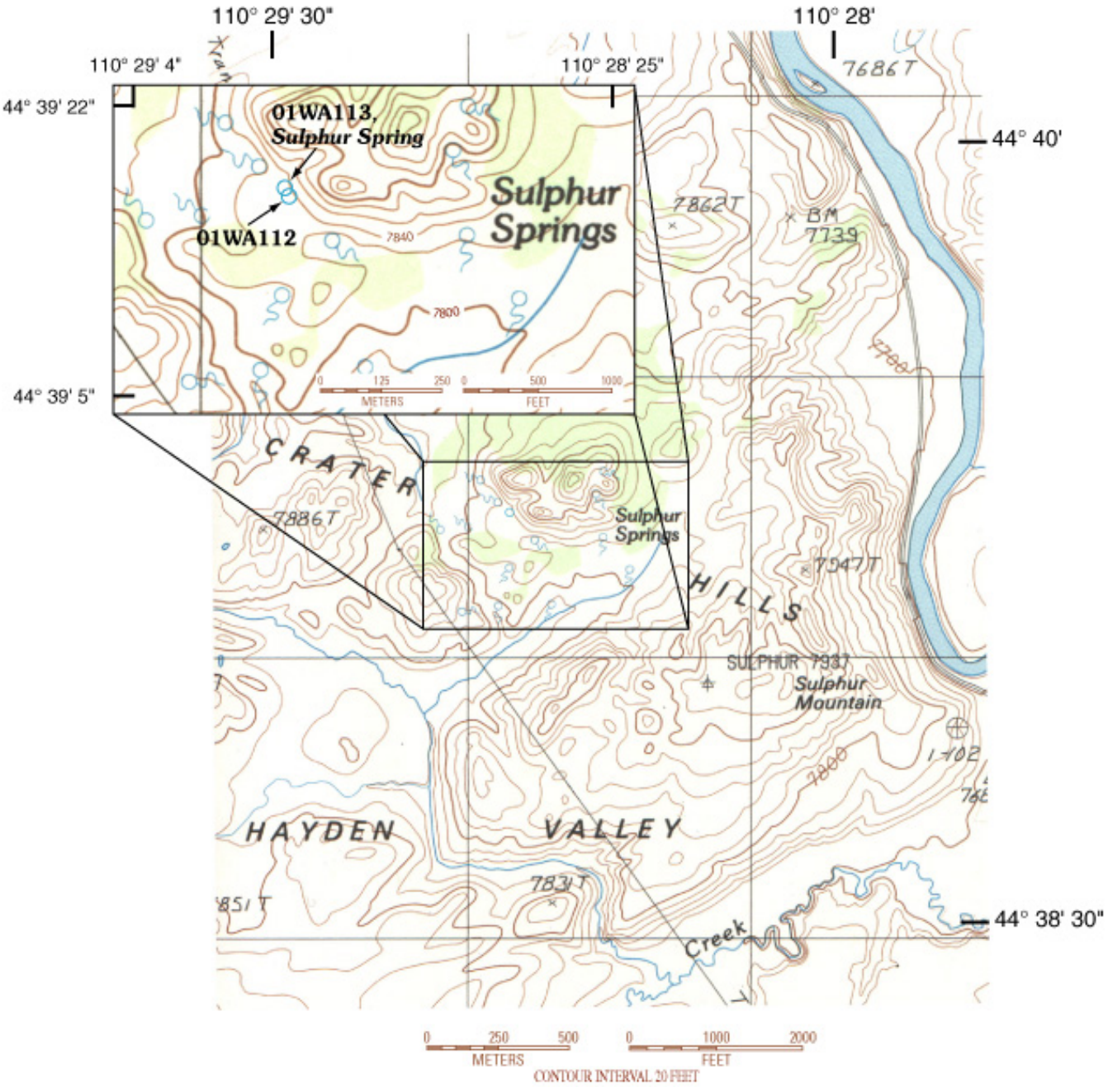
Base from U.S. Geological Survey Mammoth Quadrangle, 1:24,000 (1986)

Figure 12. Sampling locations with sample code numbers for Canary Spring and its overflow channel, Mammoth Hot Springs area, Yellowstone Park, Wyoming.



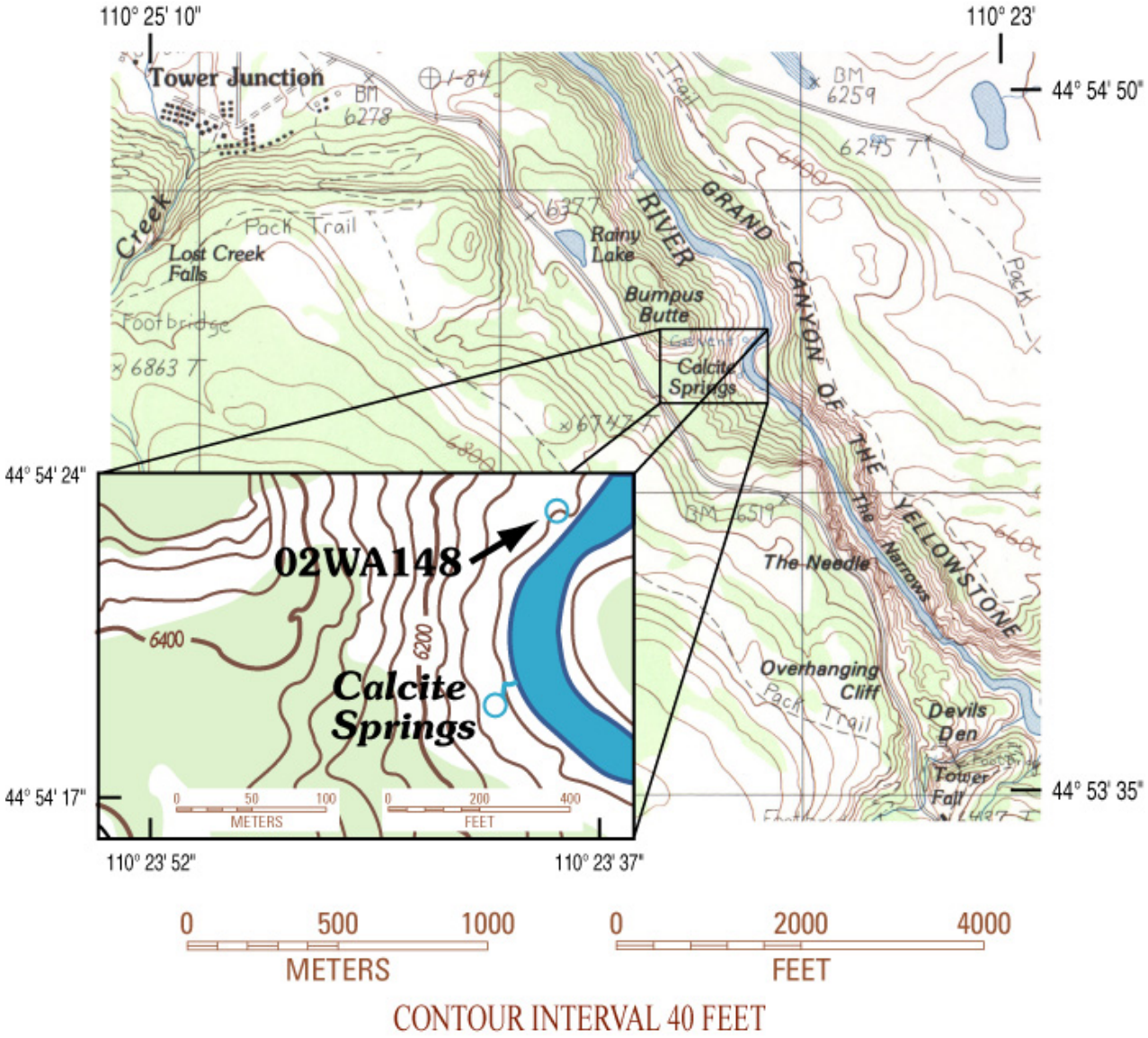
Base from U.S. Geological Survey West Thumb Quadrangle, 1:24,000 (1986)

Figure 13. Sampling locations with sample code numbers for thermal features at West Thumb Geyser Basin, Yellowstone Park, Wyoming.



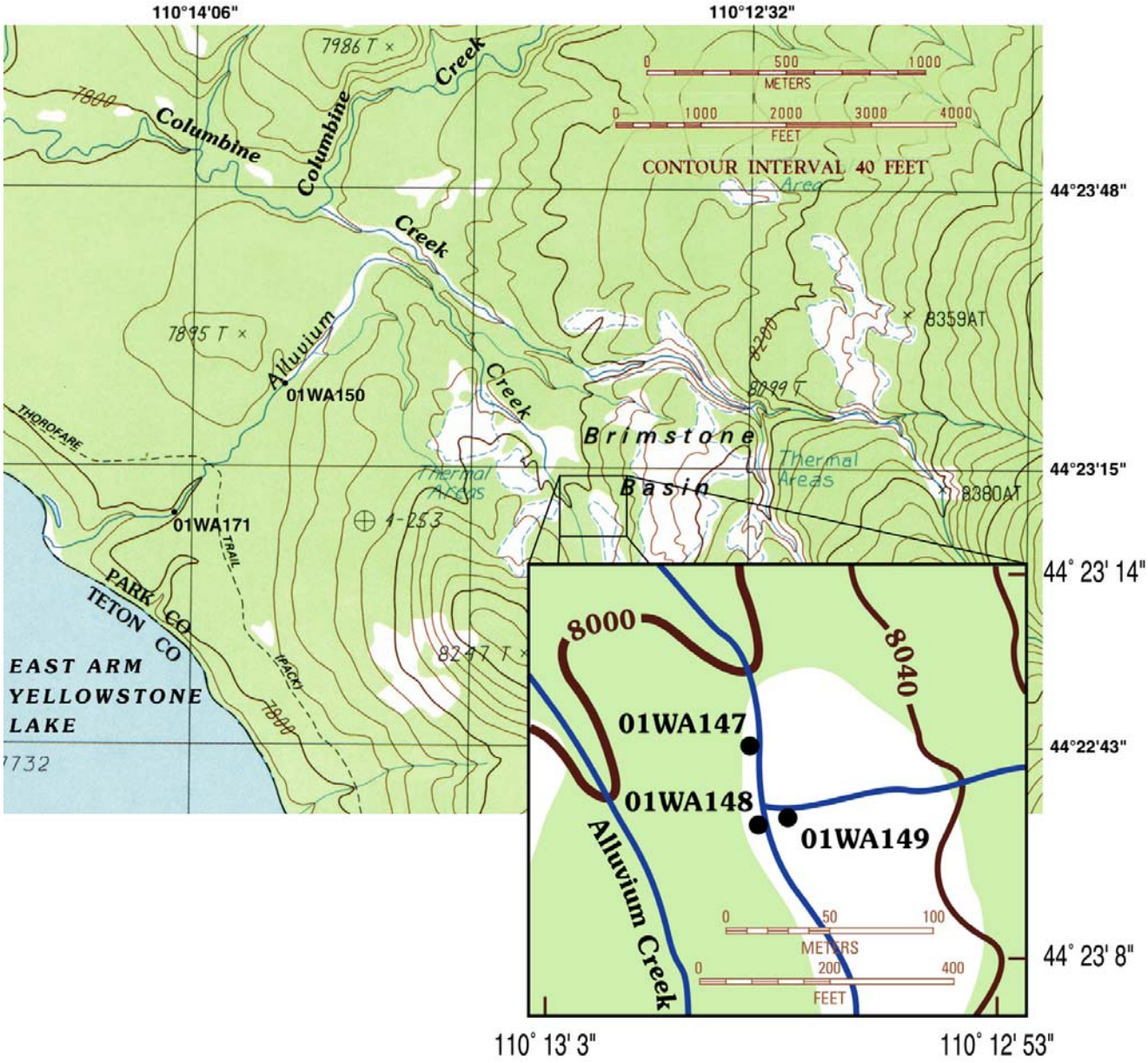
Base from U.S. Geological Survey Canyon Village Quadrangle, 1:24,000 (1986)

Figure 14. Sampling locations with sample code numbers for thermal features in the Sulphur Springs area at Crater Hills, Yellowstone Park, Wyoming.



Base from U.S. Geological Survey Tower Junction Quadrangle, 1:24,000 (1986)

Figure 15. Sampling location with sample code numbers for an unnamed spring downstream from Calcite Spring, Yellowstone Park, Wyoming.



Base from U.S. Geological Survey Sylvan Lake quadrangle, 1:24,000 (1989)

Figure 16. Sampling locations with sample code numbers for Alluvium Creek and one of its tributaries, Brimstone Basin, Yellowstone National Park, Wyoming.

WATER-CHEMISTRY DATA

Site data and water analyses for YNP springs sampled in 2001 and 2002 are presented in tables 5-10. For each sample, table 4 has a reference to the table containing the chemical data and detailed descriptions of where samples were collected and references to maps and photographs. Photographs of most of the sample sites are in appendix 2 and are ordered by increasing sample code number. Samples are sorted first by spring, then by date of sample collection, and then by sampling site along the downstream overflow channel (if present). Chemical profiles from the overflow channel transects are presented in figures 17-21.

Nymph Creek transects. Samples were collected along Nymph Creek on four occasions to investigate changes in the concentrations of As and Fe redox species. The chemical trends were similar in all four transect studies. For two of these transect sampling events (transects C and D), pH, Eh, temperature, and concentrations of H_2S, Fe(T), Fe(II), As(T), and As(III) are plotted as a function of distance from the discharge source for samples collected during the day and for samples collected from the same sample sites at night (fig. 17). There was little change in pH and As(T) and Fe(T) concentrations with distance. Specific conductance (not shown on fig. 17) and Eh increased with distance, whereas temperature and concentrations of H_2S, As(III), and Fe(II) decreased rapidly with distance. Complete oxidation of H_2S occurs within the first seven meters. Oxidation of As(III) and Fe(II) is rapid in the first seven meters and the rates are similar during the day and at night. However, the As(III) concentrations at downstream sites greater than five meters from the source were lower during the day than at night.

Washburn Springs transect. Figure 18 shows chemical profiles for the Inkpot #1 drainage at Washburn Springs (transect B). Sample pH, Eh, and NO_2 concentrations increased with distance, while temperature, alkalinity, and concentrations of H_2S decreased with distance. Concentrations of NH_4 change very little with distance.

Mushroom Spring and Octopus Springs transects. Sample pH, temperature, and concentrations of As(T), As(III), and NO_2 are plotted in relation to distance for samples collected along the Mushroom Spring drainage (transect F) and the Octopus Spring drainage (transect E) in figures 19 and 20, respectively. For both Octopus and Mushroom Springs, pH increased with distance, As(T) concentrations remained nearly constant with distance, and As(III) and NO_2 concentrations decreased with distance.

Ojo Caliente transects. Figure 21 depicts profiles of pH, temperature and concentrations of As(T), As(III), NH_4 and NO_2 along the two drainages at Ojo Caliente (transects H and I). Along both drainages, pH increased, As(T) concentrations remained fairly constant, and temperature and NH_4 concentrations decreased with distance. Arsenic remained in the reduced As(III) state along drainage A and oxidized along drainage B. Initially, NO_2 concentrations decreased along both drainages. In drainage A, NO_2 concentrations increased after about 12 meters from the source.

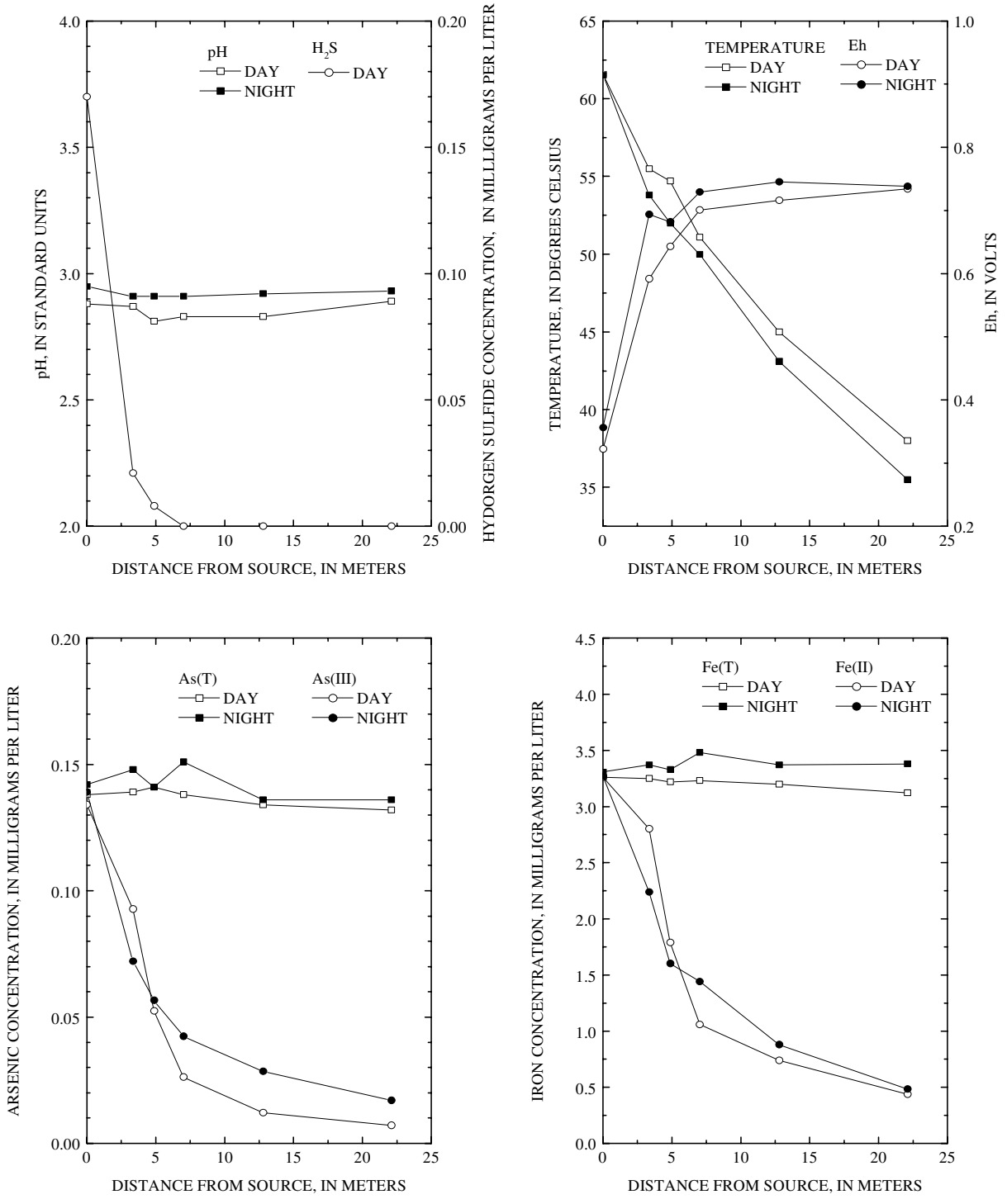


Figure 17. Sample pH, temperature, Eh, and concentrations of H_2S, As(T), As(III), Fe(T), and Fe(II) as a function of drainage distance for Nymph Creek.

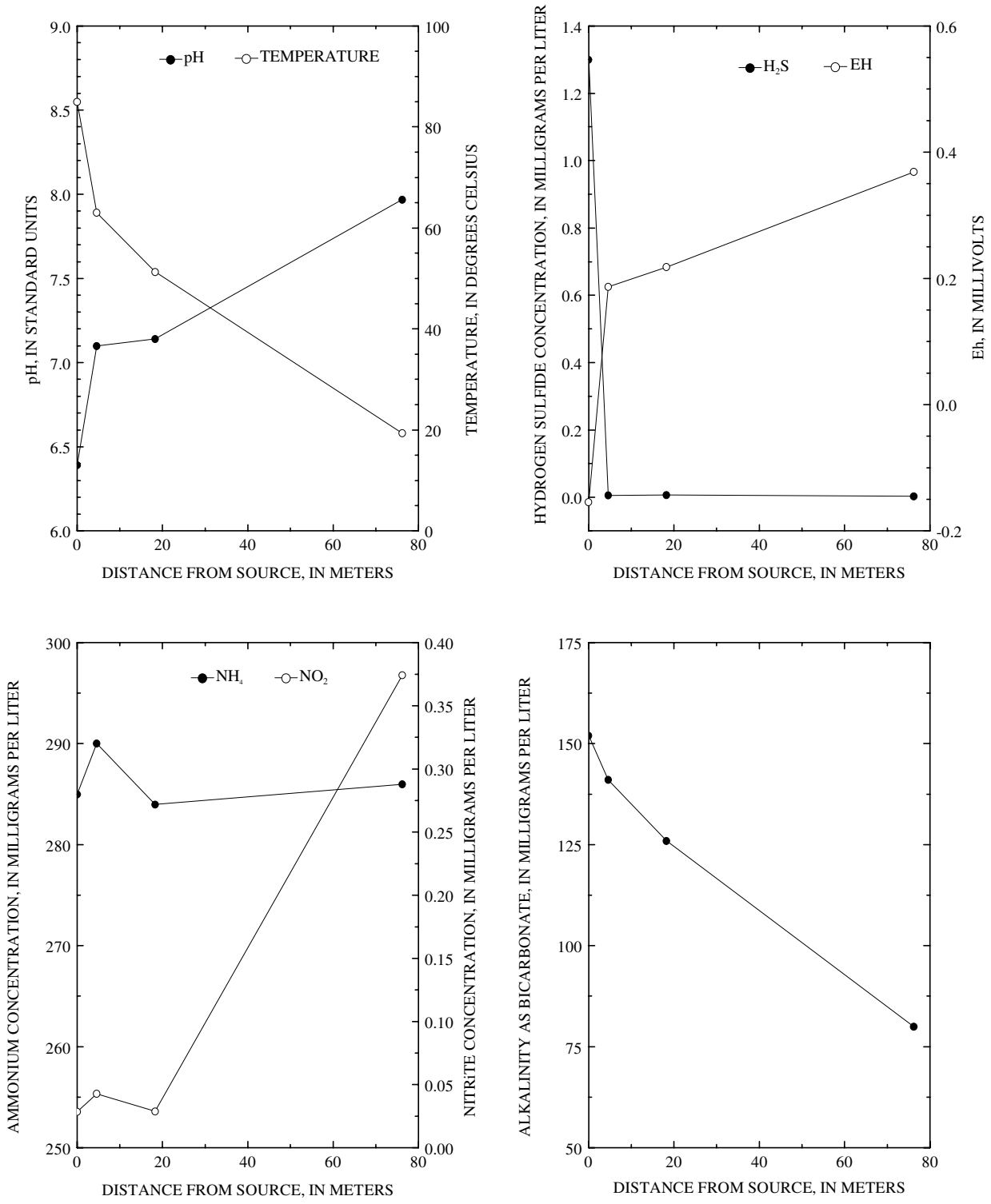


Figure 18. Sample pH, temperature, Eh, and concentrations of H_2S, NH_4, NO_2, and alkalinity as a function of drainage distance for Inkpot #1 in Washburn Springs.

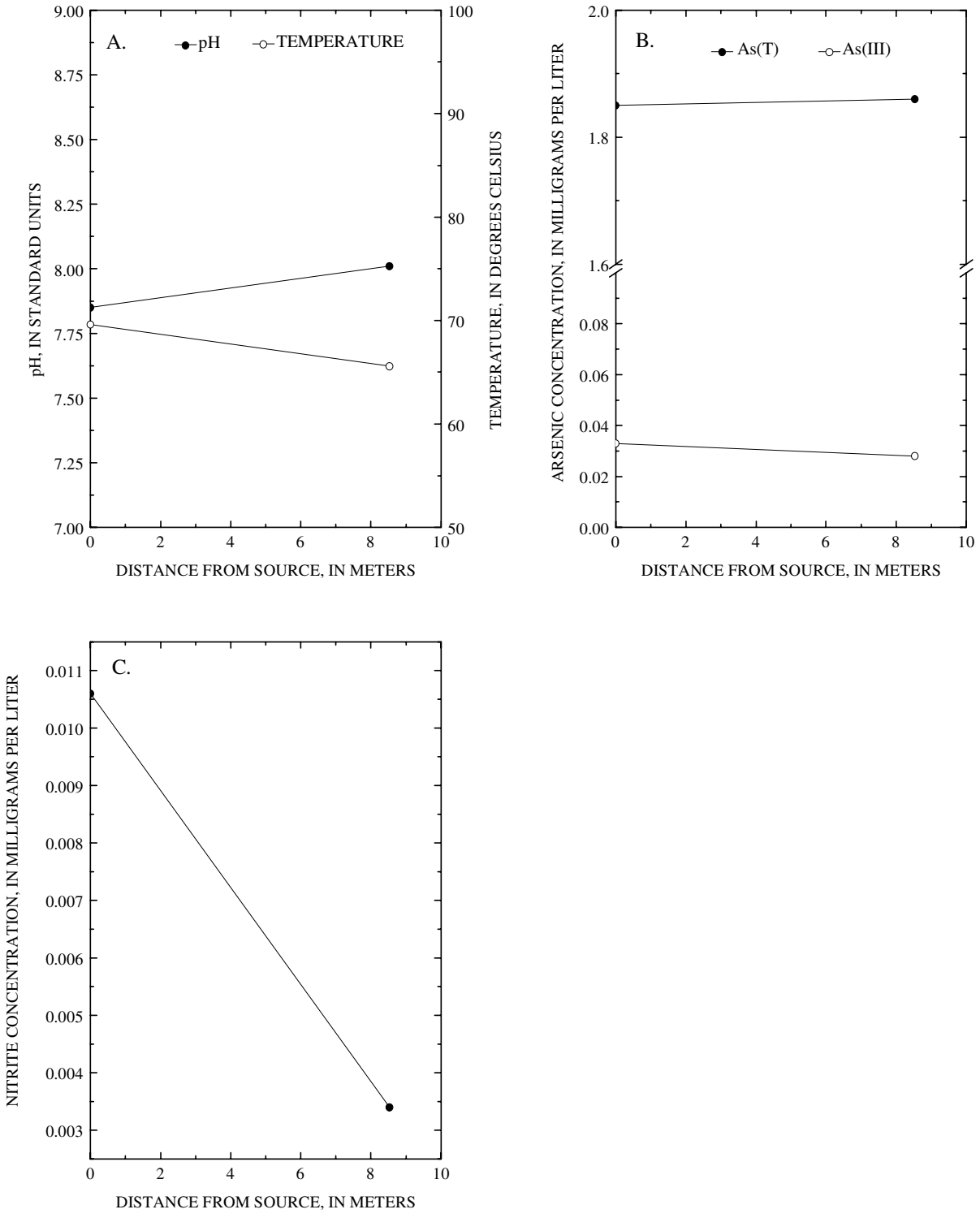


Figure 19. Sample pH, temperature, and concentrations of As(T), As(III), and NO_2 as a function of drainage distance for Mushroom Spring.

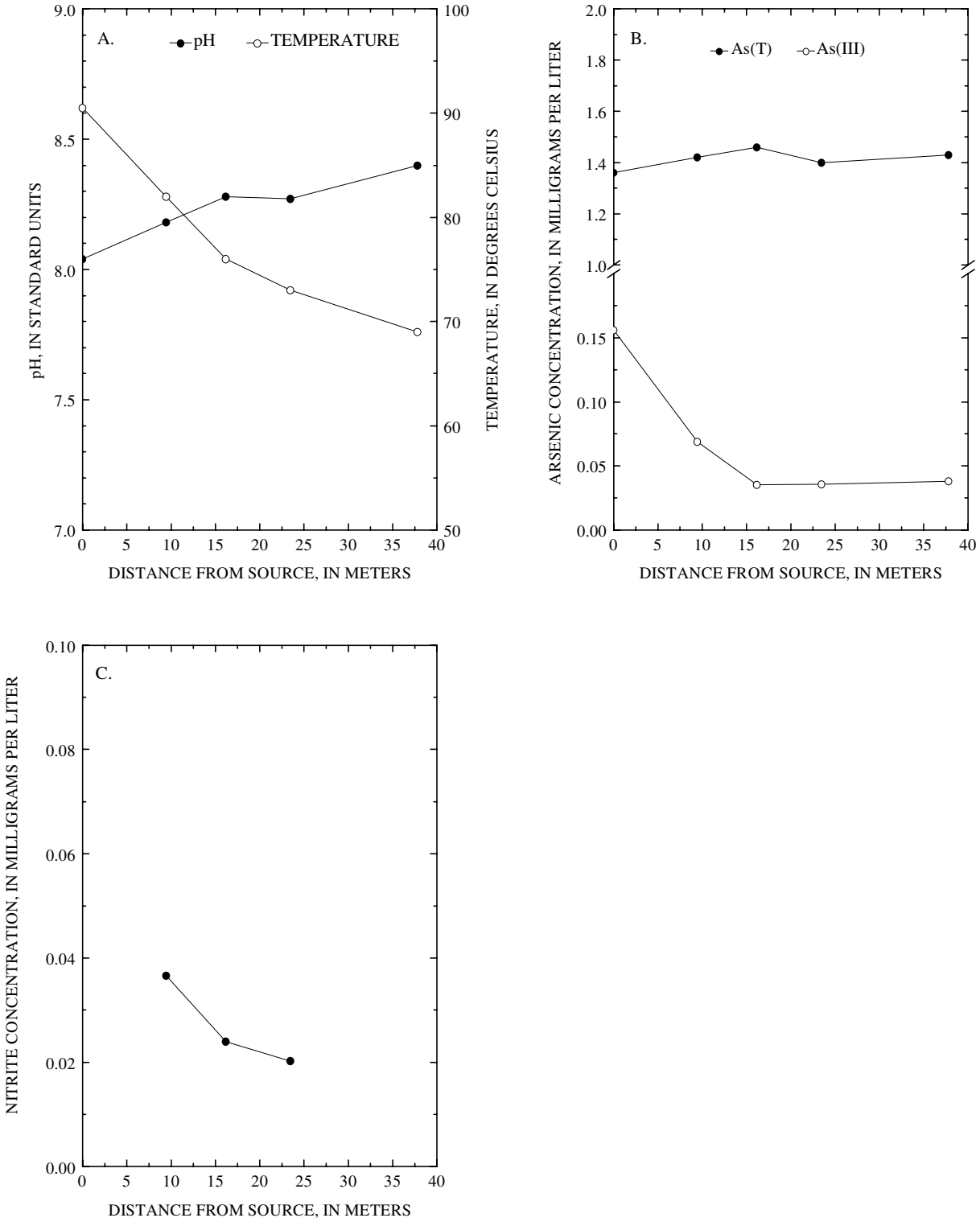


Figure 20. Sample pH, temperature, and concentrations of As(T), As(III), and NO_2 as a function of drainage distance for Octopus Spring.

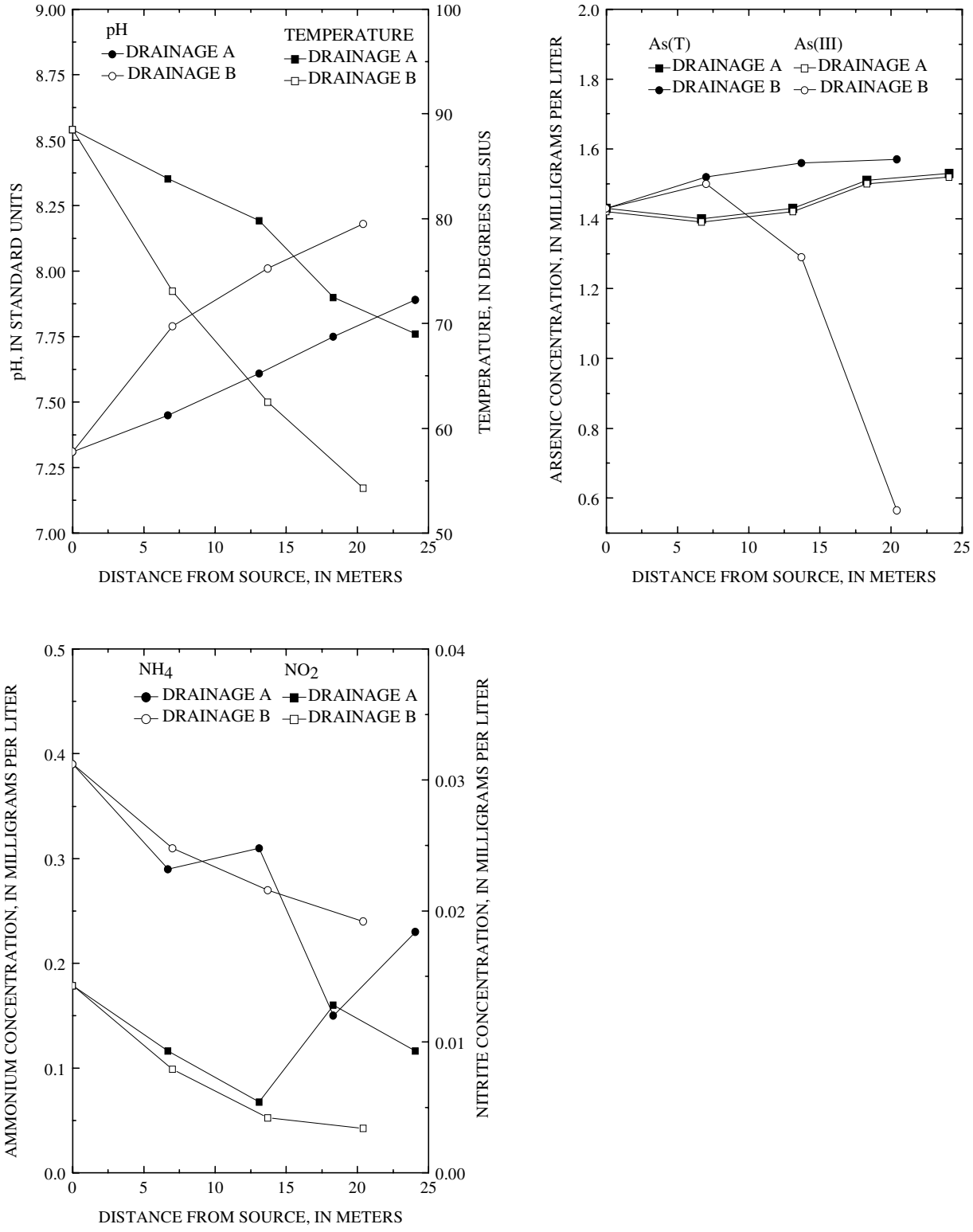


Figure 21. Sample pH, temperature, and concentrations of As(T), As(III), NH_4 and NO_2 as a function of drainage distance for Ojo Caliente Spring.

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	One Hundred Spring Plain Area				
Name and/or site description	**Cinder Pool**	**Cinder Pool (side of pool)**	**Cinder Pool**	**Cinder Pool**	**Cinder Pool (side of pool)**
Sample code number	01WA105	01WA105S	01WA126	02WA134	02WA134S
Date collected	5/22/2001	5/22/2001	9/12/2001	6/28/2002	6/28/2002
Time collected	10:30	11:00	12:00	11:30	11:30
Temperature, °C	91.2	---	88.0	91.5	---
pH (field / laboratory)	4.32 / 3.89	--- / ---	4.24 / 4.03	4.32 / 4.04	--- / ---
pH, selected	4.32	---	4.24	4.32	---
Specific conductance (field / laboratory), µS/cm	2090 / 2270	--- / ---	2140 / 2340	2050 / 2280	--- / ---
Eh, V	0.027	---	0.037	-0.020	---
Density, g/mL at 20°C	0.99936	---	0.99937	0.99941	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	5.23	5.30	5.19	5.09	---
Magnesium (Mg)	0.021	0.028	0.030	0.033	---
Strontium (Sr)	0.013	0.014	0.016	0.016	---
Barium (Ba)	0.019	0.023	0.018	0.021	---
Sodium (Na)	385	340	375	377	---
Potassium (K)	54.4	47.0	55.7	51.0	---
Lithium (Li)	4.10	4.80	4.45	4.51	---
Sulfate (SO_4)	67.0	---	61.8	66.1	---
Thiosulfate (S_2O_3)	11	---	14	14	14
Polythionate (S_nO_6), mM / n	<0.002	---	<0.002	<0.002	0.002 / 3
Hydrogen sulfide (H_2S)	0.29	---	0.30	0.41	---
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	0.221 / 0.895	--- / ---	--- / 0.487	0.163 / 0.957	--- / ---
Fluoride (F)	5.83	---	3.26	7.19	---
Chloride (Cl)	605	---	639	610	---
Bromide (Br)	0.7	---	1.9	2.0	---
Nitrate (NO_3)	<0.1	---	<0.1	<0.1	---
Nitrite (NO_2)	0.0151	---	<0.0003	<0.0003	---
Ammonium (NH_4)	5.54	---	3.65	7.58	---
Silica (SiO_2)	285	370	369	341	---
Boron (B)	9.83	9.90	10.1	9.78	---
Aluminum (Al)	1.38	1.20	1.17	1.05	---
Iron total (Fe(T))	0.038	0.039	0.018	0.021	0.018
Ferrous iron (Fe(II))	0.038	0.037	0.018	0.021	0.018
Manganese (Mn)	<0.001	0.004	0.004	<0.001	---
Copper (Cu)	<0.0005	---	<0.0005	<0.0005	---
Zinc (Zn)	0.004	0.010	0.009	<0.001	---
Cadmium (Cd)	0.0002	---	0.0001	0.0001	---
Chromium (Cr)	<0.0005	---	<0.0005	<0.0005	---
Cobalt (Co)	<0.0007	---	0.0008	<0.0007	---
Mercury (Hg), ng/L	---	---	---	161	---
Nickel (Ni)	<0.002	<0.002	0.003	<0.002	---
Lead (Pb)	0.0009	---	<0.0008	0.0009	---
Beryllium (Be)	<0.001	<0.001	<0.001	<0.001	---
Vanadium (V)	<0.002	<0.002	<0.002	<0.002	---
Molybdenum (Mo)	---	---	---	0.103	---
Antimony (Sb)	0.080	---	0.085	0.051	---
Selenium (Se)	<0.001	---	<0.001	<0.001	---
Arsenic total (As(T))	2.41	2.64	2.18	2.20	2.51
Arsenite (As(III))	2.23	2.64	2.17	2.20	2.51
Dissolved organic carbon (DOC)	---	---	0.9	1.4	1.0
δD, per mil	-127	---	-127	-126	---
$\delta^{18}O$, per mil	-10.5	---	-10.7	-10.9	---
sum cations, meq/L	19.3	---	18.9	19.1	---
sum anions, meq/L	18.6	---	19.4	18.8	---
Charge imbalance, percent	4.0	---	-2.3	1.5	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	One Hundred Spring Plain Area				
Name and/or site description	**Tantalus Creek at weir**	**Unnamed small sulfur pool**	**Unnamed mud pot**	**Unnamed mud pot**	**Unnamed large pond 220m west of 02WA125**
Sample code number	01WA130	01WA176	01WA169	02WA125	02WA126
Date collected	9/13/2001	10/23/2001	10/22/2001	6/26/2002	6/26/2002
Time collected	10:18	12:37	15:15	11:00	13:45
Temperature, °C	28.2	13.7	16.5	92.8	31.2
pH (field / laboratory)	3.00 / 2.99	2.15 / ---	2.59 / ---	4.76 / 3.34	3.32 / 3.29
pH, selected	2.97	---	---	3.34	3.32
Specific conductance (field / laboratory), µS/cm	2250 / 2300	3370 / ---	2100 / ---	420 / 788	984 / 1021
Eh, V	0.659	---	---	-0.047	0.146
Density, g/mL at 20°C	0.99933	---	---	0.99867	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	4.14	---	---	3.17	8.40
Magnesium (Mg)	0.258	---	---	0.796	1.51
Strontium (Sr)	0.015	---	---	0.046	0.073
Barium (Ba)	0.090	---	---	0.075	0.054
Sodium (Na)	303	---	---	4.96	121
Potassium (K)	58.9	---	---	17.2	29.5
Lithium (Li)	3.71	---	---	0.010	0.882
Sulfate (SO_4)	163	---	---	194	208
Thiosulfate (S_2O_3)	---	---	---	<0.1	<0.1
Polythionate (S_nO_6), mM / n	---	---	---	<0.002	<0.002
Hydrogen sulfide (H_2S)	---	---	---	0.17	<0.002
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	1.12 / 1.65	--- / ---	--- / ---	--- / ---	0.582 / 1.53
Fluoride (F)	2.72	---	---	0.10	2.29
Chloride (Cl)	510	---	---	19.6	109
Bromide (Br)	1.5	---	---	<0.03	0.6
Nitrate (NO_3)	<0.1	---	---	<0.1	<0.1
Nitrite (NO_2)	---	---	---	0.0016	0.0033
Ammonium (NH_4)	---	---	---	56.7	0.77
Silica (SiO_2)	352	---	---	106	144
Boron (B)	7.55	---	---	0.12	2.05
Aluminum (Al)	2.39	---	---	0.13	2.78
Iron total (Fe(T))	1.53	---	---	0.137	2.35
Ferrous iron (Fe(II))	0.564	---	---	0.133	1.92
Manganese (Mn)	0.080	---	---	0.062	0.128
Copper (Cu)	<0.0005	---	---	0.0107	<0.0005
Zinc (Zn)	0.017	---	---	0.661	0.025
Cadmium (Cd)	0.0001	---	---	0.0138	0.0001
Chromium (Cr)	0.0038	---	---	0.0118	0.0056
Cobalt (Co)	<0.0007	---	---	0.0007	0.0009
Mercury (Hg), ng/L	---	733	1520	520	61
Nickel (Ni)	0.003	---	---	0.003	<0.002
Lead (Pb)	0.0017	---	---	0.0095	0.0009
Beryllium (Be)	0.002	---	---	<0.001	0.001
Vanadium (V)	<0.002	---	---	<0.002	<0.002
Molybdenum (Mo)	---	---	---	<0.007	<0.007
Antimony (Sb)	0.089	---	---	0.007	0.006
Selenium (Se)	0.002	---	---	<0.001	<0.001
Arsenic total (As(T))	1.79	---	---	0.0527	0.182
Arsenite (As(III))	0.0626	---	---	0.0527	0.0422
Dissolved organic carbon (DOC)	---	---	---	---	2.3
δD, per mil	---		---	---	-125
$\delta^{18}O$, per mil	---	---	---	---	-14.1
sum cations, meq/L	16.8	---	---	4.44	7.40
sum anions, meq/L	17.6	---	---	4.16	7.18
Charge imbalance, percent	-5.0	---	---	6.7	3.0

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	One Hundred Spring Plain Area		----------Back Basin Area----------		
Name and/or site description	**Unnamed hot springs outflow along north bank of Gibbon River**	**Unnamed shallow hot springs 130m north-west of Cinder pool**	**Bathtub Spring**	**"Black Gassy Spring"**	**Black Pit**
Sample code number	01WA170	01WA109	01WA127	01WA138	02WA142
Date collected	10/22/2001	5/22/2001	9/12/2001	9/14/2001	6/30/2002
Time collected	16:10	17:00	13:30	12:15	11:30
Temperature, °C	69.8	73.0	92.5	90.9	76.5
pH (field / laboratory)	2.95 / ---	2.39 / 2.34	3.35 / 3.16	6.93 / 7.50	6.21 / 7.92
pH, selected	---	2.39	3.35	6.93	6.21
Specific conductance (field / laboratory), µS/cm	1420 / ---	1410 / 2280	2880 / 3660	2480 / 2740	538 / 557
Eh, V	---	0.589	0.236	0.000	-0.084
Density, g/mL at 20°C	---	0.99866	0.99982	0.99954	0.99882
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	---	0.448	13.4	10.8	2.58
Magnesium (Mg)	---	0.205	3.64	0.123	0.284
Strontium (Sr)	---	0.005	0.011	0.040	0.009
Barium (Ba)	---	0.087	0.022	0.023	0.022
Sodium (Na)	---	0.331	398	462	103
Potassium (K)	---	1.67	47.7	54.1	15.3
Lithium (Li)	---	<0.003	4.34	6.23	0.657
Sulfate (SO_4)	---	310	576	36.6	137
Thiosulfate (S_2O_3)	---	<0.1	<0.1	<0.1	10
Polythionate (S_nO_6), mM / n	---	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	---	<0.002	0.005	0.015	0.33
Alkalinity (HCO_3)	---	---	---	23.0	46.0
Acidity (free / total), mM	--- / ---	5.98 / 6.75	0.866 / 1.27	--- / ---	--- / ---
Fluoride (F)	---	0.11	2.16	5.17	2.20
Chloride (Cl)	---	1.7	602	781	34.9
Bromide (Br)	---	<0.1	1.8	2.4	<0.03
Nitrate (NO_3)	---	<0.1	<0.1	<0.1	<0.1
Nitrite (NO_2)	---	0.0138	<0.0003	0.0083	0.0137
Ammonium (NH_4)	---	<0.3	105	<0.04	0.54
Silica (SiO_2)	---	137	406	296	176
Boron (B)	---	<0.01	12.9	12.2	1.38
Aluminum (Al)	---	2.44	2.33	<0.07	0.10
Iron total (Fe(T))	---	0.658	7.27	0.008	0.006
Ferrous iron (Fe(II))	---	0.648	7.21	0.006	0.006
Manganese (Mn)	---	0.015	0.423	0.075	0.082
Copper (Cu)	---	<0.0005	0.0009	<0.0005	<0.0005
Zinc (Zn)	---	0.004	0.269	0.086	<0.001
Cadmium (Cd)	---	<0.0001	0.0002	<0.0001	<0.0001
Chromium (Cr)	---	0.0020	0.0140	<0.0005	0.0006
Cobalt (Co)	---	0.0037	<0.0007	<0.0007	0.0008
Mercury (Hg), ng/L	5.1	4.8	---	---	200
Nickel (Ni)	---	0.074	0.007	0.003	<0.002
Lead (Pb)	---	0.0042	0.0012	<0.0008	<0.0008
Beryllium (Be)	---	<0.001	0.004	0.001	0.001
Vanadium (V)	---	0.002	0.004	<0.002	<0.002
Molybdenum (Mo)	---	---	---	---	0.015
Antimony (Sb)	---	0.002	0.005	0.165	<0.001
Selenium (Se)	---	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	---	0.646	1.76	2.53	0.0111
Arsenite (As(III))	---	0.491	1.75	2.23	0.0110
Dissolved organic carbon (DOC)	---	---	17	0.5	1.6
δD, per mil	---	-116	-122	---	-122
$\delta^{18}O$, per mil	---	-5.4	-12.8	---	-11.0
sum cations, meq/L	---	4.72	26.1	22.9	5.10
sum anions, meq/L	---	4.81	27.5	23.5	4.64
Charge imbalance, percent	---	-2.0	-5.3	-2.3	9.4

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Back Basin Area				
Name and/or site description	**Cistern Spring**	**Cistern Spring**	**Cistern Spring**	**Hydrophane Spring**	**Orpiment Spring**
Sample code number	01WA119	01WA128	02WA141	01WA141	01WA139
Date collected	5/26/2001	9/12/2001	6/30/2002	9/14/2001	9/14/2001
Time collected	9:00	15:00	10:30	16:35	13:40
Temperature, °C	86.0	85.0	82.0	90.5	87.1
pH (field / laboratory)	5.23 / 4.28	5.10 / 5.47	5.30 / 7.06	4.36 / 4.15	4.89 / 5.34
pH, selected	5.23	5.10	5.30	4.36	4.89
Specific conductance (field / laboratory), µS/cm	1821 / 1929	1800 / 1957	1820 / 1941	2030 / 2220	2130 / 2320
Eh, V	-0.026	0.001	-0.099	0.044	0.026
Density, g/mL at 20°C	0.99938	0.99931	0.99930	0.99922	0.99934
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	2.04	2.29	2.55	2.95	7.67
Magnesium (Mg)	0.074	0.108	0.118	0.038	0.030
Strontium (Sr)	0.008	0.008	0.009	0.010	0.018
Barium (Ba)	0.018	0.019	0.020	0.019	0.004
Sodium (Na)	301	333	315	353	394
Potassium (K)	54.3	54.7	54.1	66.4	37.7
Lithium (Li)	4.06	4.05	4.16	5.08	5.78
Sulfate (SO_4)	76.0	95.9	74.2	86.5	44.1
Thiosulfate (S_2O_3)	20	11	11	6.6	4.0
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	0.27	0.29	0.16	0.11	0.058
Alkalinity (HCO_3)	<1	---	7.20	---	3.75
Acidity (free / total), mM	--- / ---	--- / 0.085	--- / ---	--- / 0.145	--- / 0.149
Fluoride (F)	4.65	4.39	5.68	4.54	4.37
Chloride (Cl)	522	518	496	601	670
Bromide (Br)	1.6	1.5	1.8	1.8	2.0
Nitrate (NO_3)	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite (NO_2)	<0.01	<0.0003	0.0092	<0.0003	0.0013
Ammonium (NH_4)	1.06	3.13	2.30	8.38	0.92
Silica (SiO_2)	494	499	490	412	358
Boron (B)	8.16	8.57	8.15	9.61	10.5
Aluminum (Al)	0.09	0.09	<0.07	0.83	0.59
Iron total (Fe(T))	0.008	0.014	<0.002	0.340	0.037
Ferrous iron (Fe(II))	0.006	0.013	<0.002	0.340	0.037
Manganese (Mn)	0.037	0.051	0.041	0.030	0.026
Copper (Cu)	<0.0005	0.0033	<0.0005	<0.0005	<0.0005
Zinc (Zn)	<0.001	0.002	<0.001	0.015	0.003
Cadmium (Cd)	0.0001	0.0002	0.0001	0.0005	0.0002
Chromium (Cr)	<0.0005	<0.0005	<0.0005	0.0008	<0.0005
Cobalt (Co)	<0.0007	<0.0007	0.0021	<0.0007	<0.0007
Mercury (Hg), ng/L	---	---	170	---	---
Nickel (Ni)	0.004	0.004	<0.002	0.003	0.003
Lead (Pb)	<0.0008	0.0016	0.0011	0.0015	0.0011
Beryllium (Be)	<0.001	0.002	<0.001	<0.001	<0.001
Vanadium (V)	<0.002	<0.002	<0.002	<0.002	<0.002
Molybdenum (Mo)	---	---	0.106	---	---
Antimony (Sb)	0.099	0.087	0.048	0.173	0.168
Selenium (Se)	0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.63	1.36	1.63	2.09	2.08
Arsenite (As(III))	1.56	1.36	1.63	2.09	2.04
Dissolved organic carbon (DOC)	1.1	1.0	1.5	---	0.8
δD, per mil	-128	-122	-127	-125	---
$\delta^{18}O$, per mil	-11.3	-10.5	-12.1	-10.9	---
sum cations, meq/L	15.2	16.7	15.9	18.4	19.4
sum anions, meq/L	16.5	16.8	15.9	18.9	20.1
Charge imbalance, percent	-8.4	-0.5	-0.1	-2.2	-3.4

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Back Basin Area				
Name and/or site description	**Perpetual Spouter**	**Pork Chop Geyser**	**Pork Chop Geyser**	**Recess Spring**	**Rediscovered Geyser**
Sample code number	01WA135	01WA137	02WA136	01WA140	02WA144
Date collected	9/13/2001	9/13/2001	6/28/2002	9/14/2001	6/30/2002
Time collected	15:45	17:45	15:15	15:07	12:30
Temperature, °C	89.8	85.2	65.0	91.0	90.2
pH (field / laboratory)	6.75 / 6.76	5.91 / 7.59	6.96 / 7.57	3.67 / 3.60	4.90 / 4.61
pH, selected	6.75	5.91	6.96	3.67	4.90
Specific conductance (field / laboratory), µS/cm	2500 / 2760	2060 / 2240	2370 / 2490	2040 / 2300	1785 / 1935
Eh, V	0.011	-0.014	0.127	0.056	0.015
Density, g/mL at 20°C	0.99948	0.99938	0.99947	0.99916	0.99936
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	10.2	4.14	4.82	6.20	2.23
Magnesium (Mg)	0.087	0.027	0.009	0.082	0.004
Strontium (Sr)	0.036	0.013	0.014	0.016	0.006
Barium (Ba)	0.020	0.012	0.010	0.025	0.002
Sodium (Na)	466	365	401	375	339
Potassium (K)	55.2	63.8	76.6	40.8	22.7
Lithium (Li)	6.20	5.43	6.49	4.80	3.67
Sulfate (SO_4)	42.4	25.1	45.9	98.8	46.2
Thiosulfate (S_2O_3)	<0.1	11	1.5	5.2	1.8
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	0.006	0.25	0.011	0.24	0.030
Alkalinity (HCO_3)	10.5	32.7	29.7	---	1.62
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / 0.602	--- / ---
Fluoride (F)	4.95	5.46	6.43	4.11	6.65
Chloride (Cl)	803	645	699	599	524
Bromide (Br)	2.5	1.9	2.3	1.8	1.8
Nitrate (NO_3)	<0.1	0.3	<0.1	<0.1	<0.1
Nitrite (NO_2)	0.0124	<0.0003	0.0251	<0.0003	0.0128
Ammonium (NH_4)	<0.04	0.54	1.20	6.04	2.08
Silica (SiO_2)	300	496	443	434	391
Boron (B)	12.3	10.2	10.8	9.96	8.77
Aluminum (Al)	0.14	<0.07	<0.07	1.13	0.15
Iron total (Fe(T))	0.134	0.012	0.002	0.138	0.009
Ferrous iron (Fe(II))	0.029	0.012	<0.002	0.138	0.009
Manganese (Mn)	0.046	0.055	0.022	0.024	0.010
Copper (Cu)	<0.0005	<0.0005	0.0020	0.0009	<0.0005
Zinc (Zn)	0.001	0.002	<0.001	0.111	<0.001
Cadmium (Cd)	0.0001	0.0001	0.0002	0.0002	0.0001
Chromium (Cr)	0.0008	<0.0005	<0.0005	0.0007	<0.0005
Cobalt (Co)	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Mercury (Hg), ng/L	---	---	8.9	---	17
Nickel (Ni)	<0.002	0.003	<0.002	0.004	<0.002
Lead (Pb)	<0.0008	<0.0008	0.0012	0.0008	<0.0008
Beryllium (Be)	0.002	<0.001	<0.001	<0.001	<0.001
Vanadium (V)	<0.002	<0.002	<0.002	<0.002	<0.002
Molybdenum (Mo)	---	---	0.239	---	0.130
Antimony (Sb)	0.179	0.175	0.164	0.073	0.067
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	2.80	1.79	2.57	1.60	2.03
Arsenite (As(III))	1.06	1.78	0.802	1.60	2.03
Dissolved organic carbon (DOC)	0.5	0.6	1.3	---	1.1
δD, per mil	-141	-131	-136	-126	-131
$\delta^{18}O$, per mil	-15.0	-11.9	-12.4	-11.0	-12.8
sum cations, meq/L	23.1	18.5	20.6	18.9	16.1
sum anions, meq/L	24.0	19.6	21.6	18.9	16.1
Charge imbalance, percent	-4.0	-5.5	-4.4	0.1	-0.1

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	----------Back Basin Area----------			----Ragged Hills Area----	
Name and/or site description	**Steamboat Geyser**	**Vixen Geyser**	**Unnamed acid spring next to Perpetual Spouter**	**Crystal Spring**	**"Lifeboat Spring"**
Sample code number	01WA142	01WA129	01WA136	02WA135	01WA108
Date collected	9/14/2001	9/12/2001	9/13/2001	6/28/2002	5/22/2001
Time collected	18:01	17:00	16:40	13:20	15:00
Temperature, °C	77.0	87.0	92.5	83.7	78.4
pH (field / laboratory)	6.55 / 7.52	3.30 / 3.14	2.81 / 2.74	6.00 / 7.13	2.76 / 2.69
pH, selected	6.55	3.14	2.81	6.00	2.76
Specific conductance (field / laboratory), µS/cm	1825 / 1799	1750 / 2035	1385 / 1953	2230 / 2400	2180 / 2640
Eh, V	0.405	0.181	0.495	-0.035	0.681
Density, g/mL at 20°C	0.99909	0.99920	0.99908	0.99949	0.99931
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	2.41	3.35	2.49	6.22	4.17
Magnesium (Mg)	0.151	0.183	0.275	0.009	0.317
Strontium (Sr)	0.009	0.013	0.013	0.013	0.012
Barium (Ba)	0.023	0.107	0.111	0.007	0.093
Sodium (Na)	301	276	168	426	269
Potassium (K)	57.7	56.1	58.2	33.9	45.9
Lithium (Li)	3.39	3.52	1.28	5.56	3.84
Sulfate (SO_4)	97.7	109	236	35.8	200
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	3.0	<0.1
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	0.052	0.11	---	0.10	<0.002
Alkalinity (HCO_3)	32.1	---	---	14.4	---
Acidity (free / total), mM	--- / ---	0.761 / 1.28	2.11 / 2.51	--- / ---	2.52 / 3.05
Fluoride (F)	4.30	2.84	0.70	5.83	0.63
Chloride (Cl)	463	492	253	690	440
Bromide (Br)	1.4	1.4	0.8	2.3	0.5
Nitrate (NO_3)	0.6	<0.1	<0.1	<0.1	<0.1
Nitrite (NO_2)	0.0015	<0.0003	<0.0003	0.0092	<0.01
Ammonium (NH_4)	0.42	1.72	1.68	1.35	0.73
Silica (SiO_2)	486	350	421	430	386
Boron (B)	7.61	7.10	3.99	10.9	7.57
Aluminum (Al)	0.12	2.11	0.73	0.20	2.31
Iron total (Fe(T))	0.007	1.74	4.05	0.035	0.727
Ferrous iron (Fe(II))	0.006	1.70	3.76	0.033	0.727
Manganese (Mn)	0.046	0.066	0.076	0.002	0.060
Copper (Cu)	<0.0005	<0.0005	<0.0005	<0.0005	0.0008
Zinc (Zn)	0.003	0.020	0.047	<0.001	0.021
Cadmium (Cd)	0.0002	0.0001	0.0002	<0.0001	0.0002
Chromium (Cr)	0.0014	0.0036	0.0098	<0.0005	0.0058
Cobalt (Co)	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Mercury (Hg), ng/L	---	---	---	52	---
Nickel (Ni)	0.006	0.004	0.003	<0.002	0.004
Lead (Pb)	0.0008	<0.0008	0.0011	0.0009	0.0012
Beryllium (Be)	0.001	0.002	0.003	<0.001	0.002
Vanadium (V)	<0.002	<0.002	<0.002	<0.002	<0.002
Molybdenum (Mo)	---	---	---	0.219	---
Antimony (Sb)	0.059	0.057	0.031	0.149	0.100
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.17	1.69	0.855	2.90	0.902
Arsenite (As(III))	1.17	1.42	0.444	2.88	0.0446
Dissolved organic carbon (DOC)	---	0.8	0.6	---	0.8
δD, per mil	-126	-139	-138	-139	-137
$\delta^{18}O$, per mil	-13.5	-15.0	-15.9	-14.1	-12.6
sum cations, meq/L	15.2	15.2	11.0	20.6	15.8
sum anions, meq/L	15.8	15.9	11.1	20.8	15.9
Charge imbalance, percent	-4.2	-5.0	-0.1	-0.9	-0.5

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Ragged Hills Area				
Name and/or site description	**"Lifeboat Spring"**	**"Persnickety Geyser"**	**Mixing area between "Persnickety Geyser" and "Titanic Spring"**	**"Persnickety Geyser"**	**"Persnickety Geyser"**
Sample code number	02WA129	01WA106	01WA106/107	01WA132	02WA128
Date collected	6/27/2002	5/22/2001	5/22/2001	9/13/2001	6/26/2002
Time collected	12:55	13:10	14:15	12:30	18:30
Temperature, °C	73.0	92.0	---	88.2	91.1
pH (field / laboratory)	3.05 / 2.96	3.73 / 3.54	--- / ---	3.13 / 2.98	3.83 / 3.63
pH, selected	3.05	3.73	---	2.98	3.83
Specific conductance (field / laboratory), µS/cm	2220 / 2510	1970 / 2160	--- / ---	1930 / 2340	1960 / 2210
Eh, V	0.539	0.266	---	0.250	0.073
Density, g/mL at 20°C	0.99946	0.99943	---	0.99926	0.99940
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	4.86	4.70	4.90	5.18	4.89
Magnesium (Mg)	0.141	0.125	0.150	0.231	0.093
Strontium (Sr)	0.011	0.015	0.015	0.017	0.014
Barium (Ba)	0.068	0.061	0.063	0.105	0.062
Sodium (Na)	343	328	300	303	352
Potassium (K)	52.4	63.8	52.0	51.3	55.5
Lithium (Li)	5.31	4.00	5.60	4.09	5.41
Sulfate (SO_4)	128	85.0	---	164	80.4
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	<0.002	0.003	---	0.035	0.009
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	1.20 / 1.85	0.368 / 0.697	--- / ---	1.19 / 1.98	0.255 / 0.539
Fluoride (F)	4.87	3.70	---	3.42	5.34
Chloride (Cl)	535	524	---	521	528
Bromide (Br)	1.9	0.9	---	1.5	1.9
Nitrate (NO_3)	<0.1	<0.1	---	<0.1	<0.1
Nitrite (NO_2)	0.0022	0.0247	---	<0.0003	0.0028
Ammonium (NH_4)	0.99	0.36	---	1.65	1.14
Silica (SiO_2)	429	411	520	402	482
Boron (B)	8.73	8.74	9.40	7.94	8.74
Aluminum (Al)	1.84	0.95	0.98	1.97	1.17
Iron total (Fe(T))	1.59	1.17	1.46	7.34	1.10
Ferrous iron (Fe(II))	0.983	1.10	1.26	7.33	1.04
Manganese (Mn)	0.030	0.030	0.028	0.056	0.022
Copper (Cu)	0.0022	<0.0005	---	0.0044	0.0049
Zinc (Zn)	0.012	0.011	0.018	0.042	0.007
Cadmium (Cd)	0.0002	0.0002	---	0.0004	0.0003
Chromium (Cr)	0.0037	0.0023	---	0.0135	0.0025
Cobalt (Co)	0.0021	<0.0007	---	<0.0007	<0.0007
Mercury (Hg), ng/L	95	---	---	---	51
Nickel (Ni)	<0.002	0.004	<0.002	0.003	<0.002
Lead (Pb)	0.0017	0.0018	---	0.0012	0.0012
Beryllium (Be)	0.001	0.002	0.002	0.003	0.001
Vanadium (V)	<0.002	<0.002	<0.002	<0.002	<0.002
Molybdenum (Mo)	0.228	---	---	---	0.180
Antimony (Sb)	0.148	0.199	---	0.145	0.126
Selenium (Se)	<0.001	0.001	---	0.001	<0.001
Arsenic total (As(T))	1.26	2.14	1.92	5.82	2.37
Arsenite (As(III))	0.0740	0.982	0.387	5.57	1.69
Dissolved organic carbon (DOC)	1.3	0.8	---	0.9	1.5
δD, per mil	-135	-141	---	-134	-138
$\delta^{18}O$, per mil	-13.1	-14.4	---	-13.2	-14.3
sum cations, meq/L	18.4	17.0	---	16.9	18.0
sum anions, meq/L	17.6	16.5	---	17.6	16.6
Charge imbalance, percent	4.6	2.4	---	-4.2	8.0

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Ragged Hills Area				
Name and/or site description	**"Titanic Spring"**	**"Titanic Spring"**	**"Titanic Spring"**	**"Verde Crater"**	**Unnamed small spouter in The Gap**
Sample code number	01WA107	01WA131	02WA130	02WA127	02WA132
Date collected	5/22/2001	9/13/2001	6/27/2002	6/26/2002	6/27/2002
Time collected	14:15	11:30	14:00	17:40	16:00
Temperature, °C	67.0	84.0	76.5	51.5	94.6
pH (field / laboratory)	3.46 / 3.37	2.87 / 2.81	3.61 / 3.47	2.36 / 2.32	3.24 / 3.13
pH, selected	3.46	2.87	3.61	2.36	3.24
Specific conductance (field / laboratory), µS/cm	2110 / 2200	1980 / 2510	2040 / 2250	2630 / 3090	1905 / 2260
Eh, V	0.542	0.350	0.175	0.728	0.173
Density, g/mL at 20°C	0.99904	0.99941	0.99943	0.99926	0.99935
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	4.86	4.60	4.97	3.56	4.44
Magnesium (Mg)	0.155	0.296	0.107	0.553	0.128
Strontium (Sr)	0.016	0.014	0.015	0.015	0.013
Barium (Ba)	0.068	0.133	0.068	0.074	0.147
Sodium (Na)	321	292	342	143	332
Potassium (K)	58.6	47.8	55.5	32.9	37.2
Lithium (Li)	4.97	3.58	5.34	1.50	4.47
Sulfate (SO_4)	110	155	94.8	543	90.1
Thiosulfate (S_2O_3)	---	3.9	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mM / n	<0.002	0.030 / 8	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	---	0.015	<0.002	<0.002	0.024
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	0.526 / 0.887	1.71 / 2.99	0.406 / 0.678	6.16 / 8.58	0.804 / 1.20
Fluoride (F)	2.38	2.62	5.21	3.00	4.95
Chloride (Cl)	543	507	557	168	547
Bromide (Br)	0.8	1.5	1.9	0.8	1.9
Nitrate (NO_3)	<0.1	<0.1	0.1	<0.1	<0.1
Nitrite (NO_2)	0.0136	<0.0003	0.0029	0.0021	<0.0003
Ammonium (NH_4)	0.77	1.47	0.96	2.29	1.30
Silica (SiO_2)	412	370	476	321	351
Boron (B)	8.87	7.72	8.71	3.09	8.42
Aluminum (Al)	1.15	3.97	1.23	13.9	2.14
Iron total (Fe(T))	1.47	9.91	1.85	9.08	1.91
Ferrous iron (Fe(II))	1.26	9.76	1.85	1.11	1.85
Manganese (Mn)	0.036	0.064	0.028	0.068	0.022
Copper (Cu)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	0.014	0.027	0.011	0.026	0.005
Cadmium (Cd)	0.0003	0.0003	0.0001	0.0002	0.0002
Chromium (Cr)	0.0027	0.0159	0.0044	0.0155	0.0039
Cobalt (Co)	0.0012	<0.0007	<0.0007	0.0030	<0.0007
Mercury (Hg), ng/L	---	---	66	82	84
Nickel (Ni)	0.004	0.003	<0.002	0.003	<0.002
Lead (Pb)	0.0019	0.0048	0.0024	0.0026	0.0026
Beryllium (Be)	0.002	0.003	0.001	0.002	<0.001
Vanadium (V)	<0.002	<0.002	<0.002	0.003	<0.002
Molybdenum (Mo)	---	---	0.221	<0.007	0.092
Antimony (Sb)	0.186	0.206	0.136	0.029	0.165
Selenium (Se)	<0.001	0.002	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.99	3.40	2.75	1.76	2.26
Arsenite (As(III))	0.200	3.37	1.38	0.128	2.00
Dissolved organic carbon (DOC)	0.9	1.0	1.3	1.5	1.5
δD, per mil	-138	-133	-137	-120	-140
$\delta^{18}O$, per mil	-13.9	-12.4	-13.8	-9.4	-14.8
sum cations, meq/L	16.9	16.8	17.7	13.6	17.1
sum anions, meq/L	17.5	17.0	17.7	13.5	17.2
Charge imbalance, percent	-3.8	-0.8	-0.2	0.6	-0.3

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Ragged Hills Area			
Name and/or site description	**Unnamed spring in The Gap downslope of explosive red crater in hillside white clay**	**Unnamed spring in The Gap downslope of explosive red crater in hillside white clay**	**Unnamed spring in The Gap, most active with fumaroles all around**	**Unnamed 15cm diameter pool with bright yellow precipitate, ~6 m west of creek, Ragged Hills**
Sample code number	01WA134	02WA131	01WA133	02WA133
Date collected	9/13/2001	6/27/2002	9/13/2001	6/27/2002
Time collected	14:26	15:00	13:40	17:15
Temperature, °C	78.8	62.4	92.5	52.9
pH (field / laboratory)	2.66 / 2.61	2.54 / 2.50	3.15 / 3.07	3.28 / 3.28
pH, selected	2.66	2.54	3.07	3.28
Specific conductance (field / laboratory), µS/cm	2490 / 3170	2030 / 2560	1945 / 2310	1295 / 1370
Eh, V	0.482	0.670	0.094	0.093
Density, g/mL at 20°C	0.99940	0.99915	0.99927	0.99885
Dissolved oxygen (DO), mg/L	---	---	---	---
Constituent, mg/L[1]				
Calcium (Ca)	4.85	3.69	4.42	1.99
Magnesium (Mg)	0.244	0.601	0.174	0.052
Strontium (Sr)	0.020	0.010	0.014	0.009
Barium (Ba)	0.189	0.077	0.158	0.155
Sodium (Na)	356	188	323	193
Potassium (K)	45.5	33.0	38.8	24.8
Lithium (Li)	4.01	2.07	4.01	2.35
Sulfate (SO_4)	226	309	110	59.8
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	0.009	<0.002	0.19	3.8
Alkalinity (HCO_3)	---	---	---	---
Acidity (free / total), mM	2.80 / 3.93	3.87 / 4.90	0.898 / 1.50	0.533 / 1.35
Fluoride (F)	2.37	1.74	3.31	2.70
Chloride (Cl)	606	271	563	303
Bromide (Br)	1.8	1.1	1.7	1.1
Nitrate (NO_3)	<0.1	<0.1	<0.1	<0.1
Nitrite (NO_2)	<0.0003	0.0024	<0.0003	0.0016
Ammonium (NH_4)	1.01	2.07	1.77	0.66
Silica (SiO_2)	350	320	351	167
Boron (B)	9.13	4.48	8.54	5.06
Aluminum (Al)	2.42	5.31	2.16	2.20
Iron total (Fe(T))	11.8	5.68	3.79	0.194
Ferrous iron (Fe(II))	11.2	3.25	3.71	0.192
Manganese (Mn)	0.060	0.078	0.030	0.004
Copper (Cu)	0.0020	0.0014	<0.0005	0.0010
Zinc (Zn)	0.020	0.034	0.012	0.039
Cadmium (Cd)	0.0002	0.0002	0.0002	0.0001
Chromium (Cr)	0.0169	0.0112	0.0069	0.0006
Cobalt (Co)	<0.0007	0.0017	<0.0007	0.0009
Mercury (Hg), ng/L	---	400	---	8.6
Nickel (Ni)	0.003	<0.002	0.003	<0.002
Lead (Pb)	0.0079	0.0012	0.0011	<0.0008
Beryllium (Be)	0.004	0.003	0.001	<0.001
Vanadium (V)	<0.002	0.002	<0.002	<0.002
Molybdenum (Mo)	---	0.039	---	<0.007
Antimony (Sb)	0.254	0.066	0.208	<0.001
Selenium (Se)	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	8.96	0.964	3.25	0.380
Arsenite (As(III))	5.52	0.0742	3.16	0.380
Dissolved organic carbon (DOC)	1.2	2.0	1.2	1.4
δD, per mil	-136	-129	-137	-146
$\delta^{18}O$, per mil	-12.7	-10.8	-14.0	-16.9
sum cations, meq/L	20.5	13.4	17.1	10.2
sum anions, meq/L	20.9	12.9	17.9	9.77
Charge imbalance, percent	-2.2	3.9	-4.4	4.3

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 5. Results of water analyses for Norris Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	"Sperm Spring"	Gibbon River - at highway 89 bridge	Gibbon River - downstream of Norris Geyser Basin
Sample code number	01WA175	01WA178	01WA177
Date collected	10/23/2001	10/23/2001	10/23/2001
Time collected	12:04	13:55	13:19
Temperature, °C	88.0	5.8	9.2
pH (field / laboratory)	7.65 / ---	7.01 / ---	6.72 / ---
pH, selected	---	---	---
Specific conductance (field / laboratory), µS/cm	1375 / ---	142 / ---	535 / ---
Eh, V	---	---	---
Density, g/mL at 20°C	---	---	---
Dissolved oxygen (DO), mg/L	---	---	---
Constituent, mg/L[1]			
Calcium (Ca)	---	---	---
Magnesium (Mg)	---	---	---
Strontium (Sr)	---	---	---
Barium (Ba)	---	---	---
Sodium (Na)	---	---	---
Potassium (K)	---	---	---
Lithium (Li)	---	---	---
Sulfate (SO_4)	---	---	---
Thiosulfate (S_2O_3)	---	---	---
Polythionate (S_nO_6), mM / n	---	---	---
Hydrogen sulfide (H_2S)	---	---	---
Alkalinity (HCO_3)	---	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---
Fluoride (F)	---	---	---
Chloride (Cl)	---	---	---
Bromide (Br)	---	---	---
Nitrate (NO_3)	---	---	---
Nitrite (NO_2)	---	---	---
Ammonium (NH_4)	---	---	---
Silica (SiO_2)	---	---	---
Boron (B)	---	---	---
Aluminum (Al)	---	---	---
Iron total (Fe(T))	---	---	---
Ferrous iron (Fe(II))	---	---	---
Manganese (Mn)	---	---	---
Copper (Cu)	---	---	---
Zinc (Zn)	---	---	---
Cadmium (Cd)	---	---	---
Chromium (Cr)	---	---	---
Cobalt (Co)	---	---	---
Mercury (Hg), ng/L	14.3	3.4	14.4
Nickel (Ni)	---	---	---
Lead (Pb)	---	---	---
Beryllium (Be)	---	---	---
Vanadium (V)	---	---	---
Molybdenum (Mo)	---	---	---
Antimony (Sb)	---	---	---
Selenium (Se)	---	---	---
Arsenic total (As(T))	---	---	---
Arsenite (As(III))	---	---	---
Dissolved organic carbon (DOC)	---	---	---
δD, per mil	---	---	---
$\delta^{18}O$, per mil	---	---	---
sum cations, meq/L	---	---	---
sum anions, meq/L	---	---	---
Charge imbalance, percent	---	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 6. Results of water analyses for Nymph Lake and Roadside, Frying Pan, and Bijah Springs, 2001-2002

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Bijah Spring	Frying Pan Spring	Nymph Creek Spring - main vent source	Nymph Creek - 4.9m from source	Nymph Creek - 10.7m feet from source
Sample code number	02WA140	01WA164	01WA103 / transect A	01WA103 A/transect A	01WA103 B/transect A
Date collected	6/29/2002	10/22/2001	5/21/2001	5/21/2001	5/21/2001
Time collected	18:00	11:30	14:45	15:00	15:15
Temperature, °C	79.0	77-88	59.3	56.0	53.0
pH (field / laboratory)	7.39 / 8.71	--- / ---	2.93 / 2.87	3.00 / ---	3.00 / ---
pH, selected	7.39	---	2.93	---	---
Specific conductance (field / laboratory), µS/cm	1270 / 1335	1415 / ---	950 / 1222	985 / ---	1010 / ---
Eh, V	-0.010	---	0.346	0.222	0.224
Density, g/mL at 20°C	0.99915	---	0.99881	---	---
Dissolved oxygen (DO), mg/L	---	---	<0.05	---	---
Constituent, mg/L[1]					
Calcium (Ca)	3.85	---	6.76	6.74	6.65
Magnesium (Mg)	0.042	---	2.28	2.38	2.34
Strontium (Sr)	0.012	---	0.016	0.018	0.018
Barium (Ba)	0.009	---	0.032	0.032	0.029
Sodium (Na)	267	---	67.4	62.6	63.3
Potassium (K)	30.1	---	42.5	36.0	37.2
Lithium (Li)	1.43	---	0.109	0.119	0.115
Sulfate (SO_4)	105	---	278	---	---
Thiosulfate (S_2O_3)	0.1	---	<0.1	---	---
Polythionate (S_nO_6), mM / n	<0.002	---	<0.002	---	---
Hydrogen sulfide (H_2S)	<0.002	---	0.066	0.011	0.003
Alkalinity (HCO_3)	290	---	---	---	---
Acidity (free / total), mM	--- / ---	--- / ---	1.80 / 2.39	--- / ---	--- / ---
Fluoride (F)	8.36	---	0.58	---	---
Chloride (Cl)	177	---	36.2	---	---
Bromide (Br)	0.7	---	<0.1	---	---
Nitrate (NO_3)	0.2	---	<0.1	---	---
Nitrite (NO_2)	0.520	---	<0.01	---	---
Ammonium (NH_4)	0.51	---	0.99	---	---
Silica (SiO_2)	273	---	251	240	230
Boron (B)	2.73	---	0.70	0.67	0.66
Aluminum (Al)	0.08	---	2.34	2.20	2.10
Iron total (Fe(T))	0.241	---	2.30	2.15	2.24
Ferrous iron (Fe(II))	0.241	---	2.19	1.99	1.64
Manganese (Mn)	0.054	---	0.107	0.110	0.110
Copper (Cu)	<0.0005	---	<0.0005	---	---
Zinc (Zn)	<0.001	---	0.024	0.030	0.030
Cadmium (Cd)	0.0001	---	0.0001	---	---
Chromium (Cr)	<0.0005	---	0.0044	---	---
Cobalt (Co)	<0.0007	---	<0.0007	---	---
Mercury (Hg), ng/L	21	76.6	---	---	---
Nickel (Ni)	<0.002	---	<0.002	0.002	0.003
Lead (Pb)	0.0012	---	<0.0008	---	---
Beryllium (Be)	0.003	---	0.001	0.002	0.003
Vanadium (V)	<0.002	---	<0.002	<0.002	<0.002
Molybdenum (Mo)	<0.007	---	---	---	---
Antimony (Sb)	0.025	---	0.003	---	---
Selenium (Se)	<0.001	---	<0.001	---	---
Arsenic total (As(T))	0.794	---	0.086	0.086	0.089
Arsenite (As(III))	0.0262	---	0.0753	0.0622	0.0471
Dissolved organic carbon (DOC)	1.8	---	---	---	---
δD, per mil	-141	---	-143	---	---
$\delta^{18}O$, per mil	-16.2	---	-18.1	---	---
sum cations, meq/L	12.7	---	5.95	---	---
sum anions, meq/L	12.3	---	6.10	---	---
Charge imbalance, percent	3.3	---	-2.5	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 6. Results of water analyses for Nymph Lake and Roadside, Frying Pan, and Bijah Springs, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Nymph Creek - 19.5m from source	Nymph Creek - 32m from source	Nymph Creek - secondary source	Nymph Creek - 3.4m from secondary source	Nymph Creek - 4.9m from secondary source
Sample code number	01WA103 C/transect A	01WA104 / transect A	01WA122 / transect C	01WA121B / transect C	01WA121A / transect C
Date collected	5/21/2001	5/21/2001	9/10/2001	9/10/2001	9/10/2001
Time collected	15:30	16:00	16:30	15:00	15:00
Temperature, °C	50.0	47.0	61.6	55.5	54.7
pH (field / laboratory)	2.99 / ---	2.99 / 2.88	2.88 / 2.84	2.87 / ---	2.81 / ---
pH, selected	---	2.99	2.88	---	---
Specific conductance (field / laboratory), µS/cm	1030 / ---	1060 / 1216	968 / 1257	1005 / ---	--- / ---
Eh, V	0.227	0.229	0.322	0.592	0.643
Density, g/mL at 20°C	---	0.99871	0.99862	---	---
Dissolved oxygen (DO), mg/L	---	<4.1	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	6.87	7.01	6.45	---	---
Magnesium (Mg)	2.25	2.34	2.37	---	---
Strontium (Sr)	0.015	0.016	0.017	---	---
Barium (Ba)	0.030	0.031	0.033	---	---
Sodium (Na)	62.2	71.2	71.2	---	---
Potassium (K)	39.3	45.9	45.4	---	---
Lithium (Li)	0.112	0.130	0.128	---	---
Sulfate (SO_4)	---	280	301	---	---
Thiosulfate (S_2O_3)	---	<0.1	---	---	---
Polythionate (S_nO_6), mM / n	---	<0.002	<0.002	---	---
Hydrogen sulfide (H_2S)	0.003	<0.002	0.17	0.021	0.008
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	--- / ---	1.76 / 2.24	1.79 / 2.26	--- / ---	--- / ---
Fluoride (F)	---	0.59	0.72	---	---
Chloride (Cl)	---	33.9	42.1	---	---
Bromide (Br)	---	<0.03	0.2	---	---
Nitrate (NO_3)	---	<0.1	<0.1	---	---
Nitrite (NO_2)	---	<0.01	<0.0003	<0.0003	0.0004
Ammonium (NH_4)	---	0.91	1.21	---	---
Silica (SiO_2)	240	231	243	---	---
Boron (B)	0.67	0.69	0.85	---	---
Aluminum (Al)	2.30	2.42	2.21	---	---
Iron total (Fe(T))	2.19	2.09	3.26	3.25	3.22
Ferrous iron (Fe(II))	0.950	0.746	3.26	2.80	1.79
Manganese (Mn)	0.110	0.111	0.113	---	---
Copper (Cu)	---	<0.0005	<0.0005	---	---
Zinc (Zn)	0.032	0.025	0.023	---	---
Cadmium (Cd)	---	0.0001	<0.0001	---	---
Chromium (Cr)	---	0.0042	0.0074	---	---
Cobalt (Co)	---	<0.0007	<0.0007	---	---
Mercury (Hg), ng/L	---	---	---	---	---
Nickel (Ni)	<0.002	<0.002	0.002	---	---
Lead (Pb)	---	<0.0008	<0.0008	---	---
Beryllium (Be)	0.002	0.002	0.002	---	---
Vanadium (V)	<0.002	<0.002	<0.002	---	---
Molybdenum (Mo)	---	---	---	---	---
Antimony (Sb)	---	0.002	0.004	---	---
Selenium (Se)	---	<0.001	<0.001	---	---
Arsenic total (As(T))	0.0830	0.0811	0.138	0.139	0.141
Arsenite (As(III))	0.0169	0.0101	0.134	0.0927	0.0525
Dissolved organic carbon (DOC)	---	---	0.9	---	---
δD, per mil	---	-141	-142	---	---
$\delta^{18}O$, per mil	---	-17.7	-17.9	---	---
sum cations, meq/L	---	6.03	6.37	---	---
sum anions, meq/L	---	6.19	6.63	---	---
Charge imbalance, percent	---	-2.6	-4.0	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 6. Results of water analyses for Nymph Lake and Roadside, Frying Pan, and Bijah Springs, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Nymph Creek - 7.0m from secondary source	Nymph Creek - 12.8m from secondary source	Nymph Creek - 22m from secondary source	Nymph Creek - secondary source	Nymph Creek - 3.4m from secondary source
Sample code number	01WA121 / transect C	01WA120A / transect C	01WA120 / transect C	01WA123E / transect D	01WA123D / transect D
Date collected	9/10/2001	9/10/2001	9/10/2001	9/10/2001	9/10/2001
Time collected	15:00	13:30	13:00	22:30	22:30
Temperature, °C	51.1	45.0	38.0	61.5	53.8
pH (field / laboratory)	2.83 / 2.83	2.83 / ---	2.89 / 2.81	2.95 / ---	2.91 / ---
pH, selected	2.83	---	2.81	---	---
Specific conductance (field / laboratory), µS/cm	1230 / 1283	1124 / ---	1230 / 1308	973 / ---	1045 / ---
Eh, V	0.701	0.716	0.734	0.356	0.694
Density, g/mL at 20°C	0.99850	---	0.99878	---	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	6.59	---	6.74	---	---
Magnesium (Mg)	2.43	---	2.47	---	---
Strontium (Sr)	0.017	---	0.018	---	---
Barium (Ba)	0.034	---	0.032	---	---
Sodium (Na)	70.9	---	72.6	---	---
Potassium (K)	45.0	---	43.9	---	---
Lithium (Li)	0.127	---	0.131	---	---
Sulfate (SO_4)	302	---	301	---	---
Thiosulfate (S_2O_3)	---	---	---	---	---
Polythionate (S_nO_6), mM / n	<0.002	---	---	---	---
Hydrogen sulfide (H_2S)	<0.002	<0.002	<0.002	---	---
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	1.82 / 2.26	--- / ---	1.89 / 2.39	--- / ---	--- / ---
Fluoride (F)	0.63	---	4.05	---	---
Chloride (Cl)	42.6	---	43.8	---	---
Bromide (Br)	0.2	---	0.2	---	---
Nitrate (NO_3)	<0.1	---	<0.1	---	---
Nitrite (NO_2)	0.0006	0.0007	0.0013	<0.0003	<0.0003
Ammonium (NH_4)	1.14	---	1.12	---	---
Silica (SiO_2)	252	---	254	---	---
Boron (B)	0.88	---	0.88	---	---
Aluminum (Al)	2.29	---	2.30	---	---
Iron total (Fe(T))	3.23	3.20	3.12	3.31	3.37
Ferrous iron (Fe(II))	1.06	0.737	0.437	3.27	2.24
Manganese (Mn)	0.117	---	0.121	---	---
Copper (Cu)	0.0019	---	<0.0005	---	---
Zinc (Zn)	0.024	---	0.024	---	---
Cadmium (Cd)	0.0002	---	0.0001	---	---
Chromium (Cr)	0.0070	---	0.0065	---	---
Cobalt (Co)	<0.0007	---	<0.0007	---	---
Mercury (Hg), ng/L	---	---	---	---	---
Nickel (Ni)	0.003	---	0.003	---	---
Lead (Pb)	<0.0008	---	<0.0008	---	---
Beryllium (Be)	0.003	---	0.002	---	---
Vanadium (V)	<0.002	---	<0.002	---	---
Molybdenum (Mo)	---	---	---	---	---
Antimony (Sb)	0.003	---	0.004	---	---
Selenium (Se)	<0.001	---	<0.001	---	---
Arsenic total (As(T))	0.138	0.134	0.132	0.142	0.148
Arsenite (As(III))	0.0262	0.0121	0.0071	0.139	0.0721
Dissolved organic carbon (DOC)	0.8	---	1.2	---	---
δD, per mil	-142	---	-140	---	---
$\delta^{18}O$, per mil	-17.6	---	-17.3	---	---
sum cations, meq/L	6.54	---	6.62	---	---
sum anions, meq/L	6.72	---	6.92	---	---
Charge imbalance, percent	-2.7	---	-4.4	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 6. Results of water analyses for Nymph Lake and Roadside, Frying Pan, and Bijah Springs, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Nymph Creek - 4.9m from secondary source	Nymph Creek - 7.0m from secondary source	Nymph Creek - 12.8m from secondary source	Nymph Creek - 22m from secondary source	Nymph Creek - source
Sample code number	01WA123C / transect D	01WA123B / transect D	01WA123A / transect D	01WA123 / transect D	02WA138 / transect G
Date collected	9/10/2001	9/10/2001	9/10/2001	9/10/2001	6/29/2002
Time collected	22:30	22:30	22:30	22:30	13:30
Temperature, °C	52.0	50.0	43.1	35.5	---
pH (field / laboratory)	2.91 / ---	2.91 / ---	2.92 / ---	2.93 / 2.81	2.93 / 2.87
pH, selected	---	---	---	2.81	2.93
Specific conductance (field / laboratory), µS/cm	1047 / ---	1073 / ---	1126 / ---	1183 / 1310	--- / 1256
Eh, V	0.682	0.729	0.745	0.738	---
Density, g/mL at 20°C	---	---	---	0.99875	0.99886
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	---	---	---	6.63	6.26
Magnesium (Mg)	---	---	---	2.47	2.15
Strontium (Sr)	---	---	---	0.016	0.017
Barium (Ba)	---	---	---	0.031	0.030
Sodium (Na)	---	---	---	73.6	71.0
Potassium (K)	---	---	---	47.5	42.6
Lithium (Li)	---	---	---	0.130	0.123
Sulfate (SO_4)	---	---	---	301	271
Thiosulfate (S_2O_3)	---	---	---	---	<0.1
Polythionate (S_nO_6), mM / n	---	---	---	---	<0.002
Hydrogen sulfide (H_2S)	---	---	---	<0.002	0.12
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	1.85 / 2.31	1.56 / 2.67
Fluoride (F)	---	---	---	0.66	1.40
Chloride (Cl)	---	---	---	42.8	34.5
Bromide (Br)	---	---	---	0.2	0.3
Nitrate (NO_3)	---	---	---	0.4	<0.1
Nitrite (NO_2)	<0.0003	<0.0003	<0.0003	<0.0003	0.0031
Ammonium (NH_4)	---	---	---	1.24	0.50
Silica (SiO_2)	---	---	---	251	226
Boron (B)	---	---	---	0.85	0.82
Aluminum (Al)	---	---	---	2.29	2.00
Iron total (Fe(T))	3.33	3.48	3.37	3.38	2.33
Ferrous iron (Fe(II))	1.60	1.44	0.877	0.483	2.32
Manganese (Mn)	---	---	---	0.117	0.106
Copper (Cu)	---	---	---	<0.0005	<0.0005
Zinc (Zn)	---	---	---	0.024	0.018
Cadmium (Cd)	---	---	---	<0.0001	<0.0001
Chromium (Cr)	---	---	---	0.0078	0.0050
Cobalt (Co)	---	---	---	<0.0007	<0.0007
Mercury (Hg), ng/L	---	---	---	---	---
Nickel (Ni)	---	---	---	0.003	<0.002
Lead (Pb)	---	---	---	<0.0008	<0.0008
Beryllium (Be)	---	---	---	0.002	0.002
Vanadium (V)	---	---	---	<0.002	<0.002
Molybdenum (Mo)	---	---	---	---	<0.007
Antimony (Sb)	---	---	---	0.004	0.002
Selenium (Se)	---	---	---	0.001	<0.001
Arsenic total (As(T))	0.141	0.151	0.136	0.136	0.102
Arsenite (As(III))	0.0566	0.0423	0.0285	0.0171	0.0851
Dissolved organic carbon (DOC)	---	---	---	1.0	1.5
δD, per mil	---	---	---	---	-144
$\delta^{18}O$, per mil	---	---	---	---	-18.0
sum cations, meq/L	---	---	---	6.83	6.04
sum anions, meq/L	---	---	---	6.83	6.06
Charge imbalance, percent	---	---	---	0.0	-0.3

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 6. Results of water analyses for Nymph Lake and Roadside, Frying Pan, and Bijah Springs, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Nymph Creek - 1.6m from source	Nymph Creek - 2.4m from source	Nymph Creek - 3.4m from source	Nymph Creek - 4.5m from source	Nymph Creek - source
Sample code number	02WA137D / transect G	02WA137C / transect G	02WA137B / transect G	02WA137A / transect G	01WA165
Date collected	6/29/2002	6/29/2002	6/29/2002	6/29/2002	10/22/2001
Time collected	13:00	12:45	12:30	12:15	12:50
Temperature, °C	---	---	---	52.3	61.0
pH (field / laboratory)	2.93 / ---	2.93 / ---	2.93 / ---	2.93 / 2.88	2.86 / ---
pH, selected	---	---	---	2.93	---
Specific conductance (field / laboratory), µS/cm	960 / ---	954 / ---	970 / ---	985 / 1158	977 / ---
Eh, V	---	---	---	0.130	---
Density, g/mL at 20°C	---	---	---	0.99878	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	---	---	---	6.29	---
Magnesium (Mg)	---	---	---	2.17	---
Strontium (Sr)	---	---	---	0.017	---
Barium (Ba)	---	---	---	0.030	---
Sodium (Na)	---	---	---	75.5	---
Potassium (K)	---	---	---	45.3	---
Lithium (Li)	---	---	---	0.118	---
Sulfate (SO_4)	---	---	---	280	---
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1	---
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002	---
Hydrogen sulfide (H_2S)	---	---	---	<0.002	---
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	1.61 / 2.13	--- / ---
Fluoride (F)	---	---	---	0.77	---
Chloride (Cl)	---	---	---	35.3	---
Bromide (Br)	---	---	---	0.3	---
Nitrate (NO_3)	---	---	---	<0.1	---
Nitrite (NO_2)	0.0029	0.0020	0.0027	0.0028	---
Ammonium (NH_4)	1.28	1.26	1.31	1.23	---
Silica (SiO_2)	---	---	---	231	---
Boron (B)	---	---	---	0.97	---
Aluminum (Al)	---	---	---	2.04	---
Iron total (Fe(T))	2.32	2.30	2.26	2.38	---
Ferrous iron (Fe(II))	2.17	1.73	1.33	1.12	---
Manganese (Mn)	---	---	---	0.106	---
Copper (Cu)	---	---	---	0.0128	---
Zinc (Zn)	---	---	---	0.024	---
Cadmium (Cd)	---	---	---	0.0005	---
Chromium (Cr)	---	---	---	0.0048	---
Cobalt (Co)	---	---	---	0.0009	---
Mercury (Hg), ng/L	---	---	---	---	10.9
Nickel (Ni)	---	---	---	<0.002	---
Lead (Pb)	---	---	---	<0.0008	---
Beryllium (Be)	---	---	---	0.002	---
Vanadium (V)	---	---	---	<0.002	---
Molybdenum (Mo)	---	---	---	<0.007	---
Antimony (Sb)	---	---	---	0.002	---
Selenium (Se)	---	---	---	<0.001	---
Arsenic total (As(T))	0.107	0.107	0.105	0.105	---
Arsenite (As(III))	0.0628	0.0534	0.0304	0.0265	---
Dissolved organic carbon (DOC)	---	---	---	1.4	---
δD, per mil	---	---	---	-142	---
$\delta^{18}O$, per mil	---	---	---	-17.8	---
sum cations, meq/L	---	---	---	6.35	---
sum anions, meq/L	---	---	---	6.21	---
Charge imbalance, percent	---	---	---	2.3	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 6. Results of water analyses for Nymph Lake and Roadside, Frying Pan, and Bijah Springs, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Nymph Lake - at shore	Roadside Spring (east)	Roadside Spring (east)	Roadside Spring (east)	Roadside Spring (west)
Sample code number	01WA168	01WA102	01WA125	01WA166	01WA124
Date collected	10/22/2001	5/21/2001	9/11/2001	10/22/2001	9/11/2001
Time collected	14:00	13:40	17:36	13:15	16:15
Temperature, °C	12.4	60.0	60.2	61.5	66.5
pH (field / laboratory)	5.77 / ---	3.72 / 3.65	4.01 / 3.90	4.05 / ---	6.44 / 8.30
pH, selected	---	3.65	3.90	---	6.44
Specific conductance (field / laboratory), µS/cm	805 / ---	926 / 1106	1230 / 1057	960 / ---	1890 / 1975
Eh, V	---	0.600	0.415	---	0.008
Density, g/mL at 20°C	---	---	0.99890	---	0.99908
Dissolved oxygen (DO), mg/L	---	<2.85	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	---	5.81	5.58	---	1.48
Magnesium (Mg)	---	0.716	0.667	---	0.017
Strontium (Sr)	---	0.016	0.018	---	0.005
Barium (Ba)	---	0.084	0.080	---	0.003
Sodium (Na)	---	147	141	---	393
Potassium (K)	---	55.1	56.8	---	8.02
Lithium (Li)	---	0.747	0.726	---	2.00
Sulfate (SO_4)	---	223	210	---	73.2
Thiosulfate (S_2O_3)	---	<0.1	<0.1	---	12
Polythionate (S_nO_6), mM / n	---	<0.002	<0.002	---	<0.002
Hydrogen sulfide (H_2S)	---	0.004	---	---	0.15
Alkalinity (HCO_3)	---	---	---	---	170
Acidity (free / total), mM	--- / ---	0.311 / 0.541	0.259 / 0.343	--- / ---	--- / ---
Fluoride (F)	---	2.28	3.36	---	15.6
Chloride (Cl)	---	167	153	---	454
Bromide (Br)	---	0.3	0.5	---	1.3
Nitrate (NO_3)	---	<0.1	<0.1	---	<0.1
Nitrite (NO_2)	---	<0.01	<0.0003	---	0.0030
Ammonium (NH_4)	---	2.15	1.64	---	<0.04
Silica (SiO_2)	---	252	259	---	285
Boron (B)	---	2.63	2.56	---	7.62
Aluminum (Al)	---	0.80	0.35	---	0.18
Iron total (Fe(T))	---	0.685	0.467	---	0.011
Ferrous iron (Fe(II))	---	0.252	0.307	---	0.011
Manganese (Mn)	---	0.192	0.193	---	0.004
Copper (Cu)	---	<0.0005	<0.0005	---	0.0027
Zinc (Zn)	---	0.005	0.001	---	<0.001
Cadmium (Cd)	---	0.0001	0.0001	---	0.0003
Chromium (Cr)	---	0.0013	0.0012	---	0.0008
Cobalt (Co)	---	<0.0007	<0.0007	---	<0.0007
Mercury (Hg), ng/L	29.1	---	---	14.9	---
Nickel (Ni)	---	<0.002	<0.002	---	<0.002
Lead (Pb)	---	<0.0008	<0.0008	---	<0.0008
Beryllium (Be)	---	0.004	0.004	---	<0.001
Vanadium (V)	---	<0.002	<0.002	---	<0.002
Molybdenum (Mo)	---	---	---	---	---
Antimony (Sb)	---	0.009	0.005	---	0.132
Selenium (Se)	---	<0.001	<0.001	---	<0.001
Arsenic total (As(T))	---	0.212	0.210	---	3.38
Arsenite (As(III))	---	0.0043	0.0168	---	3.38
Dissolved organic carbon (DOC)	---	---	0.5	---	---
δD, per mil	---	-138	-137	---	-131
$\delta^{18}O$, per mil	---	-15.7	-15.5	---	-12.1
sum cations, meq/L	---	8.53	8.15	---	17.6
sum anions, meq/L	---	9.17	8.63	---	17.9
Charge imbalance, percent	---	-7.3	-5.7	---	-1.6

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 6. Results of water analyses for Nymph Lake and Roadside, Frying Pan, and Bijah Springs, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Roadside Spring (west)	Roadside Spring (west - center of pool)	Roadside Spring (west - side of pool)	Unnamed spring east of two more prominent Roadside Springs
Sample code number	01WA167	01WA101	01WA101S	02WA139
Date collected	10/22/2001	5/21/2001	5/21/2001	6/29/2002
Time collected	13:31	11:15	11:30	15:50
Temperature, °C	66.1	62.0	---	82.0
pH (field / laboratory)	6.77 / ---	6.64 / 8.18	--- / ---	5.60 / 6.79
pH, selected	---	6.64	---	5.60
Specific conductance (field / laboratory), µS/cm	1870 / ---	1690 / 1963	--- / ---	770 / 849
Eh, V	---	0.103	---	-0.008
Density, g/mL at 20°C	---	---	0.99906	0.99882
Dissolved oxygen (DO), mg/L	---	<0.05	---	---
Constituent, mg/L[1]				
Calcium (Ca)	---	1.52	2.00	3.11
Magnesium (Mg)	---	0.011	0.060	0.393
Strontium (Sr)	---	0.001	<0.001	0.017
Barium (Ba)	---	0.002	0.003	0.092
Sodium (Na)	---	401	340	137
Potassium (K)	---	9.11	9.00	34.6
Lithium (Li)	---	1.55	1.60	0.441
Sulfate (SO_4)	---	54.8	---	164
Thiosulfate (S_2O_3)	---	14	---	<0.1
Polythionate (S_nO_6), mM / n	---	<0.002	---	<0.002
Hydrogen sulfide (H_2S)	---	0.13	---	<0.002
Alkalinity (HCO_3)	---	156	---	9.52
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	---	17.6	---	4.27
Chloride (Cl)	---	462	---	111
Bromide (Br)	---	0.9	---	0.3
Nitrate (NO_3)	---	<0.1	---	<0.1
Nitrite (NO_2)	---	0.0237	---	0.0093
Ammonium (NH_4)	---	<0.3	---	3.30
Silica (SiO_2)	---	259	260	269
Boron (B)	---	7.65	7.40	1.99
Aluminum (Al)	---	0.18	<0.07	0.16
Iron total (Fe(T))	---	0.029	0.009	0.057
Ferrous iron (Fe(II))	---	0.029	0.009	0.057
Manganese (Mn)	---	<0.001	<0.001	0.078
Copper (Cu)	---	<0.0005	---	0.0008
Zinc (Zn)	---	0.002	0.013	<0.001
Cadmium (Cd)	---	0.0002	---	<0.0001
Chromium (Cr)	---	<0.0005	---	0.0007
Cobalt (Co)	---	<0.0007	---	<0.0007
Mercury (Hg), ng/L	102	---	---	---
Nickel (Ni)	---	<0.002	<0.002	<0.002
Lead (Pb)	---	0.0021	---	<0.0008
Beryllium (Be)	---	<0.001	<0.001	<0.001
Vanadium (V)	---	<0.002	<0.002	<0.002
Molybdenum (Mo)	---	---	---	<0.007
Antimony (Sb)	---	0.174	---	0.009
Selenium (Se)	---	<0.001	---	<0.001
Arsenic total (As(T))	---	3.40	2.90	0.197
Arsenite (As(III))	---	3.34	2.08	0.100
Dissolved organic carbon (DOC)	---	---	---	2.1
δD, per mil	---	-131	---	-124
$\delta^{18}O$, per mil	---	-12.1	---	-10.4
sum cations, meq/L	---	17.9	---	7.18
sum anions, meq/L	---	17.6	---	6.83
Charge imbalance, percent	---	1.9	---	5.0

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 7. Results of water analyses for Lower Geyser Basin, 2001-2002

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Azure Spring	Bath Spring	Mushroom Spring - center of pool	Mushroom Spring - edge of pool	Mushroom Spring - 8.5m downdrainage of pool
Sample code number	02WA146	02WA147	01WA146	01WA146B / transect F	01WA146C / transect F
Date collected	6/30/2002	6/30/2002	9/16/2001	9/16/2001	9/16/2001
Time collected	15:45	16:30	15:08	15:20	15:30
Temperature, °C	72.2	93.5	69.0	69.6	65.6
pH (field / laboratory)	8.84 / 8.80	8.95 / 9.11	7.96 / 8.70	7.85 / ---	8.01 / ---
pH, selected	8.84	8.95	7.96	---	---
Specific conductance (field / laboratory), µS/cm	1540 / 1600	1490 / 1587	1310 / 1370	--- / ---	--- / ---
Eh, V	-0.084	-0.215	0.127	---	---
Density, g/mL at 20°C	0.99920	0.99920	0.99904	---	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	1.15	0.859	0.627	---	---
Magnesium (Mg)	0.002	<0.001	0.006	---	---
Strontium (Sr)	0.009	0.008	0.001	---	---
Barium (Ba)	<0.001	<0.001	<0.001	---	---
Sodium (Na)	337	316	278	---	---
Potassium (K)	14.3	12.2	19.5	---	---
Lithium (Li)	2.88	3.11	1.94	---	---
Sulfate (SO_4)	36.7	27.7	19.0	---	---
Thiosulfate (S_2O_3)	5.4	1.5	<0.1	---	---
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	---	---
Hydrogen sulfide (H_2S)	0.054	0.78	0.003	---	---
Alkalinity (HCO_3)	210	220	292	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	27.6	30.5	14.9	---	---
Chloride (Cl)	302	297	257	---	---
Bromide (Br)	1.2	1.1	0.8	---	---
Nitrate (NO_3)	<0.1	<0.1	<0.1	---	---
Nitrite (NO_2)	0.116	0.602	0.0151	0.0106	0.0034
Ammonium (NH_4)	0.16	0.30	<0.04	<0.04	<0.04
Silica (SiO_2)	253	245	296	---	---
Boron (B)	4.53	4.45	2.78	---	---
Aluminum (Al)	0.15	0.18	0.14	---	---
Iron total (Fe(T))	0.037	0.036	<0.002	<0.002	<0.002
Ferrous iron (Fe(II))	0.037	0.036	<0.002	<0.002	<0.002
Manganese (Mn)	<0.001	<0.001	0.005	---	---
Copper (Cu)	<0.0005	<0.0005	<0.0005	---	---
Zinc (Zn)	<0.001	<0.001	0.003	---	---
Cadmium (Cd)	<0.0001	0.0001	0.0001	---	---
Chromium (Cr)	<0.0005	<0.0005	<0.0005	---	---
Cobalt (Co)	0.0028	0.0025	<0.0007	---	---
Mercury (Hg), ng/L	130	37	---	---	---
Nickel (Ni)	<0.002	<0.002	0.002	---	---
Lead (Pb)	0.0011	<0.0008	0.0012	---	---
Beryllium (Be)	0.001	0.001	0.002	---	---
Vanadium (V)	<0.002	<0.002	<0.002	---	---
Molybdenum (Mo)	0.060	0.049	---	---	---
Antimony (Sb)	0.065	0.082	0.072	---	---
Selenium (Se)	<0.001	<0.001	<0.001	---	---
Arsenic total (As(T))	1.51	1.16	1.86	1.85	1.86
Arsenite (As(III))	1.51	1.14	0.0301	0.0329	0.0280
Dissolved organic carbon (DOC)	1.2	1.5	1.4	---	---
δD, per mil	-140	-140	-142	---	---
$\delta^{18}O$, per mil	-15.8	-16.5	-16.3	---	---
sum cations, meq/L	15.3	14.4	12.9	---	---
sum anions, meq/L	14.0	14.1	13.2	---	---
Charge imbalance, percent	8.8	2.1	-2.8	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 7. Results of water analyses for Lower Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Octopus Spring	Octopus Spring - edge of pool	Octopus Spring - 9.4m from edge of pool	Octopus Spring - 16.2m from edge of pool	Octopus Spring - 23.5m from edge of pool
Sample code number	01WA145	01WA145A / transect E	01WA145B / transect E	01WA145C / transect E	01WA145D / transect E
Date collected	9/16/2001	9/16/2001	9/16/2001	9/16/2001	9/16/2001
Time collected	12:20	12:20	12:40	13:00	13:20
Temperature, °C	90.5	90.5	82.0	76.0	73.0
pH (field / laboratory)	8.04 / 8.78	8.04 / ---	8.18 / ---	8.28 / ---	8.27 / ---
pH, selected	8.04	---	---	---	---
Specific conductance (field / laboratory), µS/cm	1338 / 1446	1338 / ---	--- / ---	--- / ---	--- / ---
Eh, V	-0.078	-0.007	---	---	---
Density, g/mL at 20°C	0.99911	---	---	---	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	0.765	---	---	---	---
Magnesium (Mg)	0.011	---	---	---	---
Strontium (Sr)	0.001	---	---	---	---
Barium (Ba)	<0.001	---	---	---	---
Sodium (Na)	297	---	---	---	---
Potassium (K)	15.4	---	---	---	---
Lithium (Li)	3.25	---	---	---	---
Sulfate (SO_4)	17.6	---	---	---	---
Thiosulfate (S_2O_3)	<0.1	---	---	---	---
Polythionate (S_nO_6), mM / n	<0.002	---	---	---	---
Hydrogen sulfide (H_2S)	0.024	0.027	0.009	<0.002	---
Alkalinity (HCO_3)	343	---	---	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	21.2	---	---	---	---
Chloride (Cl)	246	---	---	---	---
Bromide (Br)	0.8	---	---	---	---
Nitrate (NO_3)	<0.1	---	---	---	---
Nitrite (NO_2)	0.0630	---	0.0366	0.0240	0.0202
Ammonium (NH_4)	<0.04	---	<0.04	<0.04	<0.04
Silica (SiO_2)	288	---	---	---	---
Boron (B)	2.74	---	---	---	---
Aluminum (Al)	0.24	---	---	---	---
Iron total (Fe(T))	<0.002	---	<0.002	<0.002	<0.002
Ferrous iron (Fe(II))	<0.002	---	<0.002	<0.002	<0.002
Manganese (Mn)	0.003	---	---	---	---
Copper (Cu)	0.0010	---	---	---	---
Zinc (Zn)	0.002	---	---	---	---
Cadmium (Cd)	0.0001	---	---	---	---
Chromium (Cr)	<0.0005	---	---	---	---
Cobalt (Co)	0.0027	---	---	---	---
Mercury (Hg), ng/L	---	---	---	---	---
Nickel (Ni)	<0.002	---	---	---	---
Lead (Pb)	0.0010	---	---	---	---
Beryllium (Be)	0.002	---	---	---	---
Vanadium (V)	<0.002	---	---	---	---
Molybdenum (Mo)	---	---	---	---	---
Antimony (Sb)	0.085	---	---	---	---
Selenium (Se)	<0.001	---	---	---	---
Arsenic total (As(T))	1.37	1.36	1.42	1.46	1.40
Arsenite (As(III))	0.148	0.156	0.0689	0.0354	0.0357
Dissolved organic carbon (DOC)	1.4	---	---	---	---
δD, per mil	-144	---	---	---	---
$\delta^{18}O$, per mil	-16.9	---	---	---	---
sum cations, meq/L	13.7	---	---	---	---
sum anions, meq/L	14.0	---	---	---	---
Charge imbalance, percent	-2.0	---	---	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 7. Results of water analyses for Lower Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Octopus Spring - 37.8m from edge of pool	Ojo Caliente Spring	Ojo Caliente - edge of pool	Ojo Caliente - 6.6m from edge of pool, drainage A	Ojo Caliente - 13m from edge of pool, drainage A
Sample code number	01WA145E / transect E	02WA145	02WA145A1 / transect H/I	02WA145A2 / transect H	02WA145A3 / transect H
Date collected	9/16/2001	6/30/2002	7/1/2002	7/1/2002	7/1/2002
Time collected	13:40	14:30	15:00	15:00	15:00
Temperature, °C	69.0	93.0	88.5	83.8	79.8
pH (field / laboratory)	8.40 / ---	7.36 / 8.60	7.31 / ---	7.45 / ---	7.61 / ---
pH, selected	---	7.36	---	---	---
Specific conductance (field / laboratory), µS/cm	--- / ---	1500 / 1616	--- / ---	--- / ---	--- / ---
Eh, V	---	-0.153	---	---	---
Density, g/mL at 20°C	---	0.99916	---	---	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	---	0.857	---	---	---
Magnesium (Mg)	---	<0.001	---	---	---
Strontium (Sr)	---	0.006	---	---	---
Barium (Ba)	---	<0.001	---	---	---
Sodium (Na)	---	328	---	---	---
Potassium (K)	---	10.5	---	---	---
Lithium (Li)	---	4.17	---	---	---
Sulfate (SO_4)	---	25.4	---	---	---
Thiosulfate (S_2O_3)	---	0.6	---	---	---
Polythionate (S_nO_6), mM / n	---	<0.002	---	---	---
Hydrogen sulfide (H_2S)	---	0.37	---	---	---
Alkalinity (HCO_3)	---	240	---	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	---	28.9	---	---	---
Chloride (Cl)	---	298	---	---	---
Bromide (Br)	---	1.2	---	---	---
Nitrate (NO_3)	---	<0.1	---	---	---
Nitrite (NO_2)	---	0.184	0.0143	0.0093	0.0054
Ammonium (NH_4)	---	0.46	0.39	0.29	0.31
Silica (SiO_2)	---	229	---	---	---
Boron (B)	---	4.34	---	---	---
Aluminum (Al)	---	0.27	---	---	---
Iron total (Fe(T))	<0.002	<0.002	---	---	---
Ferrous iron (Fe(II))	<0.002	<0.002	---	---	---
Manganese (Mn)	---	<0.001	---	---	---
Copper (Cu)	---	0.0023	---	---	---
Zinc (Zn)	---	<0.001	---	---	---
Cadmium (Cd)	---	0.0001	---	---	---
Chromium (Cr)	---	<0.0005	---	---	---
Cobalt (Co)	---	0.0020	---	---	---
Mercury (Hg), ng/L	---	490	---	---	---
Nickel (Ni)	---	<0.002	---	---	---
Lead (Pb)	---	0.0011	---	---	---
Beryllium (Be)	---	0.001	---	---	---
Vanadium (V)	---	<0.002	---	---	---
Molybdenum (Mo)	---	0.039	---	---	---
Antimony (Sb)	---	0.051	---	---	---
Selenium (Se)	---	<0.001	---	---	---
Arsenic total (As(T))	1.43	1.36	1.43	1.40	1.43
Arsenite (As(III))	0.0382	1.36	1.43	1.40	1.43
Dissolved organic carbon (DOC)	---	1.6	---	---	---
δD, per mil	---	-140	---	---	---
$\delta^{18}O$, per mil	---	-16.5	---	---	---
sum cations, meq/L	---	15.2	---	---	---
sum anions, meq/L	---	14.4	---	---	---
Charge imbalance, percent	---	5.2	---	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 7. Results of water analyses for Lower Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Ojo Caliente - 18.1m from edge of pool, drainage A	Ojo Caliente - 24m from edge of pool, drainage A	Ojo Caliente - 6.9m from edge of pool, drainage B	Ojo Caliente - 13.7m from edge of pool, drainage B	Ojo Caliente - 20.5m from edge of pool, drainage B
Sample code number	02WA145A4 / transect H	02WA145A5 / transect H	02WA145B1 / transect I	02WA145B2 / transect I	02WA145B3 / transect I
Date collected	7/1/2002	7/1/2002	7/1/2002	7/1/2002	7/1/2002
Time collected	15:00	15:00	15:00	15:00	15:00
Temperature, °C	72.5	69.0	73.1	62.5	54.3
pH (field / laboratory)	7.75 / ---	7.89 / ---	7.79 / ---	8.01 / ---	8.18 / ---
pH, selected	---	---	---	---	---
Specific conductance (field / laboratory), µS/cm	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Eh, V	---	---	0.262	---	---
Density, g/mL at 20°C	---	---	---	---	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	---	---	---	---	---
Magnesium (Mg)	---	---	---	---	---
Strontium (Sr)	---	---	---	---	---
Barium (Ba)	---	---	---	---	---
Sodium (Na)	---	---	---	---	---
Potassium (K)	---	---	---	---	---
Lithium (Li)	---	---	---	---	---
Sulfate (SO_4)	---	---	---	---	---
Thiosulfate (S_2O_3)	---	---	---	---	---
Polythionate (S_nO_6), mM / n	---	---	---	---	---
Hydrogen sulfide (H_2S)	---	---	---	---	---
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	---	---	---	---	---
Chloride (Cl)	---	---	---	---	---
Bromide (Br)	---	---	---	---	---
Nitrate (NO_3)	---	---	---	---	---
Nitrite (NO_2)	0.0128	0.0093	0.0079	0.0042	0.0034
Ammonium (NH_4)	0.15	0.23	0.31	0.27	0.24
Silica (SiO_2)	---	---	---	---	---
Boron (B)	---	---	---	---	---
Aluminum (Al)	---	---	---	---	---
Iron total (Fe(T))	---	---	---	---	---
Ferrous iron (Fe(II))	---	---	---	---	---
Manganese (Mn)	---	---	---	---	---
Copper (Cu)	---	---	---	---	---
Zinc (Zn)	---	---	---	---	---
Cadmium (Cd)	---	---	---	---	---
Chromium (Cr)	---	---	---	---	---
Cobalt (Co)	---	---	---	---	---
Mercury (Hg), ng/L	---	---	---	---	---
Nickel (Ni)	---	---	---	---	---
Lead (Pb)	---	---	---	---	---
Beryllium (Be)	---	---	---	---	---
Vanadium (V)	---	---	---	---	---
Molybdenum (Mo)	---	---	---	---	---
Antimony (Sb)	---	---	---	---	---
Selenium (Se)	---	---	---	---	---
Arsenic total (As(T))	1.51	1.53	1.52	1.56	1.57
Arsenite (As(III))	1.51	1.53	1.50	1.29	0.565
Dissolved organic carbon (DOC)	---	---	---	---	---
δD, per mil	---	---	---	---	---
$\delta^{18}O$, per mil	---	---	---	---	---
sum cations, meq/L	---	---	---	---	---
sum anions, meq/L	---	---	---	---	---
Charge imbalance, percent	---	---	---	---	---

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 8. Results of water analyses for Washburn Hot Springs, 2001-2002

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Washburn Hot Springs - Inkpot #1, lower most large pool, first one encountered from trail	Washburn Hot Springs - Inkpot #1 Drainage (high)	Washburn Hot Springs - Inkpot #1 Drainage (middle)	Washburn Hot Springs - Inkpot #1 Drainage (low)	Sulfur Creek
Sample code number	01WA110 / transect B	01WA117 / transect B	01WA116 / transect B	01WA115 / transect B	01WA114 / transect B
Date collected	5/23/2001	5/25/2001	5/25/2001	5/25/2001	5/25/2001
Time collected	13:00	14:30	14:15	13:00	12:00
Temperature, °C	85.0	63.0	51.3	19.4	6.9
pH (field / laboratory)	6.39 / 7.77	7.10 / 7.80	7.14 / 7.74	7.97 / 7.55	6.72 / 6.37
pH, selected	6.39	7.10	7.14	7.97	6.72
Specific conductance (field / laboratory), µS/cm	2020 / 2210	2230 / 2300	2250 / 2290	2370 / 2330	78 / 81
Eh, V	-0.154	0.187	0.218	0.369	0.386
Density, g/mL at 20°C	0.99926	---	0.99937	---	0.99818
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	22.7	23.4	25.0	26.1	5.23
Magnesium (Mg)	8.08	7.20	5.13	5.87	2.05
Strontium (Sr)	0.178	0.182	0.191	0.202	0.047
Barium (Ba)	0.080	0.081	0.081	0.081	0.021
Sodium (Na)	35.5	40.4	32.4	34.9	3.15
Potassium (K)	13.2	13.1	13.6	14.1	1.12
Lithium (Li)	0.034	0.035	0.037	0.037	0.011
Sulfate (SO_4)	774	853	859	892	22.3
Thiosulfate (S_2O_3)	2.6	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	1.3	0.005	0.007	0.003	---
Alkalinity (HCO_3)	152	141	126	80.0	<1
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	0.34	0.31	0.42	0.35	0.13
Chloride (Cl)	3.5	2.1	2.0	1.0	3.5
Bromide (Br)	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate (NO_3)	<0.1	<0.1	<0.1	<0.1	0.4
Nitrite (NO_2)	0.0285	0.0428	0.0287	0.374	0.0175
Ammonium (NH_4)	285	290	284	286	0.48
Silica (SiO_2)	168	180	170	170	21.0
Boron (B)	7.56	8.27	8.47	8.66	0.02
Aluminum (Al)	<0.07	<0.07	0.09	0.09	0.17
Iron total (Fe(T))	0.007	0.003	0.004	0.017	0.075
Ferrous iron (Fe(II))	0.007	0.003	0.003	0.009	0.067
Manganese (Mn)	0.124	0.117	0.118	0.115	0.018
Copper (Cu)	0.0008	<0.0005	<0.0005	0.0133	<0.0005
Zinc (Zn)	<0.001	<0.001	<0.001	<0.001	0.009
Cadmium (Cd)	<0.0001	<0.0001	<0.0001	0.0006	<0.0001
Chromium (Cr)	<0.0005	0.0008	0.0012	0.0012	0.0015
Cobalt (Co)	0.0008	<0.0007	<0.0007	<0.0007	<0.0007
Mercury (Hg), ng/L	---	---	---	---	---
Nickel (Ni)	<0.002	<0.002	<0.002	<0.002	<0.002
Lead (Pb)	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008
Beryllium (Be)	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (V)	<0.002	0.002	0.002	0.003	0.002
Molybdenum (Mo)	---	---	---	---	---
Antimony (Sb)	0.001	0.003	0.003	0.002	<0.001
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	0.0008	0.0007	0.0008	0.0009	<0.0001
Arsenite (As(III))	0.0005	0.0007	0.0008	0.0007	<0.0005
Dissolved organic carbon (DOC)	4.1	4.0	4.5	5.5	4.9
δD, per mil	-115	-113	---	-110	-136
$\delta^{18}O$, per mil	-4.5	-4.0	---	-3.3	-17.8
sum cations, meq/L	17.4	17.5	17.2	17.7	0.62
sum anions, meq/L	17.2	18.6	18.6	18.5	0.57
Charge imbalance, percent	1.2	-6.4	-7.7	-4.6	9.3

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 8. Results of water analyses for Washburn Hot Springs, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Washburn Hot Springs - Inkpot #2	Washburn Hot Springs - Inkpot #3
Sample code number	01WA111	01WA118
Date collected	5/23/2001	5/25/2001
Time collected	14:22	15:00
Temperature, °C	83.7	71.5
pH (field / laboratory)	6.45 / 8.14	3.71 / 3.35
pH, selected	6.45	3.35
Specific conductance (field / laboratory), µS/cm	1980 / ---	4070 / 4450
Eh, V	-0.156	0.022
Density, g/mL at 20°C	---	1.00020
Dissolved oxygen (DO), mg/L	---	---
Constituent, mg/L[1]		
Calcium (Ca)	11.7	19.3
Magnesium (Mg)	5.45	10.0
Strontium (Sr)	0.079	0.103
Barium (Ba)	0.206	0.012
Sodium (Na)	33.2	21.7
Potassium (K)	12.0	8.07
Lithium (Li)	<0.003	0.018
Sulfate (SO_4)	606	1920
Thiosulfate (S_2O_3)	12	<0.1
Polythionate (S_nO_6), mM / n	<0.002	<0.002
Hydrogen sulfide (H_2S)	---	2.8
Alkalinity (HCO_3)	222	---
Acidity (free / total), mM	--- / ---	0.773 / 1.98
Fluoride (F)	0.56	0.22
Chloride (Cl)	13.2	3.6
Bromide (Br)	<0.03	<0.03
Nitrate (NO_3)	1.6	<0.1
Nitrite (NO_2)	<0.01	0.0271
Ammonium (NH_4)	289	618
Silica (SiO_2)	140	225
Boron (B)	1.44	5.56
Aluminum (Al)	0.11	3.31
Iron total (Fe(T))	0.022	1.02
Ferrous iron (Fe(II))	0.020	1.01
Manganese (Mn)	0.056	0.286
Copper (Cu)	---	0.0005
Zinc (Zn)	0.014	0.012
Cadmium (Cd)	---	<0.0001
Chromium (Cr)	---	0.0077
Cobalt (Co)	---	<0.0007
Mercury (Hg), ng/L	---	---
Nickel (Ni)	<0.002	0.004
Lead (Pb)	---	<0.0008
Beryllium (Be)	<0.001	0.001
Vanadium (V)	0.002	0.013
Molybdenum (Mo)	---	---
Antimony (Sb)	---	0.002
Selenium (Se)	---	<0.001
Arsenic total (As(T))	0.0228	0.0002
Arsenite (As(III))	0.0207	<0.0005
Dissolved organic carbon (DOC)	---	2.9
δD, per mil	-111	-112
$\delta^{18}O$, per mil	-2.8	-3.9
sum cations, meq/L	17.2	34.2
sum anions, meq/L	15.6	35.0
Charge imbalance, percent	9.3	-2.3

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 9. Results of water analyses for Calcite Springs, Crater Hills, Mammoth Hot Springs, and West Thumb Geyser Basin, 2001-2002

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Area	Calcite Spring Area	Crater Hills	Crater Hills	Mammoth Hot Springs	Mammoth Hot Springs
Name and/or site description	Unnamed spring, downstream from Calcite Spring	Unnamed light green flowing pool south of Sulphur Spring	Sulphur Spring	Canary Spring	Canary Springs - base of travertine terrace above wetland area
Sample code number	02WA148	01WA112	01WA113	01WA143	01WA144
Date collected	7/1/2002	5/24/2001	5/24/2001	9/15/2001	9/15/2001
Time collected	12:00	13:15	15:00	10:40	12:45
Temperature, °C	68.2	41.0	90.0	73.0	38.5
pH (field / laboratoryoratory)	2.09 / 1.98	3.47 / 3.37	3.72 / 3.49	6.50 / 7.95	8.13 / 8.03
pH, selected	2.11	3.37	3.49	6.50	8.13
Specific conductance (field / laboratory), µS/cm	4460 / 7170	4230 / 4340	3540 / 3890	2310 / 1808	2030 / 1839
Eh, V	0.193	0.421	0.196	-0.123	0.096
Density, g/mL at 20°C	1.00101	1.00056	1.00063	0.99924	0.99926
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	165	7.48	6.71	342	206
Magnesium (Mg)	21.3	0.629	0.567	75.8	82.3
Strontium (Sr)	1.50	0.135	0.122	1.89	0.970
Barium (Ba)	0.044	0.083	0.078	0.038	0.026
Sodium (Na)	193	638	546	130	137
Potassium (K)	79.5	183	158	51.4	53.8
Lithium (Li)	1.76	7.78	6.97	1.53	1.67
Sulfate (SO_4)	2060	526	436	528	565
Thiosulfate (S_2O_3)	<0.1	<0.1	1.1	<0.1	<0.1
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	<0.002	0.19	0.24	1.3	<0.002
Alkalinity (HCO_3)	---	---	---	846	362
Acidity (free / total), mM	16.5 / 25.5	1.10 / 2.67	0.865 / 2.42	--- / ---	--- / ---
Fluoride (F)	4.48	36.1	33.8	1.42	0.77
Chloride (Cl)	192	990	910	166	177
Bromide (Br)	0.9	0.9	1.5	0.6	0.6
Nitrate (NO_3)	<0.1	<0.1	<0.1	<0.1	0.2
Nitrite (NO_2)	0.0011	<0.01	---	0.0031	0.0031
Ammonium (NH_4)	44.9	3.05	2.42	0.99	<0.3
Silica (SiO_2)	259	731	718	52.3	55.9
Boron (B)	27.8	28.5	28.2	3.89	4.16
Aluminum (Al)	56.3	7.11	6.62	<0.07	<0.07
Iron total (Fe(T))	46.2	0.235	0.219	0.024	<0.002
Ferrous iron (Fe(II))	46.2	0.190	0.218	0.023	<0.002
Manganese (Mn)	0.582	0.295	0.268	0.017	0.014
Copper (Cu)	<0.0005	<0.0005	<0.0005	0.0012	<0.0005
Zinc (Zn)	0.066	0.011	0.007	0.002	0.002
Cadmium (Cd)	0.0001	0.0002	0.0002	<0.0001	<0.0001
Chromium (Cr)	0.108	0.0015	0.0015	<0.0005	<0.0005
Cobalt (Co)	0.0064	<0.0007	<0.0007	<0.0007	<0.0007
Mercury (Hg), ng/L	60	---	---	---	---
Nickel (Ni)	0.021	0.005	0.005	<0.002	<0.002
Lead (Pb)	<0.0008	0.0028	0.0026	<0.0008	<0.0008
Beryllium (Be)	0.001	0.015	0.014	0.002	<0.001
Vanadium (V)	0.081	<0.002	<0.002	<0.002	<0.002
Molybdenum (Mo)	<0.007	---	---	---	---
Antimony (Sb)	0.012	0.118	0.277	0.003	0.003
Selenium (Se)	0.003	<0.001	<0.001	0.003	0.001
Arsenic total (As(T))	1.73	6.45	6.01	0.466	0.539
Arsenite (As(III))	1.27	3.79	5.89	0.466	0.375
Dissolved organic carbon (DOC)	3.4	---	---	2.1	1.1
δD, per mil	-144	-122	-125	-148	-145
$\delta^{18}O$, per mil	-14.0	-10.8	-12.2	-18.2	-17.4
sum cations, meq/L	32.5	34.2	29.3	24.9	20.3
sum anions, meq/L	31.1	39.0	34.4	23.9	18.4
Charge imbalance, percent	4.4	-13	-16	3.9	9.9

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 9. Results of water analyses for Calcite Springs, Crater Hills, Mammoth Hot Springs, and West Thumb Geyser Basin, 2001-2002 – Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Area	West Thumb Geyser Basin	West Thumb Geyser Basin	West Thumb Geyser Basin
Name and/or site description	Lakeshore Geyser	Unnamed pool	Seismograph Pool
Sample code number	01WA173	01WA174	01WA172
Date collected	9/18/2001	9/18/2001	9/18/2001
Time collected	12:50	14:10	11:50
Temperature, °C	91.8	---	75.9
pH (field / laboratory)	7.31 / 8.63	7.50 / 8.64	7.87 / 8.78
pH, selected	7.31	7.50	7.87
Specific conductance (field / laboratory), µS/cm	1770 / 1905	--- / 2150	1920 / 1999
Eh, V	-0.055	---	0.128
Density, g/mL at 20°C	0.99931	0.99937	0.99949
Dissolved oxygen (DO), mg/L	---	---	---
Constituent, mg/L[1]			
Calcium (Ca)	1.47	1.45	0.514
Magnesium (Mg)	0.280	0.170	0.017
Strontium (Sr)	0.011	0.005	0.005
Barium (Ba)	0.003	0.004	0.003
Sodium (Na)	417	454	443
Potassium (K)	18.9	19.3	19.2
Lithium (Li)	2.94	3.94	3.26
Sulfate (SO_4)	44.2	99.5	45.3
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mM / n	<0.002	<0.002	<0.002
Hydrogen sulfide (H_2S)	0.042	---	0.005
Alkalinity (HCO_3)	532	559	554
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---
Fluoride (F)	25.6	28.0	28.7
Chloride (Cl)	285	314	307
Bromide (Br)	0.9	1.0	1.0
Nitrate (NO_3)	<0.1	<0.1	0.2
Nitrite (NO_2)	0.0211	0.0455	0.0362
Ammonium (NH_4)	<0.04	<0.04	<0.04
Silica (SiO_2)	232	427	256
Boron (B)	3.59	3.90	3.75
Aluminum (Al)	0.09	<0.07	0.16
Iron total (Fe(T))	0.002	0.012	0.004
Ferrous iron (Fe(II))	<0.002	<0.002	<0.002
Manganese (Mn)	0.012	0.048	0.001
Copper (Cu)	<0.0005	0.105	<0.0005
Zinc (Zn)	<0.001	0.036	0.005
Cadmium (Cd)	0.0001	0.0002	0.0001
Chromium (Cr)	<0.0005	<0.0005	0.0007
Cobalt (Co)	<0.0007	<0.0007	<0.0007
Mercury (Hg), ng/L	---	---	---
Nickel (Ni)	<0.002	0.006	<0.002
Lead (Pb)	0.0013	0.0018	0.0011
Beryllium (Be)	0.002	0.002	0.002
Vanadium (V)	<0.002	<0.002	<0.002
Molybdenum (Mo)	---	---	---
Antimony (Sb)	0.146	0.153	0.148
Selenium (Se)	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.76	2.09	1.80
Arsenite (As(III))	1.76	0.0335	0.0354
Dissolved organic carbon (DOC)	2.0	1.7	1.7
δD, per mil	-138	-116	-137
$\delta^{18}O$, per mil	-14.5	-7.6	-14.1
sum cations, meq/L	19.0	20.8	20.1
sum anions, meq/L	18.9	21.5	20.1
Charge imbalance, percent	0.5	-3.4	0.0

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

Table 10. Results of water analyses for Brimstone Basin, 2001-2002

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemans per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Name and/or site description	Alluvium Creek	Alluvium Creek	Tributary To Alluvium Creek	Alluvium Creek	Alluvium Creek - downstream of Thorofare Trail
Sample code number	01WA147	01WA148	01WA149	01WA150	01WA171
Date collected	9/17/2001	9/17/2001	9/17/2001	9/17/2001	9/17/2001
Time collected	11:30	12:00	12:40	14:05	15:00
Temperature, °C	13.2	16.3	13.3	21.6	9.5
pH (field / laboratoryoratory)	2.06 / 2.08	2.72 / 2.84	1.72 / 1.75	2.10 / 2.07	2.58 / 2.64
pH, selected	2.06	2.72	1.72	2.10	2.58
Specific conductance (field / laboratoryoratory), µS/cm	5520 / 5250	2430 / 2490	9640 / 9200	5480 / 5650	2460 / 2430
Eh, V	0.560	0.672	0.520	0.733	0.740
Density, g/mL at 20°C	0.99983	0.99998	1.00002	1.00071	0.99970
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	93.9	118	42.9	110	73.0
Magnesium (Mg)	120	170	52.0	130	63.0
Strontium (Sr)	0.760	0.970	0.450	1.30	1.10
Barium (Ba)	0.011	0.013	0.008	0.011	0.011
Sodium (Na)	22.6	29.3	18.1	42.5	35.3
Potassium (K)	17.0	17.9	16.7	31.1	16.6
Lithium (Li)	0.044	0.058	0.022	0.048	0.027
Sulfate (SO_4)	1710	1400	2120	2220	1360
Thiosulfate (S_2O_3)	---	---	---	---	---
Polythionate (S_nO_6), mM / n	---	---	---	---	---
Hydrogen sulfide (H_2S)	---	---	---	---	---
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	13.7 / 19.3	2.42 / 8.37	30.3 / 35.9	14.6 / 26.6	3.56 / 16.7
Fluoride (F)	0.24	0.24	0.14	0.22	0.18
Chloride (Cl)	3.1	3.3	3.9	3.6	2.6
Bromide (Br)	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate (NO_3)	<0.1	<0.1	0.1	<0.1	0.4
Nitrite (NO_2)	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Ammonium (NH_4)	<0.04	<0.04	<0.04	<0.04	<0.04
Silica (SiO_2)	80.8	80.4	81.9	97.8	120
Boron (B)	0.03	0.03	0.01	0.02	0.01
Aluminum (Al)	38.7	39.6	44.2	102	113
Iron total (Fe(T))	8.51	11.1	5.20	19.8	12.0
Ferrous iron (Fe(II))	6.22	7.16	5.01	1.90	0.156
Manganese (Mn)	2.20	3.00	1.07	2.11	1.43
Copper (Cu)	0.0032	0.0065	<0.0005	<0.0005	0.0095
Zinc (Zn)	0.048	0.035	0.039	0.063	0.076
Cadmium (Cd)	0.0002	0.0003	0.0002	0.0002	0.0002
Chromium (Cr)	0.174	0.257	0.105	0.376	0.393
Cobalt (Co)	0.0037	0.0059	0.0009	0.0061	0.0157
Mercury (Hg), ng/L	---	---	---	---	---
Nickel (Ni)	0.015	0.022	0.005	0.024	0.048
Lead (Pb)	<0.0008	<0.0008	<0.0008	0.0009	<0.0008
Beryllium (Be)	0.002	0.003	0.001	0.003	0.002
Vanadium (V)	0.046	0.049	0.036	0.094	0.031
Molybdenum (Mo)	---	---	---	---	---
Antimony (Sb)	0.004	0.004	0.002	0.004	0.003
Selenium (Se)	0.003	0.003	0.002	0.004	0.005
Arsenic total (As(T))	0.0006	0.0002	0.0001	0.0003	<0.0001
Arsenite (As(III))	0.0006	<0.0005	<0.0005	<0.0005	<0.0005
Dissolved organic carbon (DOC)	3.3	2.8	3.8	3.7	1.4
δD, per mil	-140	-139	-140	-134	-139
$\delta^{18}O$, per mil	-23.9	-23.8	-23.8	-21.3	-20.2
sum cations, meq/L	24.2	20.5	30.7	28.8	18.9
sum anions, meq/L	25.1	20.0	31.0	29.6	19.3
Charge imbalance, percent	-3.4	2.2	-0.9	-2.9	-1.6

[1] Except for acidity (mM), mercury (ng/L), polythionate (mM), and δD and $\delta^{18}O$ (per mil)

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APPENDIX 1. QUALITY ASSURANCE AND QUALITY CONTROL

QUALITY ASSURANCE AND QUALITY CONTROL

Several techniques were used to assure the quality of the analytical data. These techniques include use of C.I., USGS standard reference water samples (SRWS), replicate analyses, a field blank, spike recoveries, and determination by alternative analytical methods.

Seventy-seven samples were analyzed for major cations and anions and the data were checked for C.I. using the geochemical code WATEQ4F (Ball and Nordstrom, 1991). WATEQ4F uses equation 4 to calculate C.I.:

$$C.I.(percent) = \frac{100 \times (\text{sum cations} - \text{sum anions})}{(\text{sum cations} + \text{sum anions})/2} \quad (4)$$

where sum cations and sum anions are in milliequivalents per liter.

The C.I. is calculated on the speciated results, not the raw analytical data, because C.I. is dependent on speciation especially for acidic solutions. The C.I., sum cations (meq/L), and sum anions (meq/L) are reported in tables 5-10 for samples having major cation and anion determinations. A frequency plot of C.I. for all samples with complete analyses is shown in figure 22. The Gaussian fit C.I. mean is –1.1 percent with a standard deviation of 3.7 percent. Analyses having a C.I. less than ±10 percent are considered to be reliable for speciation calculations. One sample analysis, out of 77, had a C.I. (-12 percent) greater than 10 percent.

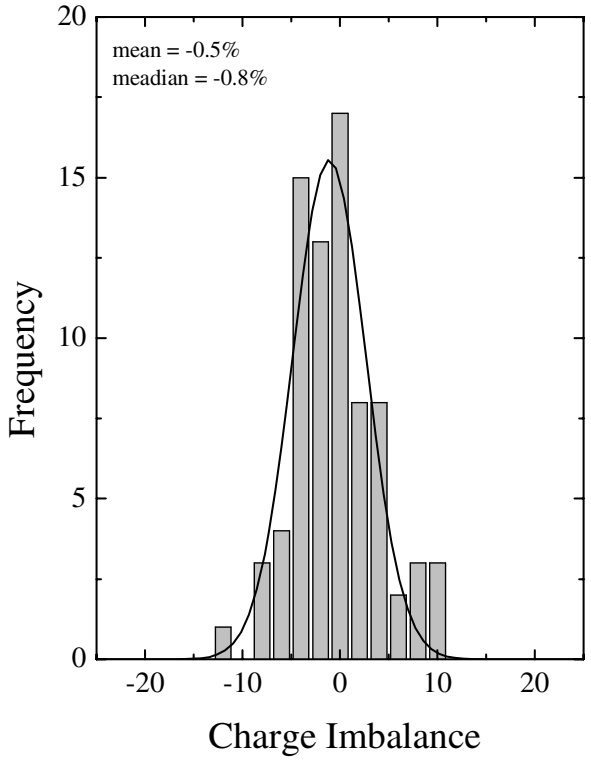


Figure 22. Frequency of charge imbalance for samples having major cation and anion determinations.

U.S. Geological Survey SRWSs were analyzed as unknowns along with the samples to check for accuracy. Standard reference water samples AMW4, T159, and T163 were used to check the analytical methods for major and trace metals, SRWS M102, M124, M134, M136, M142, M150 and M156 were used to check the analytical methods for major anions, and SRWS Hg7, Hg15, Hg22 and Hg26 were used for quality control of the mercury determinations (Farrar, 2000; Connor and others, 2001). The SRWSs were analyzed several times during each analytical run. Analytical results for the SRWSs, the most probable value (MPV) for each constituent, and the percent difference are reported in table 11. Additional information about the USGS SRWS program can be obtained at URL http://bqs.usgs.gov/srs.

A field blank was analyzed with the samples to detect environmental and laboratory contamination. The blank was collected by taking a 1-L bottle of double-distilled water to the field and processing it in the same manner as a sample. The field blank data are reported in table 12.

Spike recoveries were performed by spiking samples from Cinder Pool and Pork Chop Geyser with an ICP-OES mixed-element standard and analyzing them along with the other samples. Concentrations of B, K, Li, Na, and SiO_2 were higher than the calibration and are not reported. Recoveries for all other elements ranged from 82 to 105 percent (table 13).

Concentrations of F, As(T), Fe(T), Cd, Co, Cr, Cu, Pb, and Se were determined by more than one method. Comparing analytical results from alternative methods can serve as an accuracy check. However, one method is generally better than the other depending on sample matrix and proximity to the method detection limit. Concentrations of As(T), Fe(T), Cd, Co, Cr, Cu, Pb, and Se were determined by ICP-OES as well as by the preferred HGAAS method for As(T), FerroZine method for Fe(T), and GFAAS for Cd, Co, Cr, Cu, Pb, and Se. Concentrations of Cd, Co, Cr, Cu, Pb, and Se were near or below the ICP-OES detection limit for nearly all the samples. Therefore, comparison with the preferred method was of little value. Comparison of analytical results from alternative methods for F, total dissolved As, and total dissolved Fe are shown in figures 23 A-C. Fluoride was determined by both ion chromatography and ion-selective electrode (fig. 23A). Fluoride determined by ion chromatography is susceptible to errors owing to the water-dip, irresolvable organic-acid peaks, and shifts in retention times caused by high concentrations of chloride or sulfate. These samples often could not be diluted because doing so would dilute F below its quantitation limit. For As, the concentrations determined by HGAAS and ICP-OES are in good agreement. There are two samples that have very different Fe concentrations, 01WA108 and 02WA125, when comparing the two methods; however, the analyses are from two different sample bottles (one preserved with HCl and one with HNO_3). The results for the sample preserved with HCl are reported because the redox species are obtained from this spilt and contamination will most likely increase the concentration as is the case for the HNO_3 sample. The uncertainty was calculated based on the method with the higher detection limit. At the method detection limit the uncertainty is ±100 percent and decreases to ±5 percent at 20 times the detection limit (quantitation limit). Considering the uncertainty of the measurements, analytical results for total dissolved As and total dissolved Fe obtained by both alternative methods are in good agreement.

Table 11. Measurement of standard reference water samples

[GFAAS, graphite furnace atomic absorption spectrometry; HGAAS, hydride generation atomic absorption spectrometry; ICP-OES, inductively coupled plasma-optical emission spectrometry; ISE, ion selective electrode; mg/L, milligrams per liter; n, number of analyses; ng/L, nanograms per liter; s, standard deviation; SRWS, standard reference water sample; USGS, U.S. Geological Survey; %RSD, percent relative standard deviation; <, less than; ---, no data]

Analyte	Analytical Method	USGS SRWS	n	Mean, mg/L[1]	s	%RSD	Most Probable Value, mg/L	Percent Difference
Calcium (Ca)	ICP-OES	T159	14	25.6	0.259	1	25.5	0.3
Calcium (Ca)	ICP-OES	T163	14	6.45	0.081	1	6.3	2.4
Calcium (Ca)	ICP-OES	M156	14	31.3	1.930	6	30.2	3.6
Magnesium (Mg)	ICP-OES	T159	14	5.41	0.10	2	5.6	-3.3
Magnesium (Mg)	ICP-OES	T163	14	1.29	0.03	2	1.23	4.5
Magnesium (Mg)	ICP-OES	M156	14	6.98	0.61	9	6.92	0.8
Strontium (Sr)	ICP-OES	T159	14	0.191	0.004	2	0.19	0.8
Strontium (Sr)	ICP-OES	T163	14	0.036	0.001	3	0.0355	2.3
Strontium (Sr)	ICP-OES	M156	14	0.251	0.009	4	0.239	5.1
Barium (Ba)	ICP-OES	T159	14	0.0381	0.0010	3	0.0381	0.0
Barium (Ba)	ICP-OES	T163	14	0.0075	0.0006	8	0.0074	1.6
Sodium (Na)	ICP-OES	T159	14	98.2	4.3	4	100	-1.8
Sodium (Na)	ICP-OES	T163	14	38.2	0.8	2	39.6	-3.4
Sodium (Na)	ICP-OES	M156	14	44.8	1.4	3	44.6	0.5
Potassium (K)	ICP-OES	T159	14	1.80	0.07	4	1.52	18.7
Potassium (K)	ICP-OES	T163	14	1.06	0.04	4	1.02	3.7
Potassium (K)	ICP-OES	M156	14	2.35	0.13	5	2.13	10.5
Lithium (Li)	ICP-OES	T159	14	0.0101	0.0007	7	0.00857	17.8
Lithium (Li)	ICP-OES	T163	14	<0.003	---	---	0.0016	---
Sulfate (SO_4)	IC	M124	3	601	11	2	621	-3.2
Sulfate (SO_4)	IC	M136	2	147	5	3	150	-1.8
Sulfate (SO_4)	IC	M142	3	233	4	2	231	0.9
Sulfate (SO_4)	IC	M150	2	4.6	0.3	7	5.5	-16.5
Sulfate (SO_4)	IC	M156	16	42.1	2	4	43	-2.1
Alkalinity (HCO_3)	Titration	M102	1	231	---	---	214.6	7.5
Alkalinity (HCO_3)	Titration	M134	3	76.3	0.2	0	76.7	-0.5
Alkalinity (HCO_3)	Titration	M156	1	76.9	---	---	75.4	2.0
Fluoride (F)	IC	M150	2	0.923	0.18	19	1	-7.7
Fluoride (F)	IC	M156	8	0.592	0.12	20	0.523	13.1
Fluoride (F)	ISE	M150	1	1.12	---	---	1	12.0

Table 11. Measurement of standard reference water samples – Continued

[GFAAS, graphite furnace atomic absorption spectrometry; HGAAS, hydride generation atomic absorption spectrometry; ICP-OES, inductively coupled plasma-optical emission spectrometry; ISE, ion selective electrode; mg/L, milligrams per liter; n, number of analyses; ng/L, nanograms per liter; s, standard deviation; SRWS, standard reference water sample; USGS, U.S. Geological Survey; %RSD, percent relative standard deviation; <, less than; ---, no data]

Analyte	Analytical Method	USGS SRWS	n	Mean, mg/L[1]	s	%RSD	Most Probable Value, mg/L	Percent Difference
Chloride (Cl)	IC	M124	3	83.3	0.6	1	82.8	0.6
Chloride (Cl)	IC	M142	3	136	3.3	2	132	2.9
Chloride (Cl)	IC	M150	2	19.8	1.8	9	17	16.5
Chloride (Cl)	IC	M156	9	65.6	1.1	2	64.7	1.4
Silica (SiO_2)	ICP-OES	T159	14	11.8	0.3	3	11.5	2.8
Silica (SiO_2)	ICP-OES	T163	14	4.69	0.15	3	4.56	2.8
Silica (SiO_2)	ICP-OES	M156	14	5.40	0.32	6	4.73	14.1
Boron (B)	ICP-OES	T159	14	0.0275	0.0045	17	0.0264	4.0
Boron (B)	ICP-OES	T163	13	<0.01	---	---	0.0106	---
Boron (B)	ICP-OES	M156	14	0.0854	0.0057	7	0.0786	8.6
Aluminum (Al)	ICP-OES	T159	14	<0.07	---	---	0.0319	---
Aluminum (Al)	ICP-OES	T163	14	<0.07	---	---	0.0168	---
Iron total (Fe(T))	ICP-OES	T159	14	0.0494	0.0027	5	0.0489	1.0
Iron total (Fe(T))	ICP-OES	T163	14	0.0611	0.0022	4	0.06	1.9
Iron total (Fe(T))	FerroZine	AMW4	3	193	0.6	0	188	2.4
Iron total (Fe(T))	FerroZine	T163	2	0.0605	0.0003	0	0.060	0.8
Manganese (Mn)	ICP-OES	T159	14	0.0227	0.0008	4	0.022	3.2
Manganese (Mn)	ICP-OES	T163	14	0.0163	0.0007	4	0.0158	2.9
Copper (Cu)	GFAAS	T159	6	0.0342	0.0012	3	0.0334	2.4
Copper (Cu)	ICP-OES	T159	14	0.0340	0.0011	3	0.0334	1.7
Copper (Cu)	ICP-OES	T163	14	0.0369	0.0023	6	0.0358	3.1
Zinc (Zn)	ICP-OES	T159	14	0.0204	0.0013	6	0.0192	6.2
Zinc (Zn)	ICP-OES	T163	14	0.0203	0.0012	6	0.0185	9.7
Cadmium (Cd)	GFAAS	T163	8	0.0066	0.0002	2	0.00659	0.3
Cadmium (Cd)	ICP-OES	T159	14	0.0252	0.0008	3	0.024	5.1
Cadmium (Cd)	ICP-OES	T163	14	0.0070	0.0004	5	0.00659	6.5
Chromium (Cr)	GFAAS	T163	7	0.0400	0.0007	2	0.0401	-0.3
Chromium (Cr)	ICP-OES	T159	14	0.0268	0.0012	5	0.0268	0.1
Chromium (Cr)	ICP-OES	T163	14	0.0417	0.0019	5	0.0401	4.0
Cobalt (Co)	GFAAS	T159	6	0.0136	0.0005	3	0.0133	2.3
Cobalt (Co)	ICP-OES	T159	14	0.0138	0.0026	19	0.0133	4.0
Cobalt (Co)	ICP-OES	T163	11	0.0121	0.0012	10	0.012	0.7

Table 11. Measurement of standard reference water samples – Continued

[GFAAS, graphite furnace atomic absorption spectrometry; HGAAS, hydride generation atomic absorption spectrometry; ICP-OES, inductively coupled plasma-optical emission spectrometry; ISE, ion selective electrode; mg/L, milligrams per liter; n, number of analyses; ng/L, nanograms per liter; s, standard deviation; SRWS, standard reference water sample; USGS, U.S. Geological Survey; %RSD, percent relative standard deviation; <, less than; ---, no data]

Analyte	Analytical Method	USGS SRWS	n	Mean, mg/L[1]	s	%RSD	Most Probable Value, mg/L	Percent Difference
Mercury (Hg), ng/L	CVAFS	Hg7	12	266[1]	29	11	220[1]	20.9
Mercury (Hg), ng/L	CVAFS	Hg22	12	1180[1]	53	4	1240[1]	-4.8
Mercury (Hg), ng/L	CVAFS	Hg26	12	710[1]	74	10	700[1]	1.4
Mercury (Hg), ng/L	CVAFS	Hg15	12	380[1]	29	8	410[1]	-7.3
Nickel (Ni)	ICP-OES	T159	14	0.0224	0.0023	10	0.0222	0.9
Nickel (Ni)	ICP-OES	T163	14	0.0163	0.0020	13	0.0154	5.6
Lead (Pb)	GFAAS	T159	7	0.0160	0.0015	9	0.0166	-3.6
Lead (Pb)	ICP-OES	T159	14	0.0166	0.0023	14	0.0166	-0.3
Lead (Pb)	ICP-OES	T163	14	0.0325	0.0020	6	0.032	1.7
Beryllium (Be)	ICP-OES	T159	14	0.0110	0.0007	7	0.0108	2.1
Beryllium (Be)	ICP-OES	T163	14	0.0234	0.0008	4	0.022	6.3
Vanadium (V)	ICP-OES	T159	14	0.0136	0.0007	5	0.0144	-5.6
Vanadium (V)	ICP-OES	T163	14	0.0350	0.0008	2	0.035	-0.1
Vanadium (V)	ICP-OES	M156	14	0.0090	0.0009	10	0.00953	-5.3
Molybdenum (Mo)	ICP-OES	T159	3	0.0383	0.0012	3	0.0414	-7.5
Molybdenum (Mo)	ICP-OES	T163	5	0.0108	0.0014	13	0.0126	-14.0
Antimony (Sb)	GFAAS	T159	8	0.0135	0.0008	6	0.0139	-3.2
Antimony (Sb)	GFAAS	T163	8	0.0324	0.0038	12	0.0325	-0.3
Selenium (Se)	GFAAS	T159	23	0.0053	0.0005	10	0.00549	-3.8
Selenium (Se)	GFAAS	T163	16	0.0090	0.0011	12	0.00888	1.2
Arsenic total (As(T))	ICP-OES	T159	14	0.0281	0.0141	50	0.0284	-0.9
Arsenic total (As(T))	ICP-OES	T163	14	0.0270	0.0111	41	0.0253	6.8
Arsenic total (As(T))	HGAAS	AMW4	28	0.170	0.003	2	0.168	1.1
Arsenic total (As(T))	HGAAS	T159	27	0.0260	0.0011	4	0.0284	-8.6

[1] Except for Mercury (ng/L)

Table 12. Water analyses for field blank

[DI, deionized water; mg/L, milligrams per liter; mM, millimolar; ng/L, nanograms per liter; ---, not measured or analyzed]

Description	Field Blank
Date collected	6/30/2002
Constituent, mg/L[1]	
Calcium (Ca)	<0.1
Magnesium (Mg)	<0.001
Strontium (Sr)	<0.0003
Barium (Ba)	<0.001
Sodium (Na)	<0.1
Potassium (K)	0.011
Lithium (Li)	<0.001
Sulfate (SO_4)	<1
Thiosulfate (S_2O_3)	<0.1
Polythionate (S_nO_6), mM	<0.002
Alkalinity (as HCO_3)	---
Fluoride (F)	<0.1
Chloride (Cl)	0.8
Bromide (Br)	<0.1
Nitrate (NO_3)	<0.1
Nitrite (NO_2)	<0.0003
Ammonium (NH_4)	<0.04
Silica (SiO_2)	<0.05
Boron (B)	<0.01
Aluminum (Al)	<0.07
Iron total (Fe(T))	<0.002
Ferrous iron (Fe(II))	<0.002
Manganese (Mn)	<0.002
Copper (Cu)	<0.005
Zinc (Zn)	<0.004
Cadmium (Cd)	<0.001
Chromium (Cr)	<0.003
Cobalt (Co)	<0.003
Mercury (Hg), ng/L	3.1 (DI 3.2)
Nickel (Ni)	<0.003
Lead (Pb)	<0.006
Beryllium (Be)	<0.001
Vanadium (V)	<0.002
Molybdenum (Mo)	<0.007
Selenium (Se)	<0.05
Arsenic total (As(T))	<0.0001
Arsenite (As(III))	<0.0005
Dissolved organic carbon (DOC)	1.1

Table 13. Spike recovery results

Analyte	Pork Chop Geyser	Cinder Pool
	----------Percent Recovery----------	
Aluminum (Al)	89	95
Barium (Ba)	97	97
Beryllium (Be)	90	82
Cadmium (Cd)	91	86
Calcium (Ca)	93	92
Chromium (Cr)	94	80
Cobalt (Co)	84	85
Copper (Cu)	87	91
Iron total (Fe(T))	88	87
Lead (Pb)	88	82
Magnesium (Mg)	82	85
Molybdenum (Mo)	94	85
Manganese (Mn)	95	84
Nickel (Ni)	92	83
Strontium (Sr)	89	88
Vanadium (V)	82	82
Zinc (Zn)	105	87

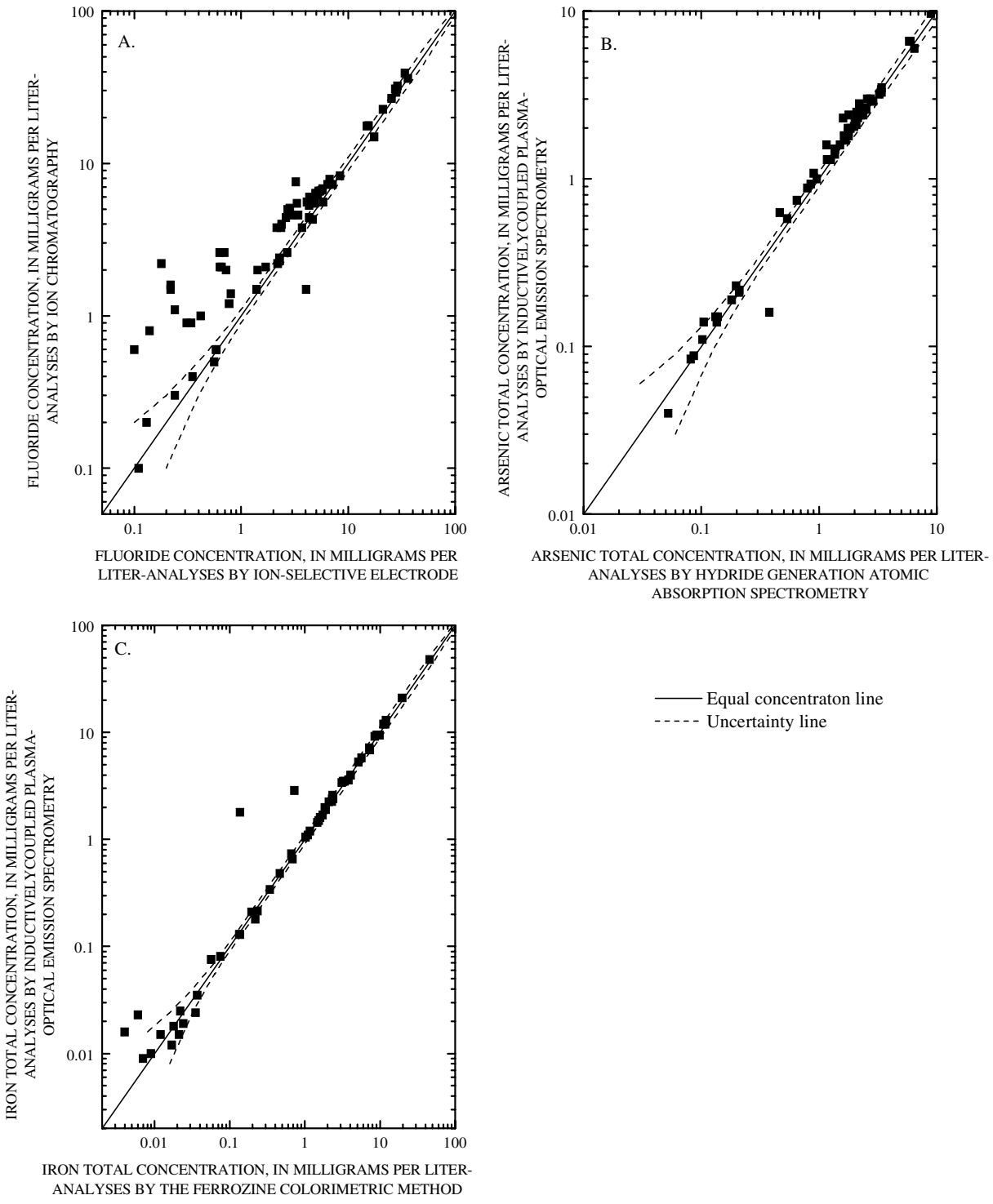


Figure 23. Fluoride (A), total dissolved arsenic (B), and total dissolved iron (C) concentrations determined by alternative methods.

APPENDIX 2. SAMPLE SITE PHOTOGRAPHS

USGS scientists Kirk Nordstrom and Blaine McCleskey sampling site 01WA101/01WA124/01WA167, Nymph Lake and Roadside Springs area

Teflon block attached to end of sampling tube was used as a weight, 01WA102 / 01WA125 / 01WA166, Nymph Lake and Roadside Springs area

JoAnn Holloway sampling site 01WA103, Nymph Lake and Roadside Springs area

Kirk Nordstrom and JoAnn Holloway sampling site 01WA104, Nymph Lake and Roadside Springs area

01WA105 / 01WA126 / 02WA134, Cinder Pool, Norris Geyser Basin

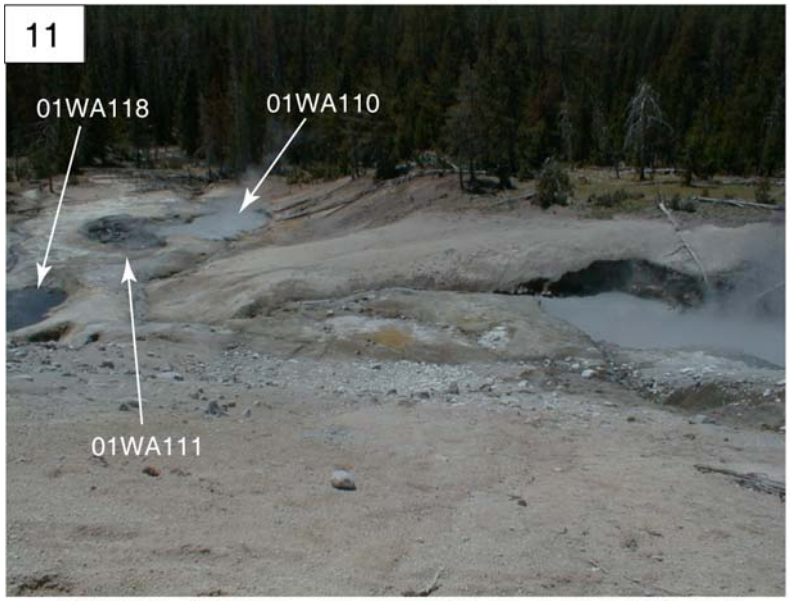
01WA106 / 01WA132 / 02WA128, Norris Geyser Basin

Sara LoVetere, Kirk Nordstrom, and Blaine McCleskey sampling
01WA107 / 01WA131 / 02WA130, Norris Geyser Basin

01WA108 / 02WA129, Norris Geyser Basin

Sara LoVetere measuring specific conductance at 01WA109, Norris Geyser Basin

01WA110, Washburn Hot Springs



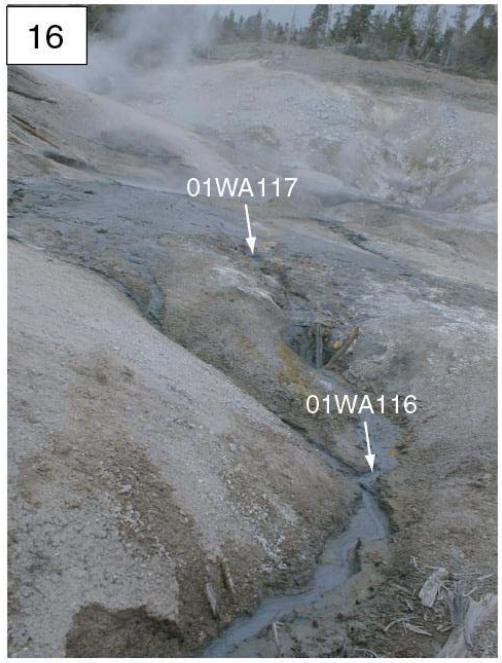
01WA110, 01WA111, and 01WA118, Washburn Hot Springs

01WA112, Crater Hills

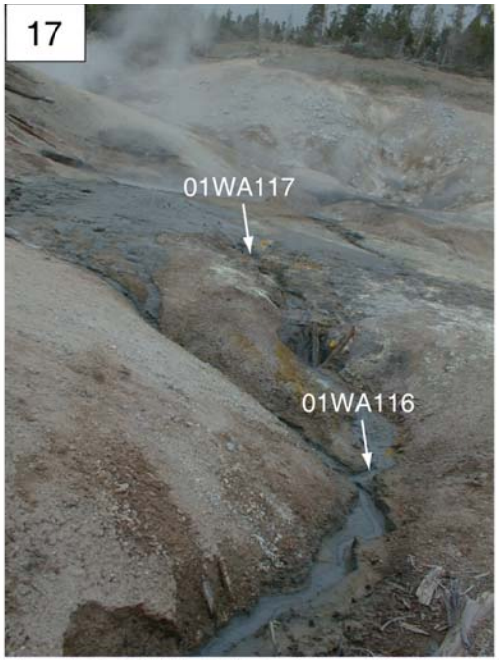
Sara LoVetere at 01WA113, Sulphur Spring, Crater Hills

01WA115, Washburn Hot Springs

01WA114, Sulphur Creek, Washburn Hot Springs

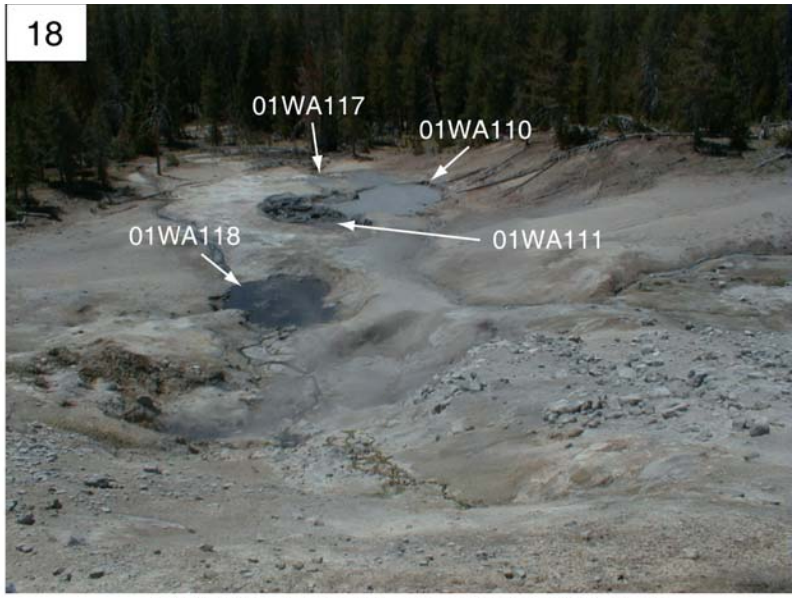


01WA116, Washburn Hot Springs drainage



01WA117, ink pot #1 (01WA110) drainage, Washburn Hot Springs

01WA119 / 01WA 128 / 02WA141, Cistern Spring, Norris Geyser Basin



01WA118, ink pot #3, Washburn Hot Springs

01WA120, Nymph Creek, Nymph Creek and Roadside Springs area

01WA121, Nymph Creek, Nymph Creek and Roadside Springs area

01WA122, Nymph Creek, Nymph Creek and Roadside Springs area

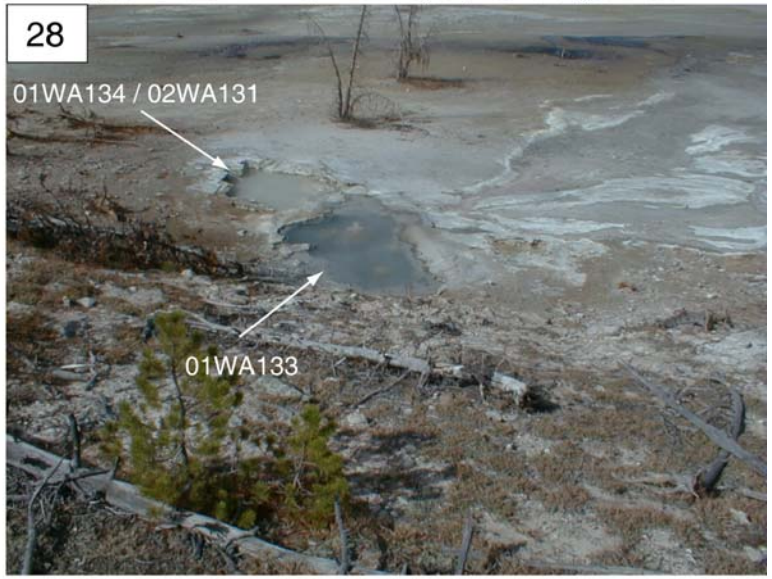
JoAnn Holloway and Kirk Nordstrom at 01WA123, Nymph Creek, Nymph Creek and Roadside Springs area

Jim Ball sampling at 01WA126, Cinder Pool, Norris Geyser Basin

Jim Ball sampling at 01WA127, Bathtub Spring, Norris Geyser Basin

Jim Ball, Blaine McCleskey, and JoAnn Holloway of the U.S. Geological Survey, Park Service volunteer Virginia Rodriguez, Spanish visiting scientist Maria Hernandez, and Park Rangers Bob and Lori Spoelhof at 01WA129, Vixen Geyser, Norris Geyser Basin

Kirk Nordstrom sampling at 01WA130, Tantalus Creek, Norris Geyser Basin



01WA133 and 01WA134, Norris Geyser Basin

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Blaine McCleskey measuring dissolved hydrogen sulfide concentration at 01WA135, Perpetual Spouter, Norris Geyser Basin

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Blaine McCleskey at 01WA135, Kirk Nordstrom taking a global positioning system reading at 01WA136, Norris Geyser Basin

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01WA137 / 02WA136, Pork Chop Geyser, Norris Geyser Basin

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Kirk Nordstrom taking a global positioning system reading at 01WA138, Norris Geyser Basin

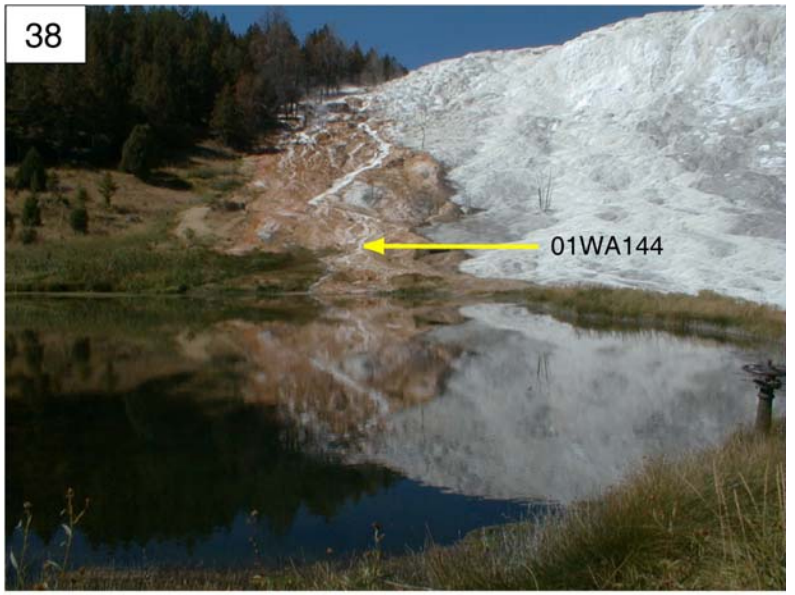
01WA139, Orpiment Spring, Norris Geyser Basin

01WA140, Recess Spring, Norris Geyser Basin

01WA141, Hydrophane Spring, Norris Geyser Basin

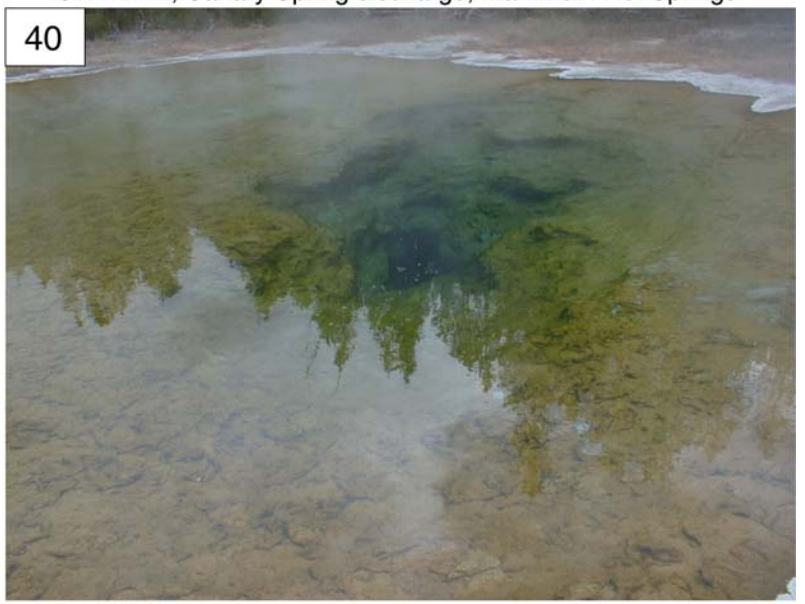
01WA142, Steamboat Geyser, Norris Geyser Basin

Kirk Nordstrom and JoAnn Holloway positioning the sample intake tubing 01WA143, Canary Spring, Mammoth Hot Springs

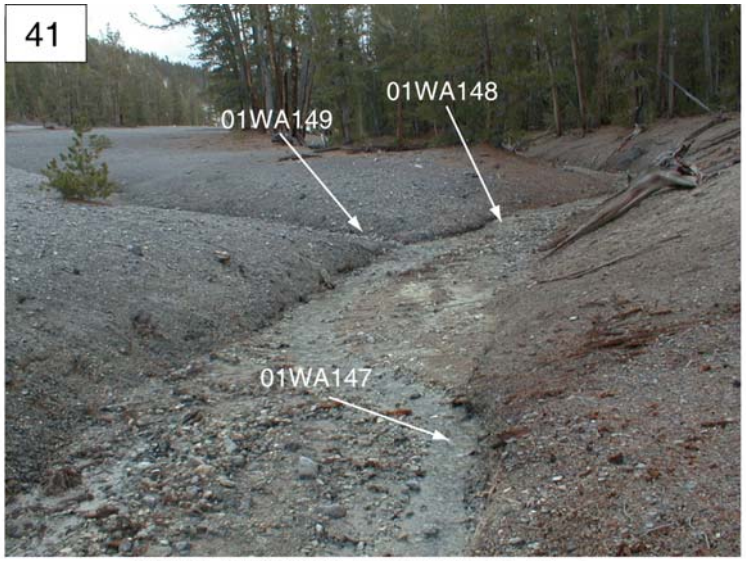


01WA144, Canary Spring discharge, Mammoth Hot Springs

Blaine McCleskey sampling at 01WA145, Octopus Spring, Lower Geyser Basin



01WA146, Mushroom Spring, Lower Geyser Basin



01WA147 / 01WA148 / 01WA149, Alluvium Creek Tributary confluence, Brimstone Basin

01WA150, Alluvium Creek at disappearance of flow, Brimstone Basin

01WA171, Alluvium Creek at reappearance of flow, Brimstone Basin

Spanish visiting scientist Maria Hernandez, U.S. Geological Survey scientist Blaine McCleskey, and unidentified park ranger at 01WA172, Seismograph Pool, West Thumb Geyser Basin

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JoAnn Holloway at 01WA173, Lakeshore Geyser,
West Thumb Geyser Basin

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01WA174, West Thumb Geyser Basin

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Miguel Cardona, JoAnn Holloway, and Blaine McCleskey
at 02WA125, Norris Geyser Basin

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Montana State University University Professor Bill Inskeep, JoAnn Holloway, German visiting scientist Britta Planer-Friedrich, Jim Ball, Blaine McCleskey, and Miguel Cardona at 02WA126, Norris Geyser Basin

02WA127, pond west of The Gap, Norris Geyser Basin

Blaine McCleskey and JoAnn Holloway sampling
at 02WA131, Norris Geyser Basin

02WA132, Norris Geyser Basin

02WA133, Norris Geyser Basin

Blaine McCleskey sampling at 02WA135,
Crystal Spring, Norris Geyser Basin

JoAnn Holloway recording data at 02WA137 and
02WA138, Nymph Lake and Roadside Springs

Peristaltic pump, gel battery, sample intake tubing, sampling pole,
and global positioning system receiver deployed for sampling
at 02WA139, Nymph Lake and Roadside Springs

Kirk Nordstrom setting up two peristaltic pumps for sampling at
02WA140, Bijah Spring, Nymph Lake and Roadside Springs

Blaine McCleskey sampling at 02WA142,
Black Pit Spring, Norris Geyser Basin

02WA144, Rediscovered Geyser, Norris Geyser Basin

02WA145, Ojo Caliente Spring, Lower Geyser Basin

Kirk Nordstrom and Jim Ball deploying sample intake
tubing at 02WA146, Azure Spring, Lower Geyser Basin

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Jim Ball and Blaine McCleskey sampling at
02WA147, Bath Spring, Lower Geyser Basin

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Sample intake tubing at 02WA148, Calcite Spring area

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Calcite Spring, upstream from 02WA148.

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