In cooperation with the Wyoming Department of Environmental Quality

Groundwater-Quality and Quality-Control Data for Two Monitoring Wells near Pavillion, Wyoming, April and May 2012

Data Series 718

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

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By Peter R. Wright, Peter B. McMahon, David K. Mueller, and Melanie L. Clark

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U.S. Geological Survey
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per hour (gal/h)	3.785	liter per hour (L/h)
	Concentration	
part per million (ppm)	1.0	milligram per liter (mg/L)
part per billion	1.0	microgram per liter (µg/L)

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) as follows:
°F=(1.8×°C)+32
°C=(°F-32)/1.8

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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

Concentrations of most chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations

$>$	greater than
$<$	less than
$\leq$	less than or equal to
±	plus or minus
ASR	Analytical Services Request (U.S. Geological Survey)
bls	below land surface
$\delta^{13}C$	ratio of carbon-13 to carbon-12 isotopes in the sample relative to the ratio in a reference standard
CFC	chlorofluorocarbon
COC	chain-of-custody
DRO	diesel-range organics
GRO	gasoline-range organics
^{3}H	tritium (hydrogen-3)
$\delta^{2}H$	ratio of hydrogen-2 to hydrogen-1 isotopes in the sample relative to the ratio in a reference standard
^{3}He	ratio of helium-3 to helium-4 isotopes in the sample relative to the ratio in a reference standard
^{3}He	helium-3
^{4}He	helium-4
HCl	hydrochloric acid
NWIS	National Water Information System (U.S. Geological Survey)
NWQL	National Water Quality Laboratory (U.S. Geological Survey)
PAHs	polycyclic aromatic hydrocarbons
QC	quality control
RPD	relative percent difference
SAP	sampling and analysis plan (U.S. Geological Survey)
SC	specific conductance
SF_6	sulfur hexafluoride
SVOC	semivolatile organic compound
TICs	tentatively identified compounds
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound
WDEQ	Wyoming Department of Environmental Quality

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Abstract

In June 2010, the U.S. Environmental Protection Agency installed two deep monitoring wells (MW01 and MW02) near Pavillion, Wyoming, to study groundwater quality. During April and May 2012, the U.S Geological Survey, in cooperation with the Wyoming Department of Environmental Quality, collected groundwater-quality data and quality-control data from monitoring well MW01 and, following well redevelopment, quality-control data for monitoring well MW02. Two groundwater-quality samples were collected from well MW01—one sample was collected after purging about 1.5 borehole volumes, and a second sample was collected after purging 3 borehole volumes. Both samples were collected and processed using methods designed to minimize atmospheric contamination or changes to water chemistry. Groundwater-quality samples were analyzed for field water-quality properties (water temperature, pH, specific conductance, dissolved oxygen, oxidation potential); inorganic constituents including naturally occurring radioactive compounds (radon, radium-226 and radium-228); organic constituents; dissolved gasses; stable isotopes of methane, water, and dissolved inorganic carbon; and environmental tracers (carbon-14, chlorofluorocarbons, sulfur hexafluoride, tritium, helium, neon, argon, krypton, xenon, and the ratio of helium-3 to helium-4). Quality-control sample results associated with well MW01 were evaluated to determine the extent to which environmental sample analytical results were affected by bias and to evaluate the variability inherent to sample collection and laboratory analyses. Field documentation, environmental data, and quality-control data for activities that occurred at the two monitoring wells during April and May 2012 are presented.

Introduction

Groundwater is the primary source of domestic water supply for the town of Pavillion, Wyoming, and its rural residential neighbors. On December 8, 2011, the U.S. Environmental Protection Agency (USEPA) released the draft report *Investigation of Ground Water Contamination near Pavillion, Wyoming* (U.S. Environmental Protection Agency, 2011) for public review. The report described and interpreted data collected for two USEPA monitoring wells from 2010 to 2011, and indicated that groundwater may contain chemicals associated with gas production practices. The Wyoming Department of Environmental Quality (WDEQ) wanted additional groundwater-quality samples collected from these USEPA monitoring wells and discussed this need with the U.S. Geological Survey (USGS) Wyoming Water Science Center. The monitoring wells are identified as wells MW01 and MW02. During April and May 2012, the USGS, in cooperation with the WDEQ, collected groundwater-quality and associated quality-control (QC) data from monitoring well MW01, and redeveloped and collected QC data from monitoring well MW02.

Both USEPA monitoring wells were installed during the summer of 2010 as part of a multi-phase investigation of groundwater quality in the Pavillion area (U.S. Environmental Protection Agency, 2011). Well MW01 was completed to a depth of 785 feet (ft) below land surface (bls) and well MW02 was completed to a depth of 980 ft bls. Both wells have a 20-ft screened interval. A dedicated submersible 3-horsepower pump was installed in each well. Detailed construction information for both wells is presented in the USEPA report (U.S. Environmental Protection Agency, 2011).

Well MW01 was purged and sampled by the USGS and USEPA on April 24, 2012. Only data collected by the USGS are presented in this report. The USGS collected two groundwater-quality (environmental) samples from well MW01—one sample was collected after purging about 1.5 borehole volumes of water from the well, and a second sample was collected after purging 3 borehole volumes. QC samples were collected in conjunction with both environmental samples from well MW01.

Using well hydraulic data collected in 2011, the USEPA estimated a yield of about 1 gallon per hour, or about 0.017 gallon per minute from well MW02 (U.S. Environmental Protection Agency, oral commun., 2012). Because of low yield, resulting in long recovery or purge times relative to the standard procedures and recommendations given in the

USGS National Field Manual (U.S. Geological Survey, variously dated), well MW02 was redeveloped by the USGS in an attempt to increase well yield. A description of the USGS efforts to redevelop well MW02 during the week of April 30, 2012, is provided in the *Sampling and Analysis Plan for the Characterization of Groundwater Quality in Two Monitoring Wells near Pavillion, Wyoming* (SAP) (Wright and McMahon, 2012). After well MW02 was redeveloped, well yield data were collected by the USEPA with assistance from the USGS. These data are described in the USGS SAP (Wright and McMahon, 2012). Well yield was not increased as a result of the redevelopment effort; consequently, well MW02 was not sampled for this study. Nevertheless, QC samples were collected to characterize water added to well MW02 during redevelopment, and to ensure that a downhole camera used to examine the well screen was clean. Analytical results for the QC samples associated with redevelopment of well MW02 are presented in this report.

Description of Study Area

The study area is in Fremont County near the town of Pavillion, Wyoming (fig. 1). This small, sparsely populated agricultural community of 231 people (U.S. Census Bureau, 2010) is composed primarily of large-acreage irrigated farms. Natural-gas development began in the area northeast of Pavillion in the early 1960s, increased in the 1980s, and in recent years has increased again, under a succession of different owner-operators (James Gores and Associates, 2011). The town of Pavillion and rural households in the area obtain their water supply from wells installed in the areally extensive, Tertiary-age (Eocene) Wind River Formation (James Gores and Associates, 2011) that underlies the town and adjacent areas.

Purpose and Scope

The purposes of this report are to present (1) the analytical results for groundwater-quality samples collected from USEPA well MW01 during April 2012; (2) analytical results for QC samples collected in association with sampling of well MW01 during April 2012; and (3) analytical results for QC samples collected in association with USGS redevelopment of USEPA well MW02 during May 2012. Methods used to collect and analyze the groundwater-quality and QC samples are described in the Methods section. Groundwater-quality samples were analyzed for field water-quality properties (water temperature, pH, specific conductance, dissolved oxygen, oxidation potential); inorganic constituents including naturally occurring radioactive compounds (radon, radium-226 and radium-228); organic constituents; dissolved gasses; stable isotopes of methane, water, and dissolved inorganic carbon; and environmental tracers [carbon-14, chlorofluorocarbons (CFCs), sulfur hexafluoride (SF_6), tritium (^3H), helium, neon, argon, krypton, and xenon , and the ratio of helium-3 to helium-4 isotopes in the sample relative to the ratio in a reference standard (δ^3He)].

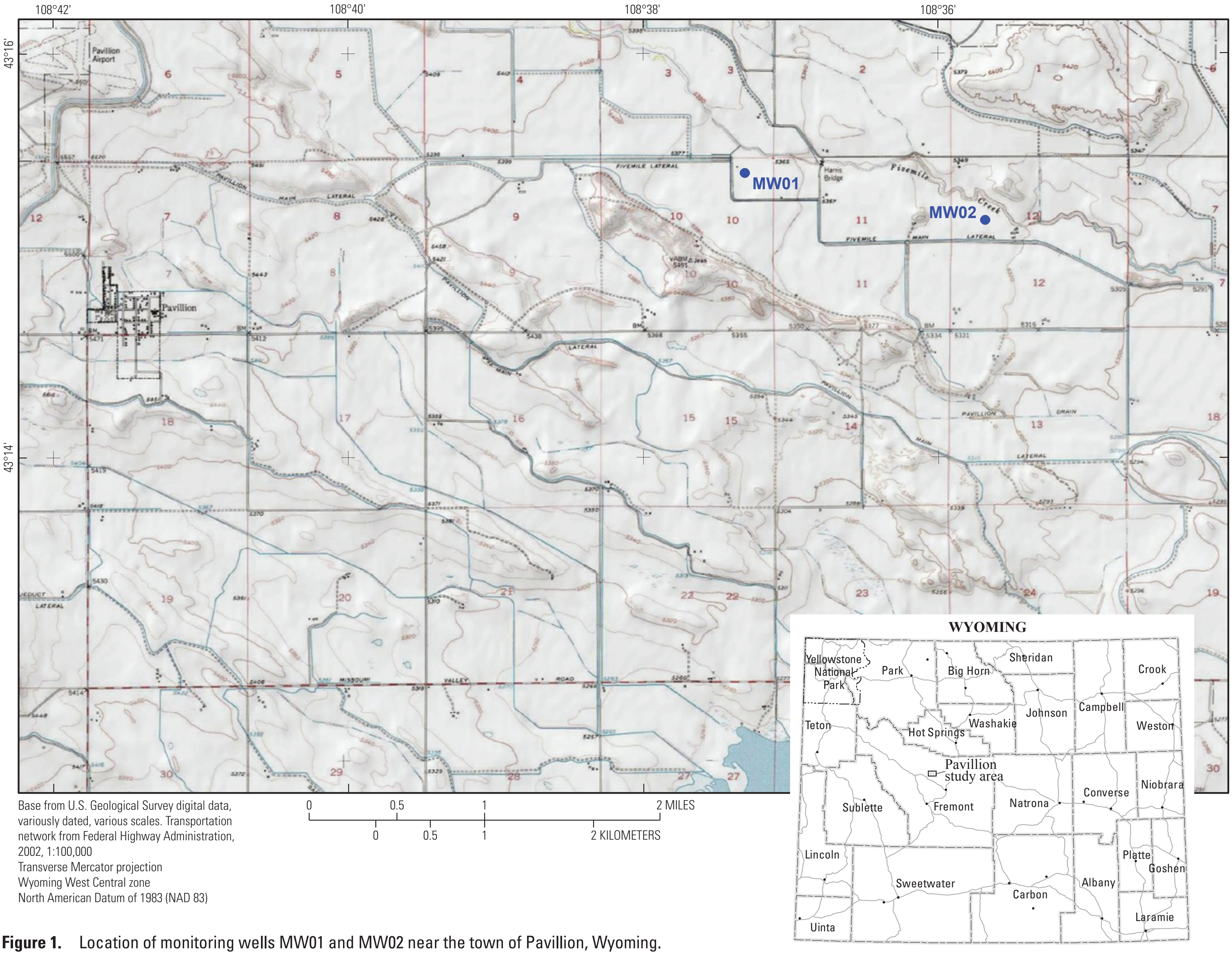
Methods

Samples collected during this study included two groundwater-quality samples from well MW01, several QC samples associated with well MW01, and two QC samples related to the redevelopment of well MW02. A brief description of the sampling design and sample collection at well MW01, the collection of QC samples related to well MW02 redevelopment, and methods used for laboratory and quality-control analyses are presented in this section.

Sampling Design

Groundwater-quality and QC samples were collected and processed using procedures described in the *Sampling and Analysis Plan for the Characterization of Groundwater Quality in Two Monitoring Wells near Pavillion, Wyoming* (SAP) (Wright and McMahon, 2012). A brief summary of the field sampling design described in the SAP is provided in this section.

Collection of two sets of groundwater-quality samples was planned for well MW01. The first sample set (environmental sample 1) was to be collected after one borehole volume of water was purged from the well. For this study, a borehole volume is defined as the wetted volume of unscreened casing plus the borehole volume throughout the screened interval, but excluding the volume of prepacked sand adjacent to the screened interval. An example of how the borehole volume was calculated is included in Wright and McMahon (2012). Sample collection also was contingent on stabilization of water temperature, specific conductance (SC), and pH of the water in successive field measurements. Stabilization of these properties was evaluated on the basis of the variability of five consecutive measurements made during a period of about 20 minutes at regularly timed intervals (Wilde, variously dated) (table 1). Water-quality properties are listed in table 1 (water temperature, SC, pH, dissolved oxygen, turbidity, and oxidation-reduction potential) that regularly are collected during groundwater sampling. Based on data USEPA had collected from well MW01, including low dissolved oxygen concentrations and excessive degassing in the sampling line, measurements of three of the properties (dissolved oxygen, turbidity, and oxidation-reduction potential) were thought to be less reliable than measurements of temperature, SC, and pH; therefore, the properties of dissolved oxygen, turbidity, and oxidation-reduction potential were not used as stabilization criteria. The second sample set (environmental sample 2) was to be collected after removal of three borehole volumes of water; sample collection was contingent on meeting the stabilization criteria for the same three field water-quality properties. In addition to the environmental samples, many different types of QC samples were proposed for the study. Three blank samples were scheduled to be collected before the well purge began (a source-solution blank, ambient blank, and a field blank), three replicate QC



Base from U.S. Geological Survey digital data, variously dated, various scales. Transportation network from Federal Highway Administration, 2002, 1:100,000
Transverse Mercator projection
Wyoming West Central zone
North American Datum of 1983 (NAD 83)

Figure 1. Location of monitoring wells MW01 and MW02 near the town of Pavillion, Wyoming.

samples were scheduled to be collected with each environmental sample (a replicate, matrix spike, and matrix-spike duplicate), and a trip blank traveled with sample bottles at all times. These QC sample types are defined in the SAP (Wright and McMahon, 2012).

Sample Collection at Monitoring Well MW01

On April 23 and 24, 2012, the USGS collected several blank samples, two groundwater-quality (environmental) samples, and several QC samples from monitoring well MW01 (table 2.) The USGS 15-digit site number and the date and time each sample was collected are shown in table 2. Sample collection generally followed the sampling design described in the SAP (Wright and McMahon, 2012), with a few modifications as described in this section. Documentation of field activities at monitoring well MW01 including field instrument calibration notes, general project notes, groundwater-quality notes for samples 1 and 2, purge logs, and alkalinity/acid-neutralizing capacity titration field notes are included in appendix 1 (figs. 1.1-1.4). As planned, three QC samples (source-solution blank, ambient blank, and field blank) were collected before beginning the well purge.

USEPA personnel measured the water level in well MW01 before and during the well purge using a sonic water-level meter. USEPA personnel also measured the pumping rate during the well purge. The pumping rate was measured using a flow meter and was verified using a bucket and a stopwatch.

Collection of environmental sample 1 and the associated QC samples was intended to begin after one borehole volume of water was purged from the well. Once a sufficient volume had been purged, sample collection started as soon as values for both SC and pH met stabilization criteria (table 1). The stabilization criterion for temperature was not used because the water line was exposed to solar heating and air temperature, so by the time water temperature was measured it was not a good indication of conditions in the well. Turbidity was not a stabilization criterion, and a turbidity sensor was not included on the multiparameter water-quality instrument. Only two turbidity measurements were made (sample aliquots collected from the sample discharge line and turbidity measured with a HACH 2100P meter; Hach Chemical Company, 2008) and noted on the purge log; both were very low, and were similar to each other. Values of SC met the criterion only briefly, but by then sampling had begun. Because it took longer for field water-quality properties of SC and pH to reach stability (based on criteria in table 1), collection of environmental sample 1 and associated QC samples actually began after about 1.5 borehole volumes had been purged from well MW01.

Table 1. Stabilization criteria and calibration guidelines for water-quality properties (modified from Wilde, variously dated).

[±, plus or minus value shown; °C, degrees Celsius; ≤, less than or equal to value shown; µS/cm, microsiemens per centimeter at 25°C; >, greater than value shown; NA, not applicable; NTRU, nephelometric turbidity ratio units; <, less than value shown; mg/L, milligrams per liter]

Water-quality property	Stabilization criteria[1] (variability should be within value shown)	Calibration guidelines
Temperature:		Calibrate annually, check calibration quarterly.
Thermistor	±0.2°C	
Specific conductance (SC):		Calibrate each morning and at end of each day. Check calibration at each additional site; recalibrate if not within 3 to 5 percent of standard value.
for ≤100 µS/cm at 25°C	±5 percent	
for >100 µS/cm at 25°C	±3 percent	
pH: (displays to 0.01 standard units)	±0.1 standard pH units. Allow ±0.3 pH units if drifting persists.	Calibrate each morning and at end of each day. Check calibration at each additional site; recalibrate if not within 0.05 pH units of standard .
Dissolved oxygen: Amperometric or optical/luminescent-method sensors	NA[2]	Calibrate each morning and at end of each day. If electrode uses a Teflon® membrane, inspect electrode for bubbles under membrane at each sample site; replace if necessary.
Turbidity:	NA[2]	Calibrate with a primary standard on a quarterly basis. Check calibration against secondary standards (HACH GELEX) each morning and at end of each day; recalibrate if not within 5 percent.
Oxidation-reduction potential	NA[2]	Check against Zobell's solution each morning and at end of each day. Recalibrate if not within ±5 millivolts.

[1] Allowable variation between five or more sequential field measurements.

[2] These field-measured properties were not used in this study as stabiliization criteria. However, the following criteria were still considered while evaluating other properties: for dissolved oxygen, ±0.2 to ±0.3 mg/L; for turbidity, ±0.5 NTRU or 5 percent of the measured value, whichever is greater when <100 NTRU; oxidation-reduction potential was not used as a stabilzation criterion; however, this property can provide useful information for groundwater studies.

Table 2. Environmental and quality-control samples collected for monitoring wells MW01 and MW02 near Pavillion, Wyoming, April and May 2012.

[USGS, U.S. Geological Survey; NWQL, National Water Quality Laboratory; IBW, inorganic free blank water; OWB, organic free blank water]

Sample	Sample collection date	Type of water	Assigned sample time
Well MW01 (431525108371901)			
Source-solution blank	4/23/2012	USGS NWQL certified IBW and OBW	2000
Ambient blank	4/24/2012	USGS NWQL certified IBW and OBW	0800
Field blank	4/24/2012	USGS NWQL certified IBW and OBW	0830
Primary environmental sample 1	4/24/2012	Environmental water	1330
Sample 1 replicate	4/24/2012	Environmental water	1331
Matrix spike	4/24/2012	Environmental water	1332
Matrix-spike duplicate	4/24/2012	Environmental water	1333
Trip blank	4/24/2012	Laboratory-prepared blank water	1334
Primary environmental sample 2	4/24/2012	Environmental water	1830
Sample 2 replicate	4/24/2012	Environmental water	1831
Well MW02 (431511108354101)			
Riverton development water	5/1/2012	City of Riverton public-supply system water	1000
Trip blank	5/1/2012	Laboratory-prepared blank water	1004
Camera blank	5/1/2012	USGS NWQL certified IBW and OBW	1700

In addition to collection of environmental sample 1, all the planned QC samples (replicate, matrix spike, and matrix-spike duplicate samples) were collected. Laboratory analyses for each sample are listed in table 3. Sample collection was sequential; collecting a full set of containers for each analytical method—first, the environmental sample was collected; then, the replicate sample was collected; finally, the matrix spike and matrix-spike duplicate were collected. All water samples sent to the TestAmerica, Eberline, Woods Hole Oceanographic Institute, and USGS Tritium laboratories were collected inside a sampling chamber (a polyvinyl chloride frame with a clear plastic bag mounted inside, reducing sample exposure to airborne contamination sources) located within a mobile water-quality laboratory. The sample for analysis of the ratio of carbon-13 to carbon-12 isotopes ($\delta^{13}C$) of dissolved inorganic carbon, sent to the USGS Reston Stable Isotopes laboratory, also was collected inside the sampling chamber. After these samples were collected, dissolved gas, radon, remaining isotopes, and environmental tracer samples were collected outside of the mobile laboratory next to the well head. For each of these analyses, different sampling equipment was required such that the sampling chamber in the mobile laboratory could not be used; however, airborne contamination sources were not a concern. The SAP provides additional information on collection of these types of samples (Wright and McMahon, 2012).

All matrix spike and matrix-spike duplicate samples were spiked at the laboratory. Analytical Services Request (ASR) forms and chain-of-custody (COC) records are presented in appendix 2 (figs. 2.1–2.9). Photographs of groundwater-sampling activities are presented in appendix 3 (figs. 3.1–3.16).

Samples for analysis of some organic constituents were collected in duplicate with one set of bottles preserved with hydrochloric acid (HCl) and a second bottle set unpreserved. Field data collected by the USEPA during previous investigations of well MW01 indicated the pH of the groundwater would be greater than 11. Samples for volatile organic compounds (VOCs), gasoline-range organics (GRO), and some of the hydrocarbon gasses [ethane, ethylene, methane, and propane analyzed by USEPA method RSKSOP-175 (U.S. Environmental Protection Agency, 1994)] commonly are preserved by adding HCl to each sample container at the time of sample collection to lower the pH to less than 2, thus extending the sample holding time (time before a sample must be analyzed by a laboratory). Because HCl reactions within these samples potentially could cause gas loss resulting in a decrease in constituent recoveries, two bottle sets were sequentially collected for VOCs, GRO, and hydrocarbon gasses. One set of bottles was preserved with HCl at the time of collection and the second bottle set was left unpreserved.

Collection of environmental sample 2 began after three borehole volumes of water were purged from well MW01. Because collection of sample 2 began late in the day (time 1830) and it would not be safe to complete field activities after dark, the matrix spike and matrix-spike duplicate samples were not collected. In the end, a full suite of samples was collected for the environmental sample and a partial suite of samples was collected in replicate (table 3).

Field water-quality properties measured during the purge of well MW01 are presented in table 4.

Table 3. Analyses done for environmental and quality-control samples collected for monitoring wells MW01 and MW02 near Pavillion, Wyoming, April and May 2012.

[--, sample not collected; X, sample collected; USEPA, U.S. Environmental Protection Agency; mod, modified; SIM, selective ion monitoring; DAI, direct aqueous injection; BTEX, the compounds benzene, toluene, ethyl benzene, and xylene; MTBE, methyl tert-butyl ether; N_2, nitrogen; Ar, argon; CH_4, methane; CO_2, carbon dioxide; O_2, oxygen; $\delta^{18}O$, ratio of oxygen-18 to oxygen-16 isotopes in the sample relative to the ratio in a reference standard; $\delta^{2}H$, ratio of hydrogen-2 to hydrogen-1 isotopes in the sample relative to the ratio in a reference standard; $\delta^{13}C$, ratio of carbon-13 to carbon-12 isotopes in the sample relative to the ratio in a reference standard; $\delta^{3}He$, ratio of helium-3 to helium-4 isotopes in the sample relative to the ratio in a reference standard]

Laboratory analytical method[1]	Analysis	Analysis group	MW01										MW02		
			Source solution blank	Ambient blank	Field blank	Environmental sample 1	Sample 1 replicate	Matrix spike	Matrix spike duplicate	Trip blank	Environmental sample 2	Sample 2 replicate	Riverton development water	Trip blank	Camera blank
							U.S. Geological Survey field analyses								
	Ferrous iron, field	Inorganic constituents	--	--	--	X	--	--	--	--	X	--	--	--	--
	Dissolved oxygen, low range, field	Inorganic constituents	--	--	--	X	--	--	--	--	X	--	--	--	--
	Alkalinity and associated constituents, field	Inorganic constituents	--	--	--	X	--	--	--	--	X	--	--	--	--
	Acid neutralizing capacity and associated constituents, field	Inorganic constituents	--	--	--	X	--	--	--	--	X	--	--	--	--
							TestAmerica Laboratories								
USEPA method 6010B	Major cations and silica	Inorganic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
USEPA method 9056	Major anions	Inorganic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
USEPA method 350.1	Nitrogen, ammonia	Inorganic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
USEPA method 353.2	Nitrate + nitrite	Inorganic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
USEPA method 365.1	Phosphorus, dissolved	Inorganic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
USEPA method 6010B and 6020	Trace elements	Inorganic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
USEPA method 7470	Mercury	Inorganic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
USEPA method 8260B	Volatile organic compounds (VOCs)	Organic constituents	X	X	X	X	X	X	X	X	X	X	X	X	X
USEPA method 8260B	Volatile organic compounds (VOCs), unpreserved	Organic constituents	X	X	X	X	X	X	X	X	X	X	--	--	--
USEPA method 8270C and 8270/SIM	Semivolatile organic compounds (SVOCs) and polycylic aromatic hydrocarbons (PAHs)	Organic constituents	--	X	X	X	X	X	X	--	X	X	X	X	X
EPA 8015B DAI in Water (8015B)	Diesel range organics (DRO)	Organic constituents	X	--	X	X	X	X	X	--	X	X	X	X	X

Table 3. Analyses done for environmental and quality-control samples collected for monitoring wells MW01 and MW02 near Pavillion, Wyoming, April and May 2012.—Continued

[--, sample not collected; X, sample collected; USEPA, U.S. Environmental Protection Agency; mod, modified; SIM, selective ion monitoring; DAI, direct aqueous injection; BTEX, the compounds benzene, toluene, ethyl benzene, and xylene; MTBE, methyl tert-butyl ether; N_2, nitrogen; Ar, argon; CH_4, methane; CO_2, carbon dioxide; O_2, oxygen; $\delta^{18}O$, ratio of oxygen-18 to oxygen-16 isotopes in the sample relative to the ratio in a reference standard; $\delta^{2}H$, ratio of hydrogen-2 to hydrogen-1 isotopes in the sample relative to the ratio in a reference standard; $\delta^{13}C$, ratio of carbon-13 to carbon-12 isotopes in the sample relative to the ratio in a reference standard; $\delta^{3}He$, ratio of helium-3 to helium-4 isotopes in the sample relative to the ratio in a reference standard]

Laboratory analytical method[1]	Analysis	Analysis group	MW01										MW02		
			Source solution blank	Ambient blank	Field blank	Environmental sample 1	Sample 1 replicate	Matrix spike	Matrix spike duplicate	Trip blank	Environmental sample 2	Sample 2 replicate	Riverton development water	Trip blank	Camera blank
USEPA 8015B DAI in Water (8015B)	Glycols, ethanol, isobutanol, isopropyl alcohol, n-butanol	Organic constituents	X	--	X	X	X	X	X	X	X	X	X	X	X
USEPA 8015B/8021 mod	Gasoline range organics (GRO) + BTEX + MTBE	Organic constituents	X	X	X	X	X	X	X	X	X	X	X	X	X
USEPA 8015B/8021 mod	Gasoline range organics (GRO) + BTEX + MTBE, unpreserved	Organic constituents	X	X	X	X	X	X	X	X	X	X	--	--	--
RSK-SOP 175	Methane, ethane, ethylene, and propane	Dissolved gases	X	X	X	X	X	X	X	X	X	X	X	X	X
RSK-SOP 175	Methane, ethane, ethylene, and propane (unpreserved)	Dissolved gases	X	X	X	X	X	X	X	X	X	X	--	--	--
USEPA method 425.1	Methylene blue active substances	Organic constituents	--	X	X	X	X	X	X	--	X	--	X	X	X
Eberline Laboratory															
	Radium-226 and radium-228	Inorganic constituents	--	--	--	X	--	--	--	--	X	--	--	--	--
U.S. Geological Survey National Water Quality Laboratory															
	Radon-222	Inorganic constituents	--	--	--	X	--	--	--	--	--	--	--	--	--
Isotech Laboratories, Inc.															
	Compositional analysis of hydrocarbon gasses	Dissolved gases	--	--	--	X[2]	--	--	--	--	X	--	--	--	--
	$\delta^{13}C$ and $\delta^{2}H$ of methane	Stable isotopes	--	--	--	X[2]	--		--	--	X	--	--	--	--
Lamont-Doherty Laboratory															
	Helium, neon, argon, krypton, xenon, and $\delta^{3}He$	Environmental tracers	--	--	--	X[3]	--	--	--	--	--	--	--	--	--
U.S. Geological Survey Reston Chlorofluorocarbon Laboratory															
	Dissolved gasses (N_2, Ar, CH_4, CO_2, O_2)	Dissolved gases	--	--	--	X	X	--	--	--	X	--	--	--	--
	Helium	Environmental tracers	--	--	--	X	--	--	--	--	X	--	--	--	--
	Chlorofluorocarbons (CFCs)	Environmental tracers	--	--	--	X	X	--	--	--	--	--	--	--	--
	Sulfur hexafluoride (SF_6)	Environmental tracers	--	--	--	X	X	--	--	--	X	--	--	--	--
U.S. Geological Survey Reston Stable Isotope Laboratory															
LC 1142	$\delta^{18}O$ and $\delta^{2}H$ of water	Stable isotopes	--	--	--	X	--	--	--	--	--	--	--	--	--

Table 3. Analyses done for environmental and quality-control samples collected for monitoring wells MW01 and MW02 near Pavillion, Wyoming, April and May 2012.—Continued

[--, sample not collected; X, sample collected; USEPA, U.S. Environmental Protection Agency; mod, modified; SIM, selective ion monitoring; DAI, direct aqueous injection; BTEX, the compounds benzene, toluene, ethyl benzene, and xylene; MTBE, methyl tert-butyl ether; N_2, nitrogen; Ar, argon; CH_4, methane; CO_2, carbon dioxide; O_2, oxygen; $\delta^{18}O$, ratio of oxygen-18 to oxygen-16 isotopes in the sample relative to the ratio in a reference standard; $\delta^{2}H$, ratio of hydrogen-2 to hydrogen-1 isotopes in the sample relative to the ratio in a reference standard; $\delta^{13}C$, ratio of carbon-13 to carbon-12 isotopes in the sample relative to the ratio in a reference standard; $\delta^{3}He$, ratio of helium-3 to helium-4 isotopes in the sample relative to the ratio in a reference standard]

Laboratory analytical method[1]	Analysis	Analysis group	MW01										MW02		
			Source solution blank	Ambient blank	Field blank	Environmental sample 1	Sample 1 replicate	Matrix spike	Matrix spike duplicate	Trip blank	Environmental sample 2	Sample 2 replicate	Riverton development water	Trip blank	Camera blank
U.S. Geological Survey Menlo Park Tritium Laboratory															
LC 1565	Tritium	Environmental tracers	--	--	--	X[3]	--	--	--	--	--	--	--	--	--
Woods Hole Oceanographic Institute															
LC 3212	$\delta^{13}C$ and carbon-14 of dissolved inorganic carbon	Stable isotopes and environmental tracers	--	--	--	X	--	--	--	--	X	--	--	--	--

[1] Laboratory analytical methods, approaches and method references are provided in table 3 of Wright and McMahon (2012).

[2] Sample was collected but could not be analyzed because of broken bottle.

[3] Sample was collected but has not yet been analyzed as of August 20, 2012.

Table 4. Field water-quality properties measured during purge of monitoring well MW01 near Pavillion, Wyoming, April 2012.

[Highlighted value indicates property met purge criteria[1] for last five measurements. ft, feet; BMP, below measuring point; gal/min, gallons per minute; °C, degrees Celsius; SC, specific conductance at 25 degrees Celsius; µS/cm, microsiemens per centimeter; DO, dissolved oxygen; mg/L, milligrams per liter; ORP, oxidation reduction potential; mV, millivolts; NTRU, nephelometric turbidity ratio units; --, no data; <, less than]

Time	Water level (ft BMP)	Draw down (ft)	Pumping rate (gal/min)	Volume (gallons)	Borehole volumes	Water Temperature (°C)	Variability[2] of last 5 temperature measurements	SC (µS/cm)	Variability[3] of last 5 SC measurements (percent)	pH (standard units)	Variability	DO (mg/L)	ORP (mV)	Turbidity (NTRU)	Comments
11:10	201.35	0.00	--	0	0.00	--	--	--	--		--	--	--	--	Pump started.
11:20	287.94	86.59	6.05	61	0.14	19.02	--	--	--	11.5	--	0.5	–170.50	--	
11:30	315.58	114.23	6.05	121	0.28	14.45	--	3,396	--	12.1	--	< 0.2	–236.30	--	
11:40	329.73	128.38	6.11	182	0.42	14.96	--	3,101	--	12.1	--	< 0.2	–248.20	--	
11:50	334.04	132.69	6.10	243	0.57	15.74	--	2,839	--	12.0	--	< 0.2	–262.80	--	
12:00	334.42	133.07	6.04	304	0.71	15.73	4.57	2,549	--	11.9	0.64	< 0.2	–272.80	--	
12:09	325.58	124.23	6.00	358	0.83	17.45	3.00	2,306	38.40	11.8	0.33	< 0.2	–283.00	--	Pumping rate decreased to 2.61.
12:15	301.47	100.12	2.63	373	0.87	12.83	4.62	2,087	39.36	11.8	0.30	< 0.2	–288.60	--	
12:20	294.34	92.99	2.50	386	0.90	14.60	4.62	2,181	31.43	11.8	0.23	< 0.2	–294.00	--	
12:25	287.15	85.80	2.58	399	0.93	14.52	4.62	1,930	28.00	11.7	0.21	< 0.2	–296.10	--	
12:30	281.73	80.38	2.58	412	0.96	14.55	4.62	1,831	22.98	11.6	0.17	< 0.2	–299.40	1.95	
12:35	278.47	77.12	2.60	425	0.99	14.45	1.77	1,812	18.75	11.6	0.21	< 0.2	–302.20	--	
12:40	278.48	77.13	2.68	438	1.02	14.31	0.29	1,735	23.50	11.6	0.21	< 0.2	–303.90	--	
12:45	273.66	72.31	2.52	451	1.05	15.11	0.80	1,763	10.75	11.5	0.16	< 0.2	–307.50	--	
12:50	271.89	70.54	2.56	463	1.08	14.54	0.80	1,751	5.40	11.5	0.10	< 0.2	–310.30	--	

Table 4. Field water-quality properties measured during purge of monitoring well MW01 near Pavillion, Wyoming, April 2012.—Continued

[Highlighted value indicates property met purge criteria[1] for last five measurements. ft, feet; BMP, below measuring point; gal/min, gallons per minute; °C, degrees Celsius; SC, specific conductance at 25 degrees Celsius; µS/cm, microsiemens per centimeter; DO, dissolved oxygen; mg/L, milligrams per liter; ORP, oxidation reduction potential; mV, millivolts; NTRU, nephelometric turbidity ratio units; --, no data; <, less than]

Time	Water level (ft BMP)	Draw down (ft)	Pumping rate (gal/min)	Volume (gallons)	Borehole volumes	Water Temperature (°C)	Variability[2] of last 5 temperature measurements	SC (µS/cm)	Variability[3] of last 5 SC measurements (percent)	pH (standard units)	Variability	DO (mg/L)	ORP (mV)	Turbidity (NTRU)	Comments
12:55	270.84	69.49	2.59	476	1.11	14.53	0.80	1,757	4.37	11.5	0.06	< 0.2	–312.70	--	
13:00	269.96	68.61	2.65	490	1.14	15.09	0.80	1,701	3.56	11.5	0.05	< 0.2	–316.30	--	
13:05	269.24	67.89	2.55	502	1.17	14.86	0.58	1,704	3.57	11.5	0.03	< 0.2	–318.40	--	
13:12	268.41	67.06	2.57	520	1.21	14.18	0.91	1,700	3.31	11.5	0.04	< 0.2	–319.90	1.22	
13:15	268.24	66.89	2.59	528	1.23	14.19	0.91	1,737	3.31	11.5	0.03	< 0.2	–320.70	--	
13:31	267.92	66.57	2.58	569	1.33	14.57	0.91	1,665	4.23	11.5	0.05	< 0.2	–328.10	--	
13:40	266.64	65.29	2.62	593	1.38	15.04	0.86	1,657	4.73	11.5	0.06	< 0.2	–335.50	--	
13:48	266.42	65.07	2.52	613	1.43	14.89	0.86	1,635	6.08	11.4	0.08	< 0.2	–336.70	--	
13:56	265.21	63.86	2.63	634	1.48	15.54	1.35	1,642	6.12	11.4	0.10	< 0.2	–340.20	--	
14:10	266.21	64.86	2.46	669	1.56	14.99	0.97	1,621	2.68	11.4	0.10	< 0.2	–343.70	--	Collection of environmental sample 1 began.
14:20	266.37	65.02	2.32	692	1.61	15.77	0.88	1,602	3.37	11.3	0.12	< 0.2	–347.60	--	
14:30	261.41	60.06	2.18	714	1.66	15.45	0.88	1,566	4.71	11.3	0.12	< 0.2	–349.80	--	
14:45	268.03	66.68	2.63	753	1.76	15.47	0.78	1,519	7.74	11.3	0.16	< 0.2	–355.50	--	
15:15	268.56	67.21	2.63	832	1.94	14.92	0.85	1,459	10.43	11.2	0.15	< 0.2	–360.80	--	
15:30	268.50	67.15	2.67	872	2.03	14.81	0.96	1,442	10.54	11.2	0.15	< 0.2	–364.40	--	
15:45	268.60	67.25	2.59	911	2.12	14.88	0.66	1,455	8.33	11.1	0.18	< 0.2	–368.40	--	
16:00	269.94	68.59	2.70	951	2.22	15.10	0.66	1,458	5.25	11.1	0.18	< 0.2	–371.40	--	
16:15	269.00	67.65	2.67	991	2.31	15.34	0.53	1,401	4.02	11.0	0.18	< 0.2	–374.90	--	
16:30	269.22	67.87	2.30	1,026	2.39	15.39	0.58	1,426	3.97	11.0	0.20	< 0.2	–377.80	--	
16:45	269.33	67.98	2.67	1,066	2.48	15.14	0.51	1,401	3.99	11.0	0.17	< 0.2	–380.30	--	
17:00	269.55	68.20	2.59	1,105	2.58	15.05	0.34	1,403	4.02	10.9	0.16	< 0.2	–382.20	--	
17:15	269.83	68.48	2.23	1,138	2.65	15.31	0.34	1,416	1.77	10.9	0.17	< 0.2	–384.20	--	
17:30	269.93	68.58	2.58	1,177	2.74	15.10	0.34	1,396	2.13	10.8	0.15	< 0.2	–385.80	--	
17:35	269.88	68.53	2.52	1,190	2.77	15.04	0.27	1,380	2.57	10.8	0.15	< 0.2	–385.50	--	
17:40	269.82	68.47	2.61	1,203	2.80	15.08	0.27	1,392	2.58	10.8	0.11	< 0.2	–386.20	--	
17:45	269.99	68.64	2.57	1,215	2.83	15.02	0.29	1,393	2.58	10.8	0.07	< 0.2	–387.40	--	
17:50	269.98	68.63	2.57	1,228	2.86	14.96	0.14	1,398	1.29	10.8	0.03	< 0.2	–389.10	--	
17:55	270.04	68.69	2.62	1,241	2.89	15.01	0.12	1,378	1.44	10.8	0.03	< 0.2	–388.40	--	
18:00	270.04	68.69	2.44	1,254	2.92	15.09	0.13	1,373	1.80	10.7	0.06	< 0.2	–388.60	--	
18:05	270.09	68.74	2.59	1,267	2.95	14.86	0.23	1,380	1.81	10.7	0.06	< 0.2	–388.90	--	
18:10	270.15	68.80	2.47	1,279	2.98	14.93	0.23	1,379	1.81	10.7	0.06	< 0.2	–390.00	--	
18:15	270.15	68.80	2.61	1,292	3.01	14.86	0.23	1,373	0.51	10.7	0.07	< 0.2	–389.80	--	Collection of environmental sample 2 began.
18:25	270.31	68.96	2.42	1,316	3.07	14.58	0.51	1,379	0.51	10.7	0.05	< 0.2	–389.90	--	
18:35	270.42	69.07	2.09	1,337	3.12	14.71	0.35	1,383	0.73	10.7	0.07	< 0.2	–391.50	--	
18:45	270.31	68.96	2.49	1,362	3.17	14.71	0.35	1,382	0.73	10.7	0.08	< 0.2	–393.00	--	
19:00	270.15	68.80	2.10	1,393	3.25	15.07	0.49	1,375	0.73	10.6	0.12	< 0.2	–392.90	--	
19:15	270.09	68.74	2.39	1,429	3.33	14.74	0.49	1,385	0.72	10.6	0.11	< 0.2	–394.20	--	
19:27	270.19	68.84	2.73	1,462	3.41	14.58	0.49	1,373	0.87	10.6	0.10	< 0.2	–395.90	--	Pump shut off.

[1] Purge criteria for this sampling program are listed in table 1.

[2] Variability for this property was calculated by subtracting the minimum of the last five measurements from the maximum of the last five measurements.

[3] Variability for this property was calculated by subtracting the minimum of the last five measurements from the maximum of the last five measurements and dividing this result by the average of the last five measurements. The result is then multiplied by 100.

Redevelopment of Monitoring Well MW02 and Collection of Associated Quality-Control Samples

In an attempt to increase well yield, monitoring well MW02 was redeveloped by the USGS during the week of April 30, 2012. Redevelopment included surging the well and bailing from the top and the bottom of the water column. As part of the redevelopment effort, potable water obtained from the public water supply of the city of Riverton was added to well MW02 before pump removal in order to decrease methane concentrations in the well and reduce the explosion hazard. A sample of the Riverton water added to the well was collected to characterize its chemical quality. The sample was collected from a sampling port in the pumping line while water was recirculated through the pump, hose, and tank used by the driller to add water to well MW02. This water, identified as Riverton development water, was analyzed for the chemical constituents listed in table 3. Documentation of field activities, including instrumentation and sampling logs; ASR forms COC records; and photographs of field activities are in appendixes 4 (figs. 4.1–4.7), 5 (figs. 5.1–5.2), and 6 (figs. 6.1–6.6), respectively.

During redevelopment of well MW02, a downhole camera was used to view and evaluate the condition of the well casing and screen. Before deploying the downhole camera, an equipment blank was collected for the camera. This camera blank was collected by pouring blank water over the camera and collecting it in sample containers. The camera blank samples were analyzed for the chemical constituents listed in table 3.

Analytical Methods

Nine laboratories analyzed samples for this study: TestAmerica Laboratories in Arvada, Colorado, Woods Hole Oceanographic Institute-National Ocean Sciences Accelerator Mass Spectrometry Facility in Woods Hole, Massachusetts, and Eberline Laboratories in Richmond, Calif., under contract with the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado; four USGS laboratories (NWQL, Reston Chlorofluorocarbon Laboratory, Reston Stable Isotope Laboratory, and Menlo Park Tritium Laboratory); Lamont-Doherty Earth Observatory Noble Gas Laboratory in Palisades, New York (contracted by the Reston Chlorofluorocarbon Laboratory); and Isotech Laboratories, Inc., in Champaign, Illinios. Analytical methods for each laboratory are listed in table 3. A list of analytical methods and method references are provided in table 3 of the SAP (Wright and McMahon, 2012).

Quality-Control Sample Collection and Data Analysis

Analytical results from QC samples collected in the field and prepared in the laboratories were used to assess the quality of data reported for environmental samples. Data from QC samples collected at well MW01 (table 2) were evaluated to determine whether qualification of environmental sample analytical data was warranted before use in interpretive reports. Specifically, QC sample results were used to evaluate the extent to which environmental data were affected by bias (for example, contamination of samples in the field or laboratory) and were used to evaluate the variability inherent to sample collection and laboratory analyses. The QC samples used to estimate bias included a variety of blanks, prepared with water that is certified free of analytes of interest (blank water), and samples that were spiked with known concentrations of target analytes. Variability was estimated by collecting replicate samples in the field and comparing the analytical results to results for the primary environmental samples.

Blank Samples

Procedures for the collection of field QC samples included in this report are described in the SAP (Wright and McMahon, 2012). Four types of blank samples were submitted to TestAmerica Laboratories for analysis: source-solution, ambient, field, and trip blanks. Each of these blank samples could have been subjected to contamination during various stages of sample collection, processing, shipping, and analysis. In addition, TestAmerica Laboratories provided results for a laboratory blank sample, prepared with reagent water. A quantified result in any blank sample was considered evidence that contamination could have affected environmental sample analytical results; consequently, analytical results for the two primary samples (environmental sample 1 and environmental sample 2) and associated replicates were compared to the maximum quantified concentration in the five blanks. In accordance with USEPA guidance (U.S. Environmental Protection Agency, 1989, p. 5–17), a reported concentration in an environmental sample that is less than five times the concentration in a related blank sample should be treated as a nondetection, and the reported concentration should be considered the quantitation limit for the analyte in that sample. These analytes are identified by a project data qualifier in the data tables (tables 5–14) presented in this report. Overall, results were qualified for 18 constituents detected in the 2 primary environmental samples. All these qualifications were based on quantified results in laboratory, ambient, or field blank samples; results for all analyses of source-solution and trip blank samples were less than method detection limits. For 13 of the constituents detected in blank samples, quantified concentrations were reported for more than 1 type of blank sample.

Laboratory Spike Samples

Laboratory reagent and matrix spike samples also contribute to evaluation of analytical bias that can affect results. This bias can be evaluated by determining the recovery of a known amount of an analyte that is spiked into reagent water or sample matrix (water collected at the field site). For this study, duplicate matrix spike samples were collected in addition to environmental sample 1. TestAmerica Laboratories spiked these matrix samples, as well as duplicate reagent samples, at the laboratory. Analyte recovery from matrix spike samples was calculated by adjusting for background concentration in the environmental sample using the following equation:

$$R = \frac{C_{ms} - C_{env}}{C_{spiked}} \times 100 \tag{1}$$

where

R = analyte recovery, in percent

C_{ms} = concentration of the analyte in the matrix spike sample,

C_{env} = background concentration of the analyte in the environmental sample,

and C_{spiked} =concentration of the spiked analyte expected in the matrix sample.

All matrix spikes collected from well MW01 were associated with environmental sample 1, so analyte concentrations in that sample were used as background concentrations in recovery calculations. Analyte recovery in the laboratory reagent samples was calculated simply as the ratio of the analyte concentration in the matrix spike sample to the expected concentration of the spiked analyte, because no background concentrations were present.

Control limits on acceptable recovery are established by the analyzing laboratory for each analyte. Recoveries outside acceptable limits are identified in the laboratory data qualifiers column in the data tables presented in this report. In addition, the project data qualifiers identify analytes with recoveries less than 70 percent or greater than 130 percent. Although these recoveries do not necessarily correspond to control limits, they provide a consistent identification of analytes for which results might be low or high because of analytical bias. Another laboratory data qualifier identifies matrix samples for which the background concentration exceeds four times the spiked concentration, in which case recovery is uncertain and control limits are not applicable. In these cases, project data qualifiers for low and high bias also were considered inapplicable. Finally, project data qualifiers for high bias were not applied if the analyte concentration was censored (reported as less than the method detection limit), because, in this case, the potential bias did not have a measurable effect. Overall, the low-bias qualifier was applied to 10 constituents and the high-bias qualifier was applied to 4 constituents.

Replicate Samples

Potential variability in reported analyte concentrations is estimated by comparison of replicate samples. Replicates were collected for both environmental samples 1 and 2 from well MW01, although the replicate for environmental sample 2 was not analyzed for all analytes. Variability for each analyte is estimated as the relative percent difference (RPD) between the two replicates:

$$RPD = \frac{\left|C_{env} - C_{rep}\right|}{\left(C_{env} + C_{rep}\right)/2} \times 100 \tag{2}$$

where

$|C_{env} - C_{rep}|$ = absolute value of the difference between concentrations of the analyte in the primary environmental sample and the replicate sample, and

$(C_{env} + C_{rep})/2$ = mean concentration of the analyte in the primary environmental sample and replicate sample.

The RPD cannot be calculated if the concentration is censored in either or both samples. For this study, RPD values greater than 20 percent were considered indicative that analytical results might be affected by high variability. Analytes with RPDs outside this criterion are identified with a project data qualifier on the primary environmental sample and replicate sample in the relevant data tables. Overall, eight constituents were qualified because of high variability in environmental sample 1, and three constituents were qualified in environmental sample 2.

In summary, four criteria for inclusion of project data qualifiers were applied to analytes in environmental samples and replicates:

1. Contamination bias: quantified concentration was less than five times the maximum concentration in a blank sample,
2. Recovery bias: potential low bias—recovery was less than 70 percent in one or more spike samples,
3. Recovery bias: potential high bias—recovery was greater than 130 percent in one or more spike samples (applied only to constituents with quantified results), and
4. Variability: RPD between the environmental sample and replicate sample was greater than 20 percent.

Major-Ion Balances

Major-ion data were quality assured by calculating a cation-anion balance. The sum of concentrations of dissolved cations in milliequivalents per liter should equal the sum of concentrations of dissolved anions in milliequivalents per liter (Hem, 1985). The percent difference between the sum of concentrations of cations and anions in milliequivalents per liter was calculated using equation 3.

$$Percent\ difference = \left(\frac{sum\ of\ dissolved\ cations - sum\ of\ dissolved\ anions}{sum\ of\ dissolved\ cations + sum\ of\ dissolved\ anions}\right) \times 100 \tag{3}$$

Groundwater-Quality Data

Results from analyses of groundwater and QC samples collected from monitoring well MW01 are presented in tables 5 through 11. Many organic constituents were collected in duplicate (one set of bottles preserved with HCl and a second bottle set unpreserved). To identify the preservation method used for each of the organic constituents, a column was added to tables 7 through 10 to indicate whether preservative was added to the sample bottle. Constituent concentrations for samples that were preserved using HCl are identified in the “preservative added to bottle” column with Yes, and constituent concentrations for samples that were unpreserved are identified with No. The QC samples collected for well MW02 are included in tables 12 through 14. Analytical results for tritium, some noble gasses (neon, krypton, and xenon), and helium isotope ratios had not been received as of August 17, 2012, and are not presented in this report; when received from the laboratories, analytical results for these constituents will be available through the USGS National Water Information System (NWIS) Web Interface, accessible at *http://waterdata.usgs.gov/wy/nwis/qw*. The USGS 15-digit site number, sample collection dates, and times needed to access water-quality data using the NWIS Web Interface are listed in table 2.

Monitoring Well MW01

Field Water-Quality Properties and Hydrologic Data Measured During the Well Purge

Field water-quality properties and basic hydrologic data measured during the purge of monitoring well MW01 are listed in table 4. Field water-quality properties and basic hydrologic data were measured at regular intervals and recorded on a purge log (see appendix 1, figs. 1.16-1.20). Water levels and pumping rates were measured to calculate water-level drawdown in response to pumping and the total volume of water purged from the well. The water level in well MW01 during the purge and sampling is shown in figure 2*A*. Variability of water temperature, SC, and pH of the pumped water during purging also were evaluated (table 4). Values of specific conductance and pH are shown in relation to purge volume in figures 2*B* and 2*C*, respectively. A graph of water temperature is not included in this report because these data were affected by heating in the sampling line between the well and the point of measurement; therefore, they do not represent conditions in the well.

The borehole volume of water purged from well MW01 was calculated using equation 2 in the SAP (Wright and McMahon, 2012); one borehole volume was about 429 gallons. Sample collection began after this amount of water had been pumped and as soon as both SC and pH met stabilization criteria. Stabilization criteria were met and collection of environmental sample began at time 14:10 on April 24, 2012 (table 4), and although SC only met the stabilization criteria briefly, sampling had already begun. The sample time associated with environmental sample 1 (time 13:30 on April 24, 2012; table 2) had been assigned to the sample in advance, in anticipation of sample collection starting after one borehole volume had been purged from the well. Collection of a water sample from MW01 after purging one borehole volume of water had been a stated objective in the SAP (Wright and McMahon, 2012). Collection of environmental sample 1 and associated QC samples included the filling of 214 sample containers, equaling collection of approximately 18 gallons of water, and took more than 2 hours to complete.

Field Water-Quality Properties and Inorganic and Radioactive Constituents

Concentrations of inorganic constituents, including naturally occurring radioactive constituents (radon, radium-226, and radium-228), in the environmental samples and replicates collected from well MW01 are listed in table 5. The data for blank and spike samples are listed in table 6.

Samples were titrated in the field to determine alkalinity (filtered sample) and acid-neutralizing capacity (unfiltered sample). Based on these titration data, the USGS alkalinity calculator, which is described in Chapter A6, Section 6.6.5.C of the USGS National Field Manual (Wilde, variously dated), was used to calculate concentrations of bicarbonate, carbonate, and hydroxide.

Ionic charge balances calculated for environmental sample 1, sample 1 replicate, and environmental sample 2 were -1.94, 0.03, and 0.23 percent, respectively. An ionic charge balance within plus or minus 5 percent is considered acceptable (Clesceri and others, 1998). An ionic charge balance was not calculated for the sample 2 replicate because major ions were not included in the analysis of that sample set.

Of the inorganic constituents detected in the environmental samples (table 5), sodium and sulfate were measured at the highest concentrations. Six detected inorganic constituents (filtered magnesium and unfiltered ammonia, phosphorus, cadmium, thallium, and uranium) were measured at concentrations less than five times the maximum concentration detected in the blank samples. Quantified concentrations for several constituents in tables 5 and 6 include an “E” remark because the concentrations are less than the reporting level, but equal to or greater than the method detection limit. Most of the nondetected inorganic constituents are trace elements (for example, beryllium, chromium, cobalt, copper, lead, mercury, selenium, silver, and zinc).

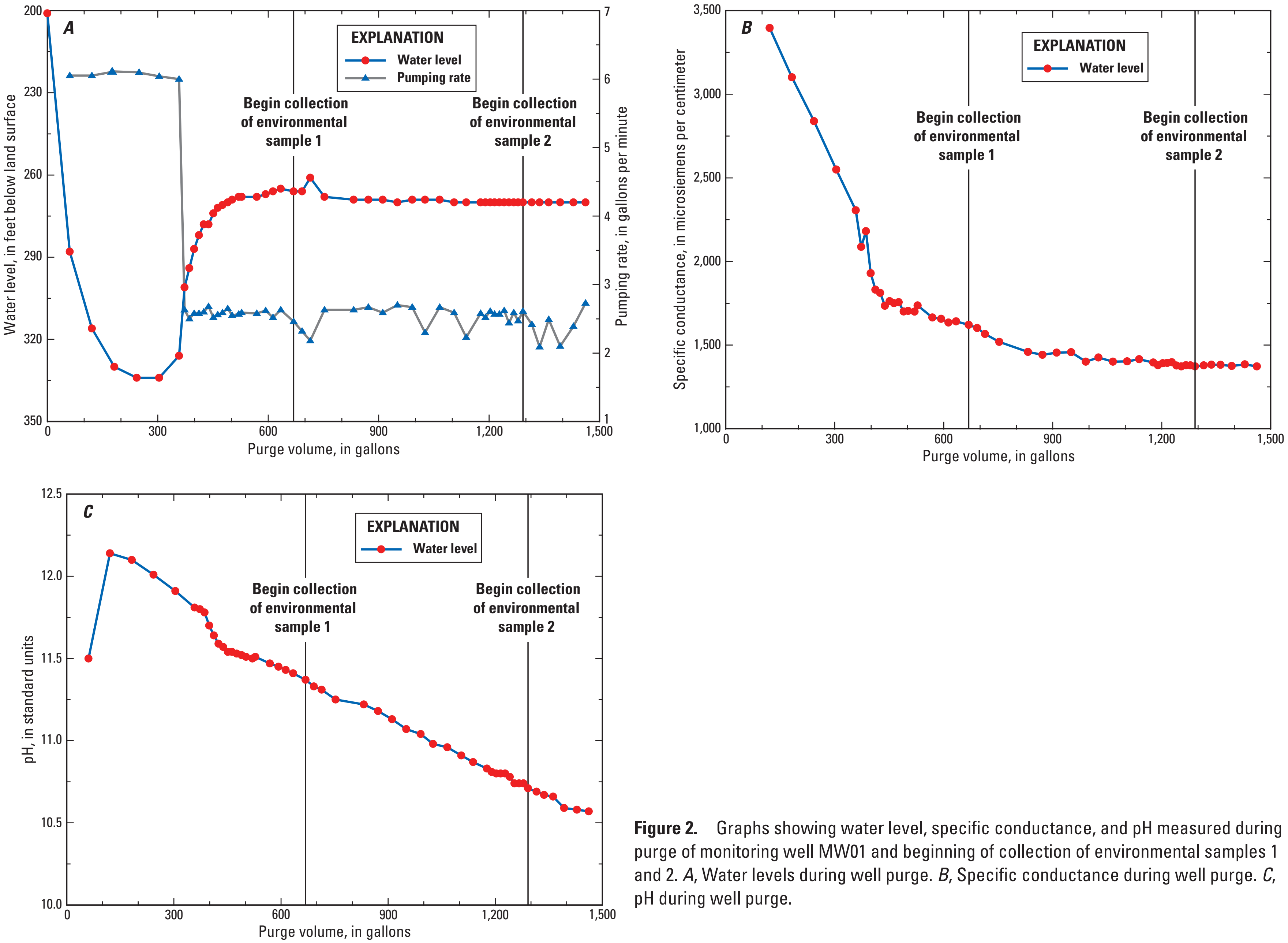


Figure 2. Graphs showing water level, specific conductance, and pH measured during purge of monitoring well MW01 and beginning of collection of environmental samples 1 and 2. *A*, Water levels during well purge. *B*, Specific conductance during well purge. *C*, pH during well purge.

Table 5. Field water-quality properties and inorganic constituents in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.

[RPD, relative percent difference; μs/cm, microsiemens per centimeter; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; μg/L, micrograms per liter; pCi/L, picocuries per liter; N, value was not determined; --, not applicable]

Field water-quality property or inorganic constituent		Environmental sample 1				Sample 1 replicate					Environmental sample 2				Sample 2 replicate				
Name	Units	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD
U.S. Geological Survey field measurements and analyses																			
Water temperature	degrees Celsius	--	15.0	--	--	--	N	--	--	--	--	14.9	--	--	--	N	--	--	--
Specific conductance at 25 degrees Celsius	μS/cm	--	1,640	--	--	--	N	--	--	--	--	1,380	--	--	--	N	--	--	--
pH	standard units	--	11.4	--	--	--	N	--	--	--	--	10.7	--	--	--	N	--	--	--
Dissolved oxygen	mg/L	<	0.2	--	--	--	N	--	--	--	<	0.2	--	--	--	N	--	--	--
Dissolved oxygen, low-range method	mg/L	--	0.19	--	--	--	N	--	--	--	--	0.11	--	--	--	N	--	--	--
Alkalinity (in filtered water)	mg/L $CaCO_3$	--	215	--	--	--	213	--	--	0.9	--	174	--	--	--	182	--	--	4.5
Hydroxide (in filtered water)	mg/L	--	10.6	--	--	E	12	--	--	12.4	--	3.7	--	--	--	4.3	--	--	15.0
Carbonate (in filtered water)	mg/L	E	101.0	--	--	E	98.0	--	--	3.0	--	76.3	--	--	--	81.1	--	--	6.1
Bicarbonate (in filtered water)	mg/L	E	19.1	--	--	E	19.0	--	--	0.5	--	44.1	--	--	--	42.3	--	--	4.2
Acid neutralizing capacity (in unfiltered water)	mg/L $CaCO_3$	--	199	--	--	--	194	--	--	2.5	--	N	--	--	--	N	--	--	--
Hydroxide (in unfiltered water)	mg/L	E	5.6	2	--	--	7.8	2	--	32.8	--	N	--	--	--	N	--	--	--
Carbonate (in unfiltered water)	mg/L	E	91.8	--	--	--	90.0	--	--	2.0	--	N	--	--	--	N	--	--	--
Bicarbonate (in unfiltered water)	mg/L	E	35.3	2	--	--	25.1	2	--	33.8	--	N	--	--	--	N	--	--	--
Ferrous iron	mg/L	--	0.02	--	--	--	N	--	--	--	--	0.04	--	--	--	N	--	--	--
TestAmerica Laboratories																			
Calcium (in filtered water)	μg/L	--	9,400	6	--	--	9,400	6	--	0.0	--	8,900	6	--	--	N	--	--	--
Calcium (in unfiltered water)	μg/L	--	9,000	6	--	--	9,000	6	--	0.0	--	8,800	6	--	--	N	--	--	--

Table 5. Field water-quality properties and inorganic constituents in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.—Continued

[RPD, relative percent difference; µs/cm, microsiemens per centimeter; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter; pCi/L, picocuries per liter; N, value was not determined; --, not applicable]

Field water-quality property or inorganic constituent		Environmental sample 1				Sample 1 replicate					Environmental sample 2				Sample 2 replicate				
Name	**Units**	**Remark[1]**	**Value**	**Project data qualifiers[2]**	**Laboratory data qualifiers[3]**	**Remark[1]**	**Value**	**Project data qualifiers[2]**	**Laboratory data qualifiers[3]**	**RPD**	**Remark[1]**	**Value**	**Project data qualifiers[2]**	**Laboratory data qualifiers[3]**	**Remark[1]**	**Value**	**Project data qualifiers[2]**	**Laboratory data qualifiers[3]**	**RPD**
Magnesium (in filtered water)	µg/L	E	140	1	J	E	150	1, 6	J	6.9	E	170	1	J	--	N		--	--
Magnesium (in unfiltered water)	µg/L	E	140	--	J	E	140	6	J	0.0	E	180	--	J	--	N	--	--	--
Sodium (in filtered water)	µg/L	--	270,000	--	B	--	280,000	6	B	3.6	--	280,000	6	B	--	N	--	--	--
Sodium (in unfiltered water)	µg/L	--	270,000	--	--	--	270,000	6	--	0.0	--	270,000	6	--	--	N	--	--	--
Potassium (in filtered water)	µg/L	--	15,000	--	--	--	16,000	6	--	6.5	--	13,000	--	--	--	N	--	--	--
Potassium (in unfiltered water)	µg/L	--	15,000	--	--	--	15,000	6	--	0.0	--	13,000	--	--	--	N	--	--	--
Chloride (in filtered water)	mg/L	--	26	--	--	--	26	--	--	0.0	--	27	--	--	--	N	--	--	--
Sulfate (in filtered water)	mg/L	--	380	--	--	--	380	--	--	0.0	--	410	--	--	--	N	--	--	--
Bromide (in filtered water)	mg/L	E	0.2	--	J	E	0.2	--	J	0.0	E	0.2	--	J	--	N	--	--	--
Fluoride (in filtered water)	mg/L	--	3	--	--	--	3	--	--	3.3	--	3	--	--	--	N	--	--	--
Silicon (in filtered water)	µg/L	--	9,000	--	--	--	8,700	--	--	3.4	--	6,400	--	--	--	N	--	--	--
Silica (in unfiltered water)	µg/L	--	18,000	--	B	--	18,000	--	B	0.0	--	13,000	--	B	--	N	--	--	--
Dissolved solids (in filtered water)	mg/L	--	800	--	--	--	800	--	--	0.0	--	800	--	--	--	N	--	--	--
Ammonia as nitrogen (in unfiltered water)	mg/L	--	0.79	1, 3	B	E	0.71	1, 3	B	10.7	E	0.34	1, 3	B	--	N	--	--	--
Nitrate-plus-nitrite as nitrogen (in unfiltered water)	mg/L	<	0.019	--	--	<	0.019	--	--	--	<	0.02	--	--	--	N	--	--	--
Phosphorus (in filtered water)	µg/L	--	57	2, 3	--	--	89	2, 3	--	43.8	--	61	3	--	--	N	--	--	--
Phosphorus (in unfiltered water)	µg/L	--	100	1	B	--	98	1	B	2.0	--	84	1	B	--	N	--	--	--

Table 5. Field water-quality properties and inorganic constituents in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.—Continued

[RPD, relative percent difference; µs/cm, microsiemens per centimeter; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter; pCi/L, picocuries per liter; N, value was not determined; --, not applicable]

Field water-quality property or inorganic constituent		Environmental sample 1				Sample 1 replicate					Environmental sample 2				Sample 2 replicate				
Name	Units	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD
Dissolved organic carbon (in filtered water)	mg/L	--	4.3	6	--	--	4.4	6	--	2.3	--	3	6	--	--	N	--	--	--
Total organic carbon (in unfiltered water)	mg/L	--	4.0	6	--	--	4.1	6	--	2.5	--	2.9	6	--	--	N	--	--	--
Dissolved inorganic carbon (in filtered water)	mg/L	--	20	--	--	--	19	--	--	5.1	--	21	--	--	--	N	--	--	--
Total inorganic carbon (in unfiltered water)	mg/L	--	22	--	--	--	21	--	--	4.7	--	22	--	--	--	N	--	--	--
Aluminum (in filtered water)	µg/L	--	170	--	--	--	170	--	--	0.0	--	100	--	--	--	N	--	--	--
Aluminum (in unfiltered water)	µg/L	--	170	--	--	--	170	--	--	0.0	--	110	--	--	--	N	--	--	--
Antimony (in filtered water)	µg/L	<	0.4	--	--	E	0.54	1, 6	J, ^, B	--	<	0.4	--	--	--	N	--	--	--
Antimony (in unfiltered water)	µg/L	<	0.4	--	--	<	0.4	6	--	--	<	0.4	--	--	--	N	--	--	--
Arsenic (in filtered water)	µg/L	E	0.62	6	J	<	0.33	--	--	--	<	0.33	--	--	--	N	--	--	--
Arsenic (in unfiltered water)	µg/L	E	0.38	2, 6	J	E	0.51	2	J	29.2	E	0.48	--	J	--	N	--	--	--
Barium (in filtered water)	µg/L	--	23	6	--	--	20	--	--	14.0	--	21	--	--	--	N	--	--	--
Barium (in unfiltered water)	µg/L	--	19	6	--	--	20	--	--	5.1	--	21	--	--	--	N	--	--	--
Beryllium (in filtered water)	µg/L	<	0.08	--	--	<	0.08	--	--	--	<	0.08	--	--	--	N	--	--	--
Beryllium (in unfiltered water)	µg/L	<	0.08	--	--	<	0.08	--	--	--	<	0.08	--	--	--	N	--	--	--
Boron (in filtered water)	µg/L	--	130	--	--	--	130	6	--	0.0	--	120	6	--	--	N	--	--	--
Boron (in unfiltered water)	µg/L	--	130	--	--	--	120	6	--	8.0	--	110	6	--	--	N	--	--	--

Table 5. Field water-quality properties and inorganic constituents in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.—Continued

[RPD, relative percent difference; µs/cm, microsiemens per centimeter; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter; pCi/L, picocuries per liter; N, value was not determined; --, not applicable]

Field water-quality property or inorganic constituent		Environmental sample 1				Sample 1 replicate					Environmental sample 2				Sample 2 replicate				
Name	Units	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD
Cadmium (in filtered water)	µg/L	<	0.1	--	--	<	0.1	--	--	--	<	0.1	--	--	--	N	--	--	--
Cadmium (in unfiltered water)	µg/L	E	0.11	1	J	<	0.1	--	--	--	<	0.1	--	--	--	N	--	--	--
Chromium (in filtered water)	µg/L	<	0.5	--	--	<	0.5	--	--	--	<	0.5	--	--	--	N	--	--	--
Chromium (in unfiltered water)	µg/L	<	0.5	--	--	<	0.5	--	--	--	<	0.5	--	--	--	N	--	--	--
Cobalt (in filtered water)	µg/L	<	0.054	--	--	<	0.054	--	--	--	<	0.054	--	--	--	N	--	--	--
Cobalt (in unfiltered water)	µg/L	<	0.054	--	--	<	0.054	--	--	--	<	0.054	--	--	--	N	--	--	--
Copper (in filtered water)	µg/L	<	0.56	--	--	<	0.56	--	--	--	<	0.56	--	--	--	N	--	--	--
Copper (in unfiltered water)	µg/L	<	0.56	--	--	<	0.56	--	--	--	<	0.56	--	--	--	N	--	--	--
Iron (in filtered water)	µg/L	<	22	--	--	<	22	--	--	--	<	22	--	--	--	N	--	--	--
Iron (in unfiltered water)	µg/L	<	22	--	--	<	22	--	--	--	E	55	--	J ^	--	N	--	--	--
Lead (in filtered water)	µg/L	<	0.18	--	--	<	0.18	--	--	--	<	0.18	--	--	--	N	--	--	--
Lead (in unfiltered water)	µg/L	<	0.18	--	--	<	0.18	--	--	--	<	0.18	--	--	--	N	--	--	--
Lithium (in filtered water)	µg/L	--	44	--	--	--	45	6	--	2.2	--	33	--	--	--	N	--	--	--
Lithium (in unfiltered water)	µg/L	--	44	--	--	--	43	6	--	2.3	--	36	--	--	--	N	--	--	--
Manganese (in filtered water)	µg/L	<	0.31	--	--	--	1	6	--	--	E	0.42	--	J	--	N	--	--	--
Manganese (in unfiltered water)	µg/L	E	0.57	2	J	E	0.46	2, 6	J	21.4	E	0.80	--	J	--	N	--	--	--
Mercury (in filtered water)	µg/L	<	0.027	--	--	<	0.027	--	--	--	<	0.027	--	--	--	N	--	--	--
Mercury (in unfiltered water)	µg/L	<	0.027	--	--	<	0.027	--	--	--	<	0.027	--	--	--	N	--	--	--
Molybdenum (in filtered water)	µg/L	--	10	6	--	--	9.7	--	--	3.0	--	7.6	--	--	--	N	--	--	--

Table 5. Field water-quality properties and inorganic constituents in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.—Continued

[RPD, relative percent difference; µs/cm, microsiemens per centimeter; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter; pCi/L, picocuries per liter; N, value was not determined; --, not applicable]

Field water-quality property or inorganic constituent		Environmental sample 1				Sample 1 replicate					Environmental sample 2				Sample 2 replicate				
Name	Units	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD
Molybdenum (in unfiltered water)	µg/L	--	9.8	6	--	--	10	--	--	2.0	--	7.8	--	--	--	N	--	--	--
Nickel (in filtered water)	µg/L	<	0.3	--	--	<	0.3	--	--	--	<	0.3	--	--	--	N	--	--	--
Nickel (in unfiltered water)	µg/L	E	0.3	2	J	E	0.44	2	J	37.8	<	0.3	--	--	--	N	--	--	--
Selenium (in filtered water)	µg/L	<	0.7	--	--	<	0.7	--	--	--	<	0.7	--	--	--	N	--	--	--
Selenium (in unfiltered water)	µg/L	<	0.7	--	--	<	0.7	--	--	--	<	0.7	--	--	--	N	--	--	--
Silver (in filtered water)	µg/L	<	0.033	--	--	<	0.033	--	--	--	<	0.033	--	--	--	N	--	--	--
Silver (in unfiltered water)	µg/L	<	0.033	--	--	<	0.033	--	--	--	<	0.033	--	--	--	N	--	--	--
Strontium (in filtered water)	µg/L	--	300	--	--	--	310	6	--	3.3	--	280	--	--	--	N	--	--	--
Strontium (in unfiltered water)	µg/L	--	300	--	--	--	300	6	--	0.0	--	280	--	--	--	N	--	--	--
Thallium (in filtered water)	µg/L	<	0.05	--	--	<	0.05	--	--	--	<	0.05	--	--	--	N	--	--	--
Thallium (in unfiltered water)	µg/L	E	0.068	1	J	<	0.05	--	--	--	E	0.096	1	J	--	N	--	--	--
Titanium (in filtered water)	µg/L	<	0.6	--	--	<	0.6	--	--	--	<	0.6	--	--	--	N	--	--	--
Titanium (in unfiltered water)	µg/L	<	0.6	--	--	<	0.6	--	--	--	E	0.69	--	J	--	N	--	--	--
Uranium (in filtered water)	µg/L	<	0.05	--	--	<	0.05	--	--	--	<	0.05	--	--	--	N	--	--	--
Uranium (in unfiltered water)	µg/L	E	0.14	1	J	<	0.05	--	--	--	E	0.14	1	J	--	N	--	--	--
Vanadium (in filtered water)	µg/L	E	0.6	6	J	<	0.5	--	--	--	<	0.5	--	--	--	N	--	--	--
Vanadium (in unfiltered water)	µg/L	<	0.5	6	--	<	0.5	--	--	--	E	0.53	--	J	--	N	--	--	--
Zinc (in filtered water)	µg/L	<	2	--	^	<	2	--	^	--	<	2	--	^	--	N	--	--	--
Zinc (in unfiltered water)	µg/L	<	2	--	--	<	2	--	--	--	<	2	--	--	--	N	--	--	--

Table 5. Field water-quality properties and inorganic constituents in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.—Continued

[RPD, relative percent difference; µs/cm, microsiemens per centimeter; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter; pCi/L, picocuries per liter; N, value was not determined; --, not applicable]

Field water-quality property or inorganic constituent		Environmental sample 1				Sample 1 replicate					Environmental sample 2				Sample 2 replicate				
Name	Units	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	Remark[1]	Value	Project data qualifiers[2]	Laboratory data qualifiers[3]	RPD
Eberline Laboratory																			
Radium-226 (in filtered water) with radon method	pCi/L	--	0.087	--	--	--	N	--	--	--	--	0.100	--	--	--	N	--	--	--
Radium-228 (in filtered water)	pCi/L	R	0.16	--	--	--	N	--	--	--	--	0.23	--	--	--	N	--	--	--
U.S. Geological Survey National Water Quality Laboratory																			
Radon-222 (in unfiltered water)	pCi/L	--	1,060	--	--	--	N	--	--	--	--	N	--	--	--	N	--	--	--

[1] Remarks used in table:

<, less than.

E, less than the reporting level, but equal to or greater than the method detection limit.

R, value below sample-specific critical level.

[2] Project data qualifiers used in table:

1 - Quantified concentration in the environmental sample is less than five times the maximum concentration in a blank sample.

2 - Relative percent difference (RPD) between the environmental sample and replicate sample was greater than 20 percent.

3 - Potential low bias; recovery was less than 70 percent in one or more spike samples.

4 - Potential high bias; recovery was greater than 130 percent in one or more spike samples (only applied to constituents with quantified results).

5 - Value is mean of two results reported by the laboratory.

6 - Filtered value exceeds unfiltered value.

[3] Laboratory data qualifiers used in table:

^ - Instrument related quality control exceeds the control limits.

4 - The analyte present in the environmental sample is four times greater than the matrix spike concentration; therefore, control limits are not applicable.

E - Result exceeded calibration range.

F - Recovery in the matrix spike or matrix-spike duplicate exceeds the control limits.

B - Detected compound was also found in the laboratory blank.

J - Result is less than the reporting limit but greater than or equal to the method detection limit, and the concentration is an approximate value.

Table 6. Inorganic constituents in quality-control samples collected for monitoring well MW01 near Pavillion, Wyoming, April 2012.

Organic Constituents

Concentrations of organic constituents included in analysis of the environmental samples and sample replicates collected from well MW01 are listed in table 7. Blank and spike sample analytical results are listed in table 8. Acrylonitrile was the only VOC detected, and that compound was detected only in the sample 1 replicate. Acrylonitrile is a component of nitrile gloves, which were worn during sample collection and processing. Nitrile gloves also were used by TestAmerica Laboratories (TestAmerica Laboratories, oral commun., 2012). VOCs could go undetected in an environmental sample if the analytical method used to measure them has poor recovery for those compounds. Of the 80 VOCs that were analyzed, only 1,1,2,2-tetrachloroethane, carbon disulfide, and isopropanol had spike recoveries less than 70 percent for any spiked sample.

Four semivolatile organic compounds (SVOCs)—3- and 4-methylphenol, benzoic acid, benzyl alcohol, and phenol—were detected in environmental samples; however, the concentration for benzyl alcohol (table 7) was less than five times the maximum concentration detected in associated laboratory and field blank samples (table 8). Benzoic acid was detected in all the environmental samples; however, spike recoveries for this compound were greater than 130 percent (table 8), indicating these concentrations might be biased high. Reported concentrations for several SVOCs include an “E” remark (table 7) because they are less than the reporting level, but equal to or greater than the method detection limit. Five of the SVOCs (2,4-dimethylphenol, 3,3’-dichlorobenzidine, aniline, hexachlorocyclopentadiene, and hexachloroethane) that were not detected in environmental samples had spike recoveries less than 70 percent (table 8). For example, the recovery for hexachlorocyclopentadiene was as low as 12 percent.

Analytical results from methods used to analyze VOCs and SVOCs included tentatively identified compounds (TICs), which are not part of the standard suite of reported analytes. TIC analyses provide a qualitative measure of the presence of compounds, but require additional analytical testing to confirm. Concentrations of TICs included in analysis of the environmental samples and QC samples (replicates and blanks) collected from well MW01 are listed in appendix 7. Thirty VOC TICs and three SVOC TICs were quantified in various environmental samples and blanks. One of these compounds (cyclotetrasiloxane, octamethyl-) was identified only in a laboratory blank; one other compound (silanol, trimethyl-) was identified in a single environmental sample, but also in two blanks at similar concentrations, indicating potential contamination bias. Eight compounds were identified in all environmental samples, both preserved and unpreserved. Concentrations of these were similar within each sample set (environmental sample and replicate), but were different between the two samples (1 and 2). Concentrations of propane in the TIC analyses were less than one-half the concentrations reported by TestAmerica Laboratories for dissolved gas analysis (table 9). One compound of interest in the Pavillion area, 2-butoxyethanol, was not identified in the TIC analyses of any of the environmental samples.

Table 7. Organic constituents in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.

Table 8. Organic constituents in quality-control samples collected for monitoring well MW01 near Pavillion, Wyoming, April 2012.

Concentrations for several other classes of organic compounds (tables 7 and 8) also included an “E” remark (less than the reporting level, but equal to or greater than the method detection limit). Diesel-range organics and gasoline-range organics were detected in all environmental samples and associated replicates, although all the concentrations for diesel-range organics (DRO) included an “E” remark. Twelve polycyclic aromatic hydrocarbons (PAHs) were detected in the environmental samples and associated replicates, but the maximum concentrations for 10 of these PAHs were less than five times the maximum concentration detected in associated laboratory and field blanks. All reported PAH concentrations included an “E” remark. No glycols were detected in any samples. Spike recoveries for glycols ranged from 93 to 106 percent, and method detection limits ranged from 7.73 to 18.70 milligrams per liter (mg/L). Methylene blue active substances were detected in the environmental samples, but all reported concentrations included an “E” remark and are less than five times the maximum concentration detected in the field blank.

Dissolved Gasses

Dissolved gasses measured in environmental samples and QC samples (replicates) collected from well MW01 are listed in table 9. Blank and spike sample analytical results are listed in table 10. Several different hydrocarbon gasses, including methane, ethane, propane, and several higher molecular weight compounds, were detected in the groundwater-quality samples. Many of the gasses (including argon, carbon dioxide, ethane, ethylene, methane, nitrogen, oxygen, and propane) were analyzed by more than one laboratory; using different analytical methods. For example, methane was analyzed by TestAmerica Laboratories, Isotech Laboratories, Inc., and the USGS Chlorofluorocarbon Laboratory. Because of the laboratory overlap of analyses of several dissolved gasses, a short description of the differences in gas concentrations between laboratories follows.

Methane concentrations reported by TestAmerica Laboratories and the USGS Reston Chlorofluorocarbon Laboratory are similar (table 9). For example, TestAmerica reported methane concentrations ranging from 20 to 30.5 mg/L (or 20,000 to

30,500 micrograms per liter) for environmental sample 1 and the sample 1 replicate, and the USGS Reston Chlorofluorocarbon Laboratory reported methane concentrations ranging from 26 to 28 mg/L.

Carbon dioxide concentrations reported by Isotech Laboratories, Inc., and the USGS Reston Chlorofluorocarbon Laboratory are not similar. Isotech Laboratories, Inc., did not detect carbon dioxide in environmental sample 2, whereas the USGS Reston Chlorofluorocarbon Laboratory reported carbon dioxide concentrations in environmental sample 2 greater than 100 mg/L. This difference may be due to different methods for stripping gas from solution before the analysis. Isotech Laboratories, Inc., and the USGS Reston Chlorofluorocarbon Laboratory reported very small concentrations of dissolved oxygen in the samples, which is in agreement with the field measurements (table 5).

A full suite of QC samples (replicates; laboratory, source solution, trip, ambient and field blanks; and reagent and matrix spikes) were collected and analyzed for dissolved gas samples sent to TestAmerica Laboratories (table 10). Dissolved gasses were not detected in any of the blank samples. Recoveries of dissolved gasses in the reagent spikes ranged from 89 to 95 percent. Recoveries in the matrix spikes were much more variable ranging from -33 to 1,004 percent; this large variability likely is due to the dissolved gasses present at concentrations at least four times greater than the matrix spike concentration. In these cases, recovery-control limits likely are not applicable.

Two dissolved gas samples (environmental sample 1 and environmental sample 2) were sent to Isotech Laboratories, Inc., for analysis. The container for environmental sample 1 was cracked, and therefore, was not analyzed. Environmental sample 2 was analyzed for 16 dissolved gasses; 13 gasses were detected (table 9). These data have no qualifiers because no QC samples were sent to Isotech Laboratories, Inc., for analysis.

Table 9. Dissolved gasses in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.

Table 10. Dissolved gasses in quality-control samples collected for monitoring well MW01 near Pavillion, Wyoming, April 2012.

Isotopes and Environmental Tracers

Isotopic values and concentrations of environmental tracers in environmental samples collected from well MW01 are listed in table 11. Stable isotopic data are provided for methane (hydrogen and carbon), water (hydrogen and oxygen), and dissolved inorganic carbon (carbon). Groundwater-quality samples also were analyzed for environmental tracers, including carbon-14 of dissolved inorganic carbon, the chlorofluorocarbons CFC-11, CFC-12, and CFC-113; SF_6; tritium; the noble gasses helium, neon, argon, krypton, and zenon; and δ^3He. Analytical results for tritium, neon, krypton, xenon,, and δ^3He had not been reported by the laboratories as of August 17, 2012, but analytical results will be entered in the USGS NWIS database when available and will be accessible through the USGS NWIS Web Interface at *http://waterdata.usgs.gov/wy/nwis/qw*. Many of these environmental tracers can be used to determine the presence of young or modern water or the apparent age of groundwater (Dunkle and others, 1993; Ekwurzel and others, 1994; Busenberg and Plummer, 2000; Plummer and others, 2004; McMahon and others, 2011).

Table 11. Isotopes and environmental tracers in environmental samples collected from monitoring well MW01 near Pavillion, Wyoming, April 2012.

Quality-Control Results for Monitoring Well MW01

The implications of QC results for the environmental sample results from monitoring well MW01 can be summarized from project data qualifiers listed in tables 5, 7, 9, and 11. Laboratory analytical results were reported for 234 constituents in various samples. Results were less than method detection limits in all blank samples for 215 (92 percent) of those constituents. There were 1,194 total analytical results for those 234 constituents in the 2 environmental samples and 2 replicate samples. Forty-three results (3.6 percent) were qualified because they were less than 5 times the maximum concentration in associated blanks. Concentrations for replicate samples were reported for 244 constituents in 570 environmental-sample/replicate pairs. Variability was within 20 percent for 559 (98 percent) of those pairs. One result each for 11 constituents was qualified because replicate variability exceeded the 20-percent criterion. Recoveries for spike samples were available for 210 constituents. Recoveries were within 70–130 percent for 195 (93 percent) of those constituents. Of the 1,050 results for those 210 constituents in the 2 environmental samples and 2 replicates, 42 results (4 percent) were qualified because of low recovery and 16 results (1.5 percent) were qualified because of high recovery. Overall, 646 analytical results were available for constituents with some type of QC data for the 2 primary environmental samples. Sixty-one of these results (9.4 percent) were qualified because of potential blank contamination, high variability, high recovery, or low recovery.

Quality-Control Results for Monitoring Well MW02

Groundwater-quality samples were not collected from monitoring well MW02. The USGS redeveloped well MW02 during the week of April 30, 2012. Two QC samples were collected during redevelopment.

The QC samples were analyzed for several inorganic and organic constituents and dissolved gasses (table 3). Analytical results for both QC samples are listed in tables 12, 13, and 14. Analytical results from these two samples are not described further in this report because well MW02 was not sampled.

Table 12. Inorganic constituents in quality-control samples collected for monitoring well MW02 near Pavillion, Wyoming, May 2012.

Table 13. Organic constituents in quality-control samples collected for monitoring well MW02 near Pavillion, Wyoming, May 2012.

Table 14. Dissolved gasses in quality-control samples collected for monitoring well MW02 near Pavillion, Wyoming, May 2012.

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Appendix 1. Monitoring Well MW01 field notes—Field instrument calibration notes, general project notes, groundwater-quality notes for samples 1 and 2, alkalinity/acid-neutralizing capacity titration field notes and results (figures 1.1.1–1.3.2)

This appendix contains copies of field related project notes collected for activities related to monitoring well MW01. Specifically this appendix contains field instrument calibration notes (figures 1.1.1 and 1.1.2), general project notes (figures 1.2.1 through 1.2.12), groundwater-quality notes for Monitoring Well MW01 environmental sample 1 (figures 1.2.13 through 1.2.15, 1.2.21), the purge log for Monitoring Well MW01 samples 1 and 2 (figures 1.2.16 through 1.2.20), a list of analytes collected from Monitoring Well MW01 during sample 1 (figures 1.2.22 through 1.2.24), groundwater-quality notes for Monitoring Well MW01 environmental sample 2 (figures 1.2.25 through 1.2.27), field analysis notes for alkalinity, acid-neutralization capacity and miscellaneous measurements for Monitoring Well MW01 samples 1 and 2 (figures 1.3.1 through 1.3.9), and alkalinity and acid-neutralization capacity results for Monitoring Well MW01 samples 1 and 2 (figures 1.4.1 through 1.4.6).

Appendix 2. Monitoring Well MW01 laboratory-related documents—Analytical Services Request forms, Chain of Custody records (figures 2.1.1–2.9.7)

This appendix contains copies of laboratory analytical request forms (ASRs) and chain-of-custody forms (CoC), which accompanied environmental and quality-control samples during shipment to respective laboratories. This appendix includes ASR/CoC forms for the source solution (figures 2.1.1 through 2.1.3); ambient (figures 2.2.1 through 2.2.4) and field blanks (figures 2.3.1 through 2.3.5); ASR and COC forms for environmental sample 1 (figures 2.4.1 through 2.4.8, 2.4.10, and 2.4.17); the sample 1 replicate (2.5.1 through 2.5.5); environmental sample 2 (figures 2.6.1 through 2.6.7); the sample 2 replicate (2.7.1 through 2.7.4); the matrix spike sample (figures 2.8.1 through 2.8.5); the matrix-spike duplicate sample (figures 2.9.1 through 2.9.5); and the trip blank (2.9.6 and 2.9.7). Chain-of-custody records that relate to both samples 1 and 2 are included as figures 2.4.9 and 2.4.11 through 2.4.16.

Appendix 3. Monitoring Well MW01 photographs (figures 3.1–3.1.6)

This appendix contains a selection of photographs taken April 24, 2012, to document sampling activities at Monitoring Well MW01.

Appendix 4. Monitoring Well MW02 field notes—Groundwater-quality and field notes for collection of samples related to work at this well (figures 4.1–4.7)

This appendix contains copies of field related project notes collected for activities related to monitoring well MW02. Specifically, this appendix includes project notes (figure 4.1), groundwater- quality notes for the collection of a sample of public water supply of the city of Riverton, Wyoming (figures 4.2 through 4.6), and field notes for the collection of a downhole camera equipment blank (figure 4.7).

Appendix 5. Monitoring Well MW02 laboratory-related documents—Analytical Services Request forms, Chain of Custody records (figures 5.1.1–5.2.4)

This appendix contains copies of laboratory analytical request forms (ASRs) and chain-of-custody forms (CoC) that accompanied the sample of public water supply of the city of Riverton, Wyoming (figures 5.1.1 through 5.1.5) and the downhole camera blank (figures 5.2.1 through 5.2.4) to TestAmerica Laboratories.

Appendix 6. Monitoring Well MW02 photographs (figures 6.1–6.6)

This appendix contains a selection of photographs taken May 1st and 2nd, 2012 to document redevelopment related activities at Monitoring Well MW02.

Appendix 7. Tentatively identified compounds identified in environmental and quality-control samples collected for monitoring well MW01 near Pavillion, Wyoming

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