LMS/RVT/S09799

2012 Enhanced Characterization and Monitoring Report Riverton, Wyoming, Processing Site

June 2013

U.S. DEPARTMENT OF
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2012 Enhanced Characterization and Monitoring Report Riverton, Wyoming, Processing Site (June 2013)

The U.S. Department of Energy (DOE) has prepared a report entitled *2012 Enhanced Characterization and Monitoring Report, Riverton, Wyoming, Processing Site* (June 2013). **At your request, you are receiving a hard copy of the report.**

The report is also available for your review on the Internet at the DOE Office of Legacy Management (LM) website http://energy.gov/lm. From the LM website home page, select the LM SITES MAP. Then select the Riverton Site from the LM Sites list in the right column. The report will be available on the Riverton Site page of the LM website under Site Documents and Links.

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Abbreviations

ASW	artificial site water
AWSS	alternate water supply system
bgs	below ground surface
cfs	cubic feet per second
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	foot
ft/s	feet per second
g	grams
GCAP	Groundwater Compliance Action Plan
GV	Groundwater Vistas
IC	institutional control
K_d	distribution coefficient
LM	Office of Legacy Management
LTMP	*Long-Term Management Plan for the Riverton, Wyoming, Processing Site*
MCL	maximum concentration limit
µg/g	micrograms per gram
mg/L	milligrams per liter
mL	milliliters
mL/g	milliliters per gram
mL/min	milliliters per minute
mm	millimeters
NRC	U.S. Nuclear Regulatory Commission
pCi/L	picocuries per liter
PD	percent difference
SOWP	Site Observational Work Plan
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act

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Executive Summary

Verification monitoring in 2012 at the Riverton, Wyoming, Processing Site involved routine sampling of groundwater, surface water, and domestic wells, and a flushing and monitoring program of the alternate water supply system that was reinstituted in late 2011. Concentrations of uranium and molybdenum at the site remained above their respective groundwater standards in surficial aquifer wells; however, concentrations in 2012 decreased to near 2009 levels after spiking following the 2010 flood of the Little Wind River. Sampling results from domestic wells continued to indicate no impact from site-related contaminants, and the flushing program for the alternate water supply system was effective in controlling the buildup of radionuclides in the system.

An enhanced characterization of the surficial aquifer was conducted in 2012, which included installation of 103 boreholes along 9 transects with a Geoprobe, collection of 103 water samples and 65 soil samples, laboratory tests on the soil samples, and additional groundwater modeling. Analysis of groundwater samples resulted in a better understanding of the size and shape of contaminant plumes for manganese, molybdenum, sulfate, and uranium. Laboratory soil testing indicated that there is uranium in the soils above the water table that can be mobilized by flood events; however, the concentration of uranium in unsaturated zone samples alone does not appear to be high enough to have caused the spikes observed in the groundwater after the 2010 flood.

Several types of information, including uranium mobilized by flood events, current plume size and concentration, groundwater modeling results, historical data, and experience at other Uranium Mill Tailings Radiation Control Act (UMTRCA) sites, indicates natural flushing of the surficial aquifer is occurring at the Riverton site, but the rate at which it is occurring might not meet the 100-year regulatory time frame. Additional information will be needed and additional work conducted to gain a better understanding of the site before a final decision can be made regarding the natural flushing compliance strategy or before a selection of an alternate compliance strategy can be made.

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1.0 Introduction

This Riverton, Wyoming, Processing Site enhanced characterization and monitoring report does the following: presents data collected during calendar year 2012, presents and evaluates enhanced characterization efforts to update the site conceptual model, provides an update on the natural flushing compliance strategy, and provides recommendations for future work. Data from 2012 were generated from two routine groundwater and surface water sampling events conducted at the Riverton site during June and December, an enhanced characterization effort with the field investigation conducted in August, a flushing event of the alternate water supply system (AWSS) conducted in October, and soils testing and groundwater modeling in the fall and winter.

2.0 Verification Monitoring

The compliance strategy for the Riverton site is natural flushing in conjunction with institutional controls (ICs) (DOE 1998a). Monitoring required during the natural flushing period is referred to as verification monitoring because the purpose of the monitoring is to verify that the natural flushing strategy is progressing as predicted, and to verify that ICs are in place and functioning as intended. Data collected during verification monitoring are reported annually in a Verification Monitoring Report. These reports have been issued annually since 2001, and the reports from 2005 to 2011can be found on the U. S. Department of Energy's (DOE) Office of Legacy Management (LM) website at http://www.lm.doe.gov/Riverton/Sites.aspx. All water quality data for the Riverton site are archived in the LM's environmental database in Grand Junction, Colorado. Water quality data also are available for viewing with dynamic mapping via the Geospatial Environmental Mapping System (GEMS) website at http://gems.lm.doe.gov/imf/sites/gems_continental_us/jsp/launch.jsp.
The monitoring program at the Riverton site is specified in the *Long-Term Management Plan for the Riverton, Wyoming, Processing Site* (LTMP) (DOE 2009).

2.1 Site Conditions

2.1.1 Uranium Mill Tailings Remedial Action (UMTRA) Site and Surface Remediation

A uranium and vanadium-ore-processing mill operated from1958 to 1963 at the Riverton site. A tailings pile covered about 72 acres of the 140-acre site. In 1988 and 1989, the tailings pile was excavated down to an average depth of 4 feet (ft) below ground surface (bgs) based on a radium-226 soil standard. Surface remediation activities resulted in removal of about 1.8 million cubic yards of tailings and associated materials from the site, which were encapsulated at the Gas Hills East, Wyoming, Disposal Site (Figure 1) (DOE 1998b). Soils at and below the water table with elevated thorium-230 concentrations were left in place on portions of the former mill site by applying supplemental standards. An easement and covenant to restrict land use on the former mill site is in place to prevent exposure to and disturbance of the supplemental-standard areas.

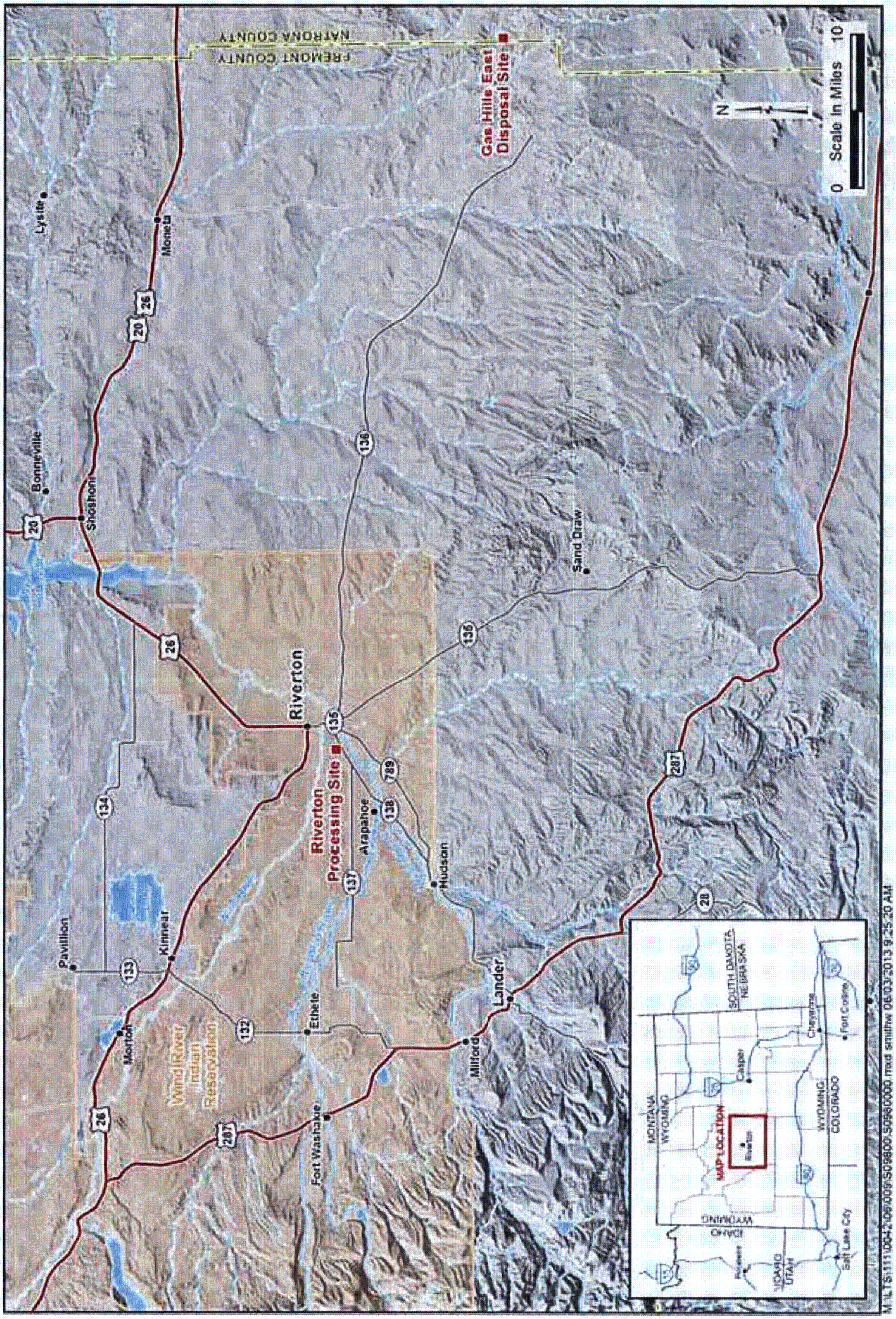

Figure 1. Site Location Map

2.1.2 Hydrogeology

The Riverton site is located on an alluvial terrace between the Wind River and the Little Wind River approximately 2.3 miles southwest of the town of Riverton, Wyoming (Figure 1). Groundwater is in three aquifers beneath the site: (1) a surficial unconfined aquifer (surficial aquifer), (2) a middle semiconfined aquifer, and (3) a deeper confined aquifer (DOE 1998b). The surficial aquifer consists of approximately 15 to 20 ft of unconsolidated alluvial material; the semiconfined and confined aquifers are composed of shales and sandstones of the upper units of the Eocene Wind River Formation, which is over 500 ft thick in the vicinity of the site. Depth to groundwater in the surficial aquifer is generally less than 10 ft bgs. For compliance purposes, the surficial aquifer and semiconfined aquifer comprise the uppermost aquifer, which is the aquifer where compliance with groundwater standards is assessed. Groundwater in the uppermost aquifer flows to the southeast.

Because the Riverton site is located on an alluvial terrace between the Wind River and the Little Wind River, site conditions have been influenced by periodic flooding of these rivers. Influence of river flooding on site conditions includes the following: formation of an oxbow lake in 1995; spikes in groundwater contaminant concentrations; high groundwater levels leaving contaminants in the unsaturated zone; and high groundwater levels that leached contaminants from the former tailings pile (White et al.1984). Significant floods of the Little Wind River that likely affected the site occurred in 1963, 1965, 1967, 1983, 1991, 1995, and 2010 when peak river discharge was greater than 8,000 cubic feet per second (cfs) (USGS 2012a). Significant floods of the Wind River that likely affected the site occurred in 1963, 1967, 1971, 1991, 1997, 1999, and 2011 when peak stream discharge was greater than 8,000 cfs (USGS 2012b). Discharge data and flood data from the Little Wind River are presented in Section 2.3.2.1.

2.1.3 Water Quality

Shallow groundwater beneath and downgradient from the site was contaminated as a result of uranium-processing activities from 1958 through 1963 (DOE 1998b). Contaminants of potential concern (COPCs) in the groundwater beneath the Riverton site are manganese, molybdenum, sulfate, and uranium. COPCs were selected using a screening process that compared contaminant concentrations with the maximum concentration limits (MCLs) in Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192), as appropriate, and evaluated potential human health risks and ecological risks. (Note: The MCLs discussed in this document are not the same as the maximum contaminant levels that the U.S. Environmental Protection Agency (EPA) sets as drinking water standards.) The COPC-selection process is detailed in the *Environmental Assessment of Ground Water Compliance at the Riverton, Wyoming, Uranium Mill Tailings Site* (DOE 1998c). Molybdenum and uranium were selected as indicator contaminants for compliance monitoring in the *Final Ground Water Compliance Action Plan for the Riverton, Wyoming, Title I UMTRA Project Site* (DOE 1998a). These contaminants were selected as indicator contaminants because they are the most widely distributed and because they form significant aqueous plumes in the uppermost aquifer in the vicinity of the site. The MCLs for molybdenum and uranium are 0.10 milligram per liter (mg/L) and 30 picocuries per liter (pCi/L), respectively.

In order to provide a consistent comparison with historical data, uranium concentrations continue to be measured in mg/L; therefore, the uranium standard referenced in this report has been converted from 30 pCi/L to 0.044 mg/L (which assumes secular equilibrium of uranium isotopes) to allow direct comparison of uranium data to the standard.

2.1.4 Institutional Controls

To protect human health and the environment during the natural flushing period, ICs are required to control exposure to contaminated groundwater. An IC boundary has been established at the Riverton site (Figure 2), delineating the area that requires protection. The IC boundary was set to encompass the area of current groundwater contamination and a surrounding buffer zone to account for potential future plume migration.

2.1.4.1 Site Institutional Controls

All IC components have not been finalized, but there is an ongoing cooperative effort among DOE, the Northern Arapaho and Eastern Shoshone Tribes, and the State of Wyoming in order to final additional viable and enforceable ICs at the Riverton site. ICs currently in place include the following components:

- An AWSS, funded by DOE and currently operated by the Great Plains Utility Organization, supplies potable water to residents within the IC boundary to minimize use of groundwater.
- Warning signs installed around the oxbow lake (Figure 3) explain that the contaminated water is not safe for human consumption, with instructions not to drink from, fish in, or swim in the lake.
- A Tribal Ordinance places restrictions on well installation, prohibits surface impoundments, authorizes access to inspect and sample new wells, and provides notification to drilling contractors of the groundwater contamination within the IC boundary. Restrictions on well installation include a minimum depth of 150 ft bgs (approximately 50 ft below the top of the confined aquifer) and installation of surface casing through the contaminated upper aquifer.
- DOE will notify area drilling contractors of the existing groundwater contamination.
- A State of Wyoming Department of Environmental Quality notification of existing groundwater contamination will be provided to persons on privately owned land who apply for a gravel pit permit within the IC boundary.
- A U.S. Bureau of Indian Affairs notification of existing groundwater contamination will be provided to persons on tribal land applying for a surface impoundment within or adjacent to the IC boundary.
- The State of Wyoming State Engineer's Office will inform DOE when permit applications are received for wells or surface impoundments within or adjacent to the IC boundary, provide DOE with a copy of the application (so that DOE may comment on it), and incorporate DOE's comments on the permit, if approved.
- An easement and covenant to restrict land use and well drilling on the former mill site property was finalized on June 29, 2009, and the former mill site was purchased by Chemtrade Refinery Services Inc.

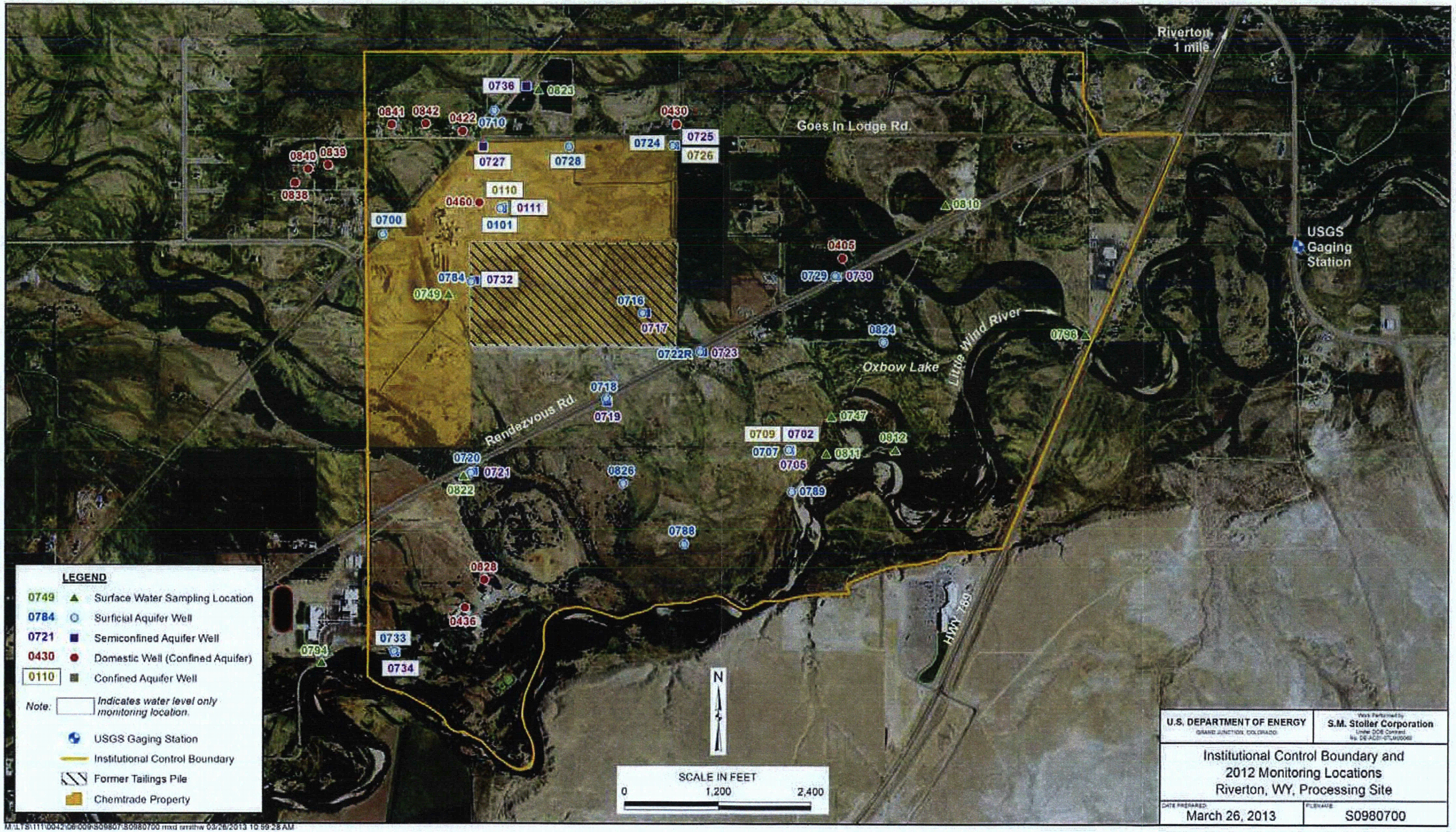

Figure 2. Institutional Control Boundary and 2012 Monitoring Locations at the Riverton Site

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Figure 3. Warning Sign at the Oxbow Lake

ICs that are in progress, but not finalized, include the following:

- A U.S. Bureau of Indian Affairs–provided notification of existing groundwater contamination will be provided to all residents on tribal land within or adjacent to the IC boundary.
- A notification of existing groundwater contamination will be provided to fee-land property owners within the IC boundary every 5 years.

2.1.4.2 Institutional Control Monitoring

The LTMP specifies ongoing IC monitoring to verify that ICs are in place and working, in order to ensure that potential exposure to contaminated groundwater is minimized during the natural flushing period. IC monitoring consists of two components: (1) sampling and (2) land and water use verification. The sampling component consists of sampling of domestic wells and the AWSS. The land and water use verification consists of periodic inspection of lands within the IC boundary to verify and document that no additional land or water uses expose or involve shallow groundwater, such as new wells, gravel pits, and recreational ponds.

All known domestic wells used as a potable water source within the IC boundary were sampled during June and December in 2012, and the results are presented in Section 2.3.1.3 and Appendix C.

The Great Plains Utility Organization is responsible for ensuring that the quality, safety, and quantity of the water in the AWSS are adequate. The Great Plains Utility Organization is also required to maintain compliance with EPA standards that regulate community water systems. To assist in this effort and to maintain the AWSS as a viable IC, DOE has a cooperative agreement with the Northern Arapaho Tribe to ensure cooperative efforts and funding for ongoing maintenance, flushing, sampling, and capital improvements on the AWSS.

An AWSS hydrant flushing program was restarted in October of 2011 as specified in the cooperative agreement with the Northern Arapaho Tribe. As a result of some erroneous laboratory results from the October 2011 hydrant flushing and sampling event that were disclosed to DOE prior to a public meeting on May, 6, 2012, DOE committed to managing the sampling and analysis portion of the hydrant flushing program to ensure samples were analyzed by an accredited and audited analytical laboratory. In 2012, flushing and sampling events were conducted in April and October. The April hydrant flushing event (prior to the public meeting) was conducted by the Great Plains Utility Organization and the Tribal Engineer's Office, and the October hydrant flushing event was conducted as a joint effort among the Great Plains Utility Organization, the Tribal Engineer's Office, and DOE. Results of the October hydrant flushing event are presented in Section 2.3.3 and Appendix E.

Verification that one component of the institutional controls is working as intended was received in 2012. DOE received a letter from the State Engineer's Office on December 18, 2012, requesting comments on a proposed well in the vicinity of the Riverton site. DOE reviewed the application for the well, and determined that the well installation could proceed because the proposed location of the well was outside of the IC boundary. A response letter was drafted and sent to the State Engineer's Office in early 2013.

Sampling crews inspected areas within the IC boundary during each semiannual sampling event and found no evidence of new land or water use that would expose groundwater.

2.2 Monitoring Program

The verification monitoring program for 2012 consisted of 18 monitoring wells, 11 domestic wells, and 9 surface water locations, which are listed in Table 1 and shown in Figure 2. In addition, 7 AWSS hydrant locations and 4 AWSS tap locations were sampled and are listed in Table 1 and discussed in Section 2.3.3. Domestic wells 0838, 0839, and 0840 were sampled only in June at the request of the homeowners; these wells are outside the IC boundary and will not be included in the long-term monitoring program. Water levels were measured at 15 additional monitoring wells. Sampling events were conducted in June (groundwater, surface water, and domestic wells), October (AWSS), and December (groundwater, surface water, and domestic wells). Samples collected in June and December were analyzed for manganese, molybdenum, selenium (June only), sulfate, and uranium, and field measurements of temperature, pH, specific conductance, oxidation-reduction potential, dissolved oxygen, alkalinity, and turbidity were measured at each sampling location. Samples collected in October were analyzed for radium-226, radium-228, and uranium and field measurements of chlorine, temperature, pH, specific conductance, oxidation-reduction potential, dissolved oxygen, alkalinity, and turbidity.

Table 1. 2012 Sampling Network at the Riverton Site

Location ID	Description	Sampling Event	Rationale
DOE Monitoring Wells			
0705	Semiconfined aquifer	June, December	Monitor semiconfined aquifer
0707	Surficial aquifer	June, December	Monitor centroid of plume
0710	Surficial aquifer	June, December	Background location
0716	Surficial aquifer	June, December	Monitor upgradient portion of plume
0717	Semiconfined aquifer	June, December	Monitor semiconfined aquifer
0718	Surficial aquifer	June, December	Monitor lateral plume movement
0719	Semiconfined aquifer	June, December	Monitor semiconfined aquifer
0720	Surficial aquifer	June, December	Monitor lateral plume movement
0721	Semiconfined aquifer	June, December	Monitor semiconfined aquifer
0722R	Surficial aquifer	June, December	Monitor centroid of plume
0723	Semiconfined aquifer	June, December	Monitor semiconfined aquifer
0729	Surficial aquifer	June, December	Monitor lateral plume movement
0730	Semiconfined aquifer	June, December	Monitor semiconfined aquifer
0784	Surficial aquifer	June, December	Monitor lateral plume movement
0788	Surficial aquifer	June, December	Monitor lateral plume movement
0789	Surficial aquifer	June, December	Monitor centroid of plume
0824	Surficial aquifer	June, December	Monitor lateral plume movement
0826	Surficial aquifer	June, December	Monitor lateral plume movement
Domestic Wells[a]			
0405	Private residence	June, December	Potential point of exposure
0422	Private residence	June, December	Potential point of exposure
0430	Private residence	June, December	Potential point of exposure
0436	St Stephens Mission	June, December	Potential point of exposure
0460	Chemtrade Refinery	June, December	Potential point of exposure
0828	St. Stephens Mission	June, December	Potential point of exposure
0838	Private residence	June	Homeowner request
0839	Private residence	June	Homeowner request
0840	Private residence	June	Homeowner request
0841	Private residence	June, December	Potential point of exposure
0842	Private residence	June, December	Potential point of exposure
Surface Water			
0747	Oxbow lake	June, December	Impacted by groundwater discharge
0749	Chemtrade Refinery discharge ditch	June, December	Effluent from sulfuric acid plant
0794	Little Wind River	June, December	Upstream of predicted plume discharge
0796	Little Wind River	June, December	Downstream of predicted plume discharge
0810	Pond—former gravel pit	June, December	Potential for impact—within IC boundary
0811	Little Wind River	June, December	Within area of predicted plume discharge
0812	Little Wind River	June, December	Within area of predicted plume discharge
0822	West side irrigation ditch	June, December	Potential for impact—within IC boundary
0823	Pond—former gravel pit	June, December	Upgradient of plume—within IC area
AWSS Hydrants			
0818	AWSS flushing hydrant	October	Verify effectiveness of flushing program
0819	AWSS flushing hydrant	October	Verify effectiveness of flushing program
0820	AWSS flushing hydrant	October	Verify effectiveness of flushing program
0821	AWSS flushing hydrant	October	Verify effectiveness of flushing program
0829	AWSS flushing hydrant	October	Verify effectiveness of flushing program
0830	AWSS flushing hydrant	October	Verify effectiveness of flushing program
0834	AWSS flushing hydrant	October	Verify effectiveness of flushing program

Table 1 (continued). 2012 Sampling Network at the Riverton Site

Location ID	Description	Sampling Event	Rationale
AWSS Taps			
0813	AWSS tap at house	October	Verify taps unaffected by flushing process
0815	AWSS tap at house	October	Verify taps unaffected by flushing process
0816	AWSS tap at house	October	Verify taps unaffected by flushing process
0837	AWSS tap at house	October	Verify taps unaffected by flushing process

[a] All domestic wells are completed in the confined aquifer, except for well 0841, which might be completed in the semiconfined aquifer

2.3 Results of 2012 Monitoring

2.3.1 Groundwater

2.3.1.1 Groundwater Flow

Water levels were measured at all wells in the monitoring network in June and December in order to verify groundwater flow direction and to assess vertical gradients throughout the IC area. Water level data are included in Appendix A.

Assessment of horizontal groundwater flow direction in the surficial aquifer is required to ensure that the monitoring network is adequate for assessing contaminant plume movement and to ensure that the IC boundary provides a sufficient buffer to prevent access to contaminated groundwater. As shown in Figure 4 and Figure 5, groundwater elevation contours for the surficial aquifer indicate a general flow direction to the southeast in June and December. Water levels have been historically consistent as shown in Figure 5, which compares December 2012 and February 1997 water levels. Contaminant plume configurations tend to have a more southerly axis than the measured groundwater flow direction, which may be explained by different flow patterns during milling operations caused by groundwater mounding in the tailings area coupled by irrigation practices to the east of the site. In addition to water levels measured during each sampling event, continuous water-level measurements recorded by pressure transducers installed in wells along the groundwater flow path demonstrate that, based on groundwater elevations, the groundwater flow does not reverse direction throughout the year (Figure 6).

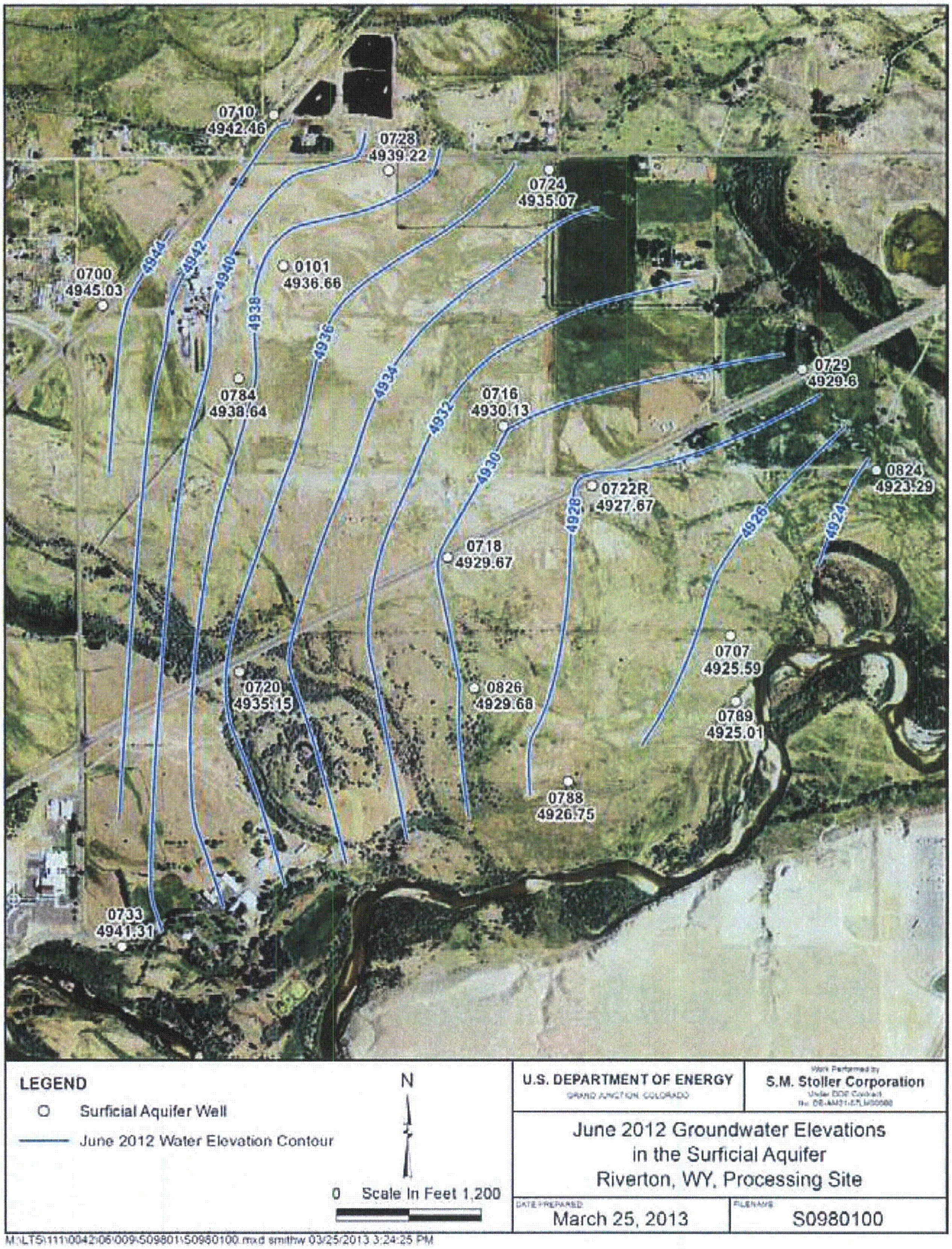

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Figure 4. June 2012 Groundwater Elevations in the Surficial Aquifer at the Riverton Site

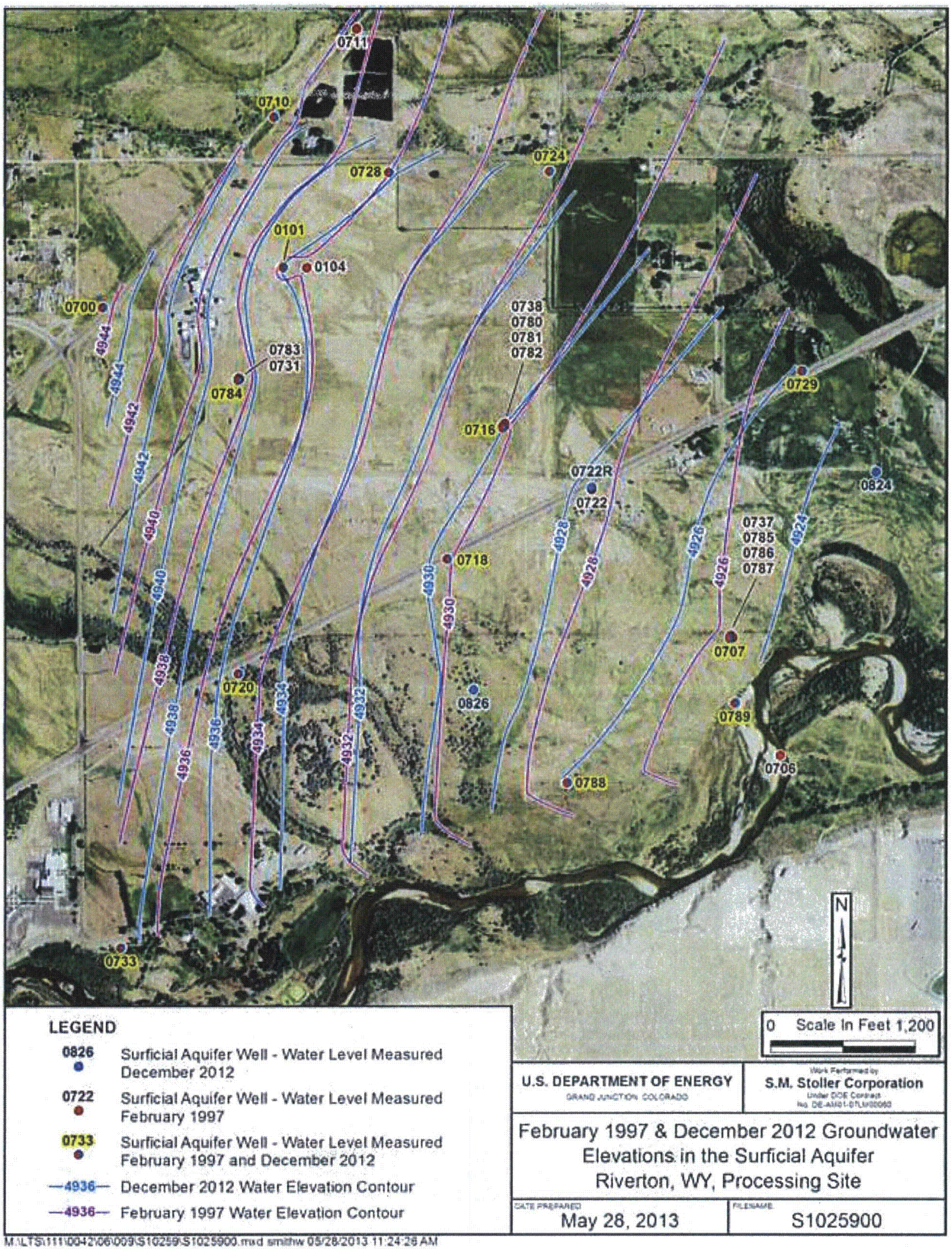


Figure 5. February 1997 and December 2012 Groundwater Elevations in the Surficial Aquifer at the Riverton Site

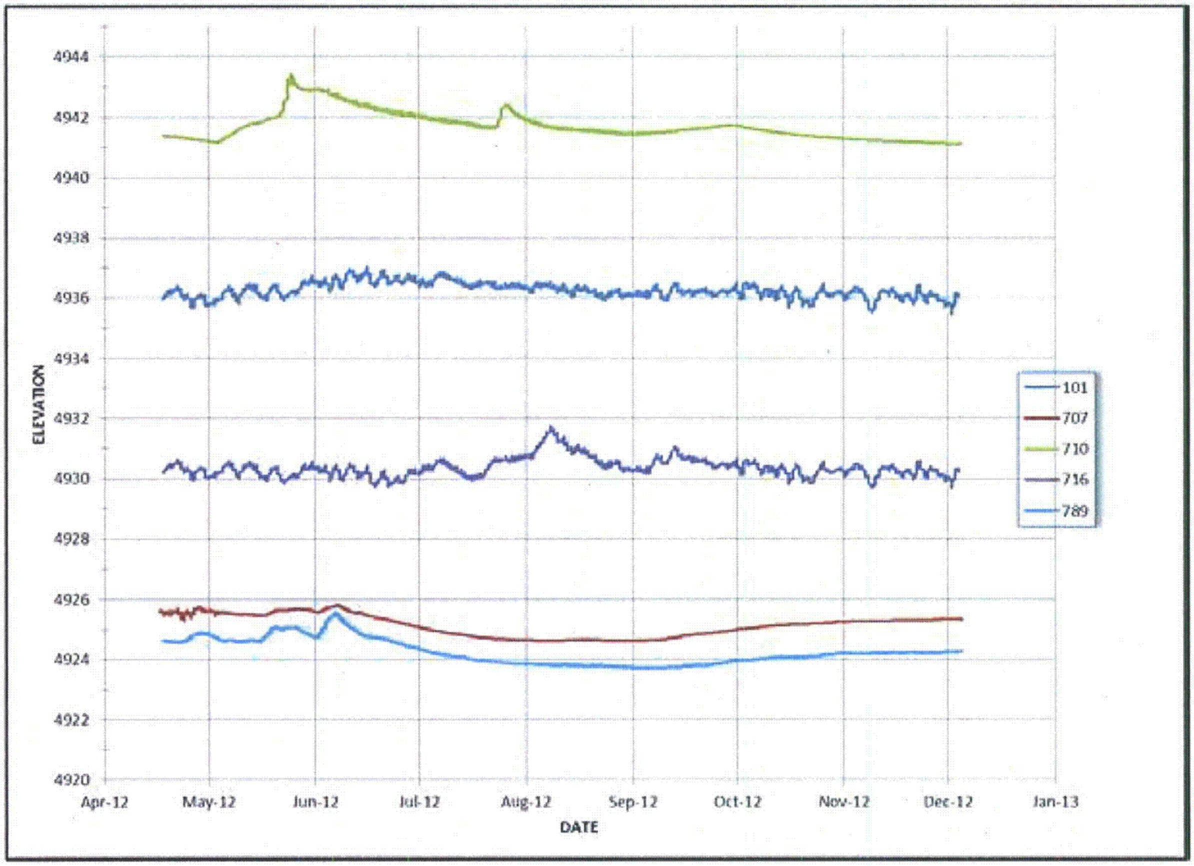


Figure 6. Continuous Water Elevations in Selected Surficial Aquifer Wells

Vertical gradients are used to assess the direction that groundwater will flow vertically. Using the methods that have traditionally been applied to assess vertical flow, a negative gradient indicates potential for upward groundwater flow, and a positive gradient indicates potential for downward groundwater flow. Regardless of the direction indicated by gradient, vertical migration of groundwater between the Riverton site aquifers is expected to be relatively minor because of the low vertical hydraulic conductivities of the confining layers separating aquifers. Vertical gradients are calculated from monitoring wells in an upper aquifer$_1$ and lower aquifer$_2$ using the following formula: $(GE_1\text{-}GE_2) \div (SE_1\text{-}SE_2)$, where GE = groundwater elevation and SE = screen elevation at the midpoint of the screen. Vertical gradients calculated from June and December data from grouped monitoring wells are shown in Table 2. General observations from Table 2 include the following:

- Vertical gradients in the confined aquifer are upward or 0 at two locations and mixed at one location.
- The well cluster adjacent to the sulfuric acid plant (0101, 0111, and 0110) typically shows downward vertical gradient between the confined aquifer and surficial aquifer, which is likely a reflection of continuous long-term pumping of the confined aquifer from the acid-plant production well; in 2012, the gradient was slightly upward in December.
- Although the well cluster adjacent to the sulfuric acid plant typically indicates a downward vertical gradient in the confined aquifer, an upward vertical gradient is indicated in the semiconfined aquifer, which confirms that the semiconfined and confined aquifers are hydrologically isolated.

- Vertical gradients between the surficial and semiconfined aquifer vary but tend to be downward near surface water features, and upward away from surface water features. Surface water is likely recharging the surficial aquifer, causing a localized increase in heads in the surficial aquifer and a resulting downward vertical gradient.

Table 2. Riverton Vertical Gradients

Well ID	Aquifer	Water Elevation June 2012	Water Elevation December 2012	Vertical Gradient[a] June 2012	Vertical Gradient December 2012
0724	Surficial	4935.07	4932.7		
0725	Semiconfined	4935.19	4932.68	-0.007	0.001
0726	Confined	4935.7	4933.83	-0.006	-0.010
0101	Surficial	4936.66	4935.88		
0111	Semiconfined	4937.82	4936	-0.043	-0.004
0110	Confined	4932	4935.99	0.089	-0.002
0784	Surficial	4938.64	4938.73		
0732	Semiconfined	4937.02	4936.84	0.061	0.072
0716	Surficial	4930.13	4929.98		
0717	Semiconfined	4930.17	4929.98	-0.001	0
0707	Surficial	4925.59	4925.25		
0705	Semiconfined	4924.48	4924.06	0.039	0.042
0709	Confined	4927.68	4925.25	-0.027	0
0718	Surficial	4929.67	4929.35		
0719	Semiconfined	4930.05	4929.66	-0.019	-0.016
0722R	Surficial	4927.67	4927.65		
0723	Semiconfined	4927.89	4927.86	-0.007	-0.007
0720	Surficial	4935.15	4935.09		
0721	Semiconfined	4932.56	4932.45	0.072	0.073
0729	Surficial	4929.6	4925.83		
0730	Semiconfined	4928.1	4925.44	0.065	0.017
0733	Surficial	4941.31	4938.52		
0734	Semiconfined	4938.92	4936.76	0.105	0.077

[a] The vertical gradient from the semiconfined aquifer is between the semiconfined aquifer and the surficial aquifer, and the vertical gradient from the confined aquifer is between the confined aquifer and the surficial aquifer. A negative value indicates an upward vertical gradient.

2.3.1.2 *Groundwater Quality*

Surficial aquifer data from the 2012 sampling events are summarized in the following plots and figures. Time-concentration plots for molybdenum in wells located within contaminant plumes and wells bordering the contaminant plumes in the surficial aquifer are shown in Figure 7 and Figure 8, respectively. The distribution of molybdenum in the surficial aquifer from the June and December 2012 sampling events is shown in Figure 9 and Figure 10, respectively. Time-concentration plots for uranium in wells located within contaminant plumes and wells on the lateral edge of the contaminant plumes in the surficial aquifer are shown in Figure 11 and Figure 12, respectively. The distribution of uranium in the surficial aquifer, based on June and December 2012 sampling results, is shown in Figure 13 and Figure 14, respectively.

As shown in the plots and figures, concentrations of molybdenum and uranium in groundwater in the surficial aquifer are still above their respective MCLs. In June 2010, a dramatic increase in uranium concentrations was observed in wells 0707, 0788, 0789, and 0826 where flooding of the Little Wind River occurred. These increases in uranium concentrations included wells on the western edge of the plume (0788 and 0826), where sample concentrations exceeded the uranium standard, indicating lateral expansion of the plume. In addition, molybdenum concentrations increased dramatically in well 0707 during the June sampling event (Figure 7). In 2012, the concentration of uranium in sample collected from well 0707 in December was back to a pre-flood level.

Concentrations of molybdenum and uranium in groundwater in the semiconfined aquifer are still below corresponding MCLs in areas where the overlying surficial aquifer groundwater is contaminated, which indicate no significant impact from site-related contamination in this unit (Figure 15 and Figure 16).

Groundwater quality data by parameter for monitoring wells in the long-term monitoring network sampled during 2012 are provided in Appendix B.

In response to a review of groundwater quality data that was documented in the *Evaluation of Groundwater Constituents and Seasonal Variation at the Riverton, Wyoming, Processing Site* (DOE 2012a), samples collected from all wells were analyzed for selenium during the June sampling event. All selenium concentrations were one to two orders of magnitude below the selenium MCL of 0.01 mg/L, which confirms that this contaminant is not a concern at the Riverton site and will not be included in the long-term monitoring program. Selenium data are provided in Appendix B.

2.3.1.3 Domestic Wells

Domestic wells at residences within the IC boundary used as a potable water source and three wells outside the IC boundary were sampled in 2012; most of these wells are completed in the confined aquifer with the exception of well 0841, which is likely completed in the semiconfined aquifer. Results from domestic wells did not indicate any impacts from the Riverton site. Concentrations of molybdenum in samples collected from domestic wells were two orders of magnitude below the standard, and concentrations of uranium in samples collected from domestic wells were one to three orders of magnitude below the standard. Time-concentration graphs for molybdenum and uranium are shown in Figure 17 and Figure 18, respectively. Selenium concentrations measured in samples collected in June were low (below or near the detection limit) and two to three orders of magnitude below the MCL. Data obtained from sampling of domestic wells in 2012 are provided in Appendix C.

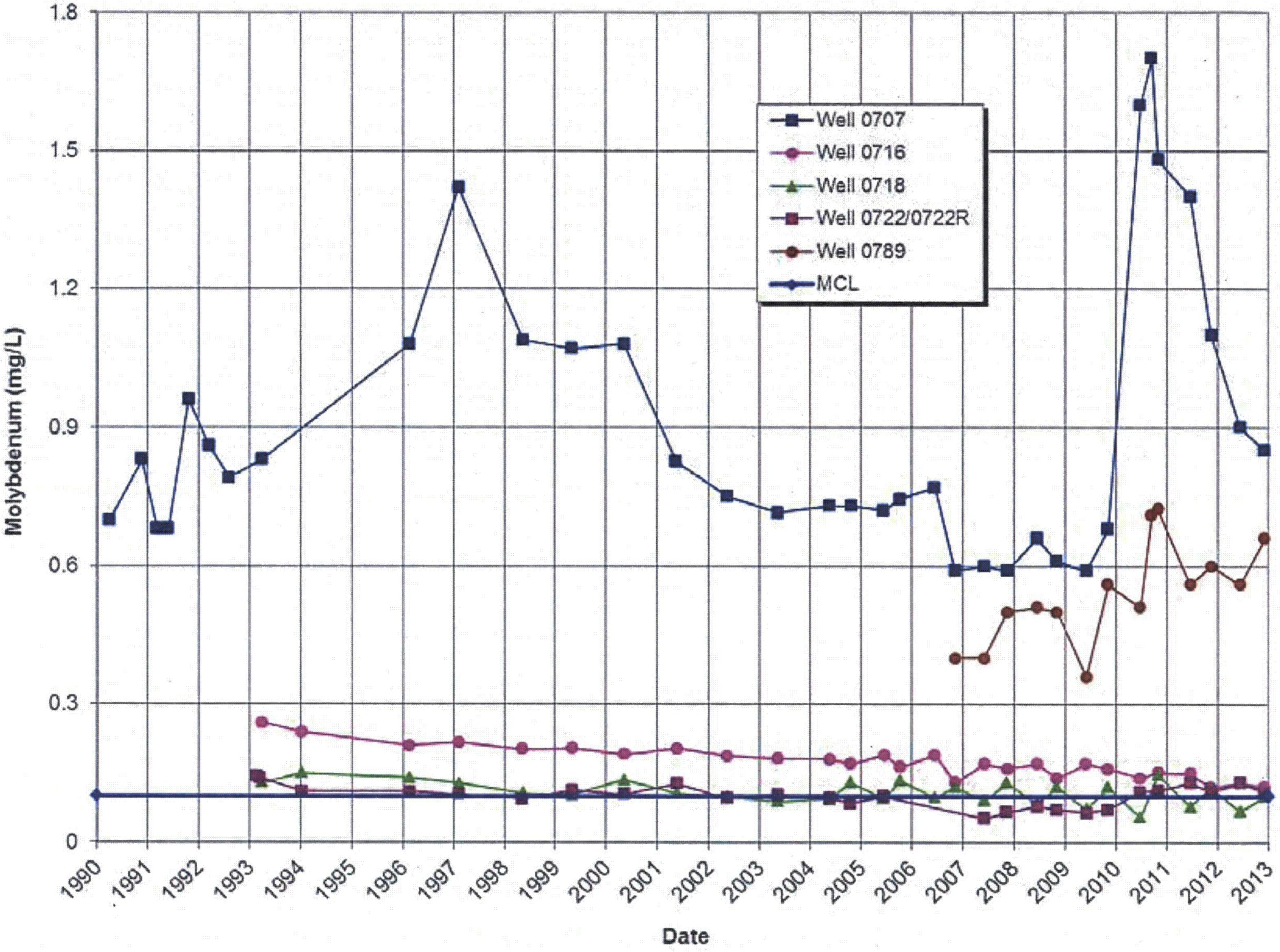
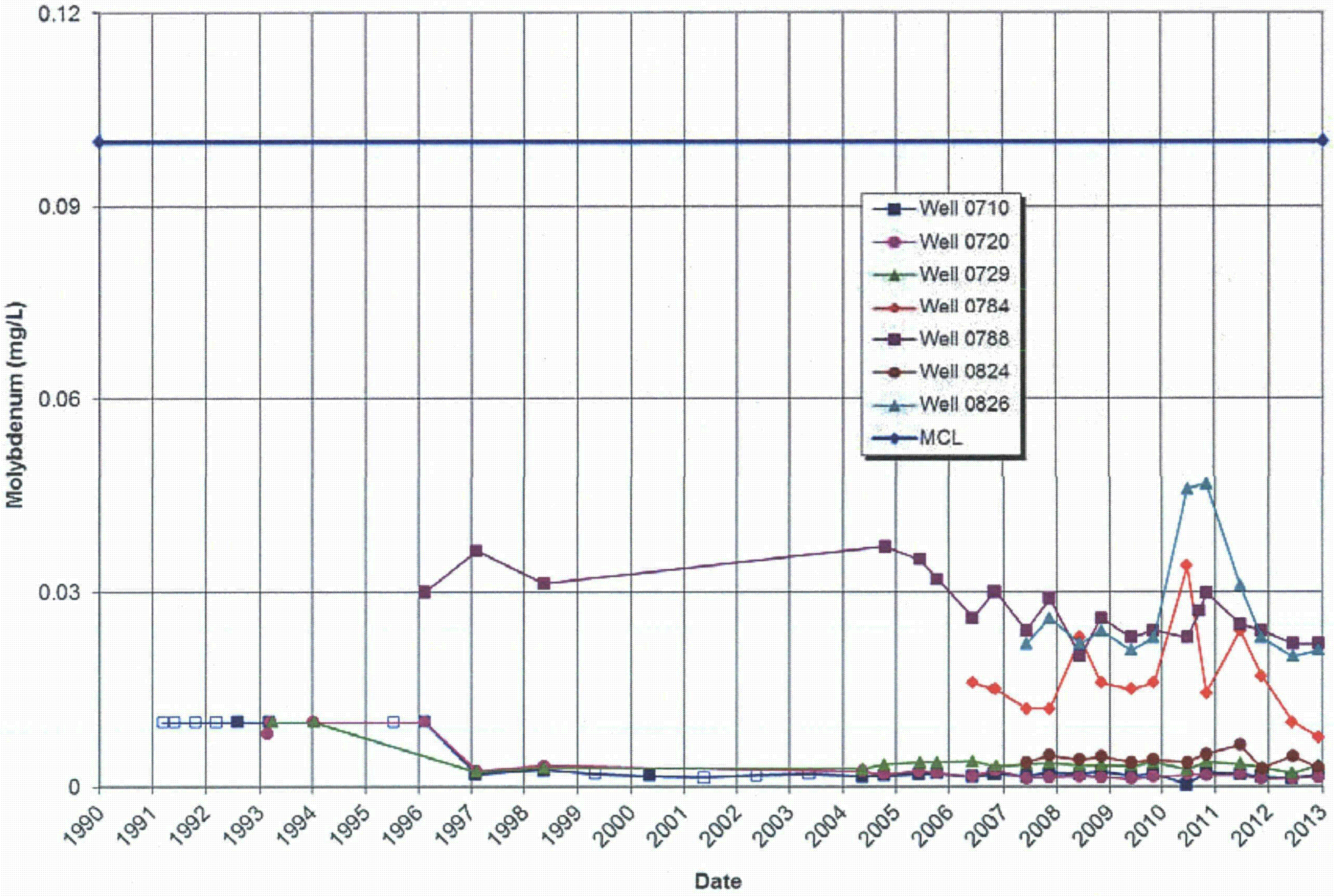


Figure 7. Molybdenum Concentrations in Surficial Aquifer Wells within the Contaminant Plume



Note: A hollow symbol denotes an analytical result below the detection limit.

Figure 8. Molybdenum Concentrations in Surficial Aquifer Wells on the Edge of the Contaminant Plume

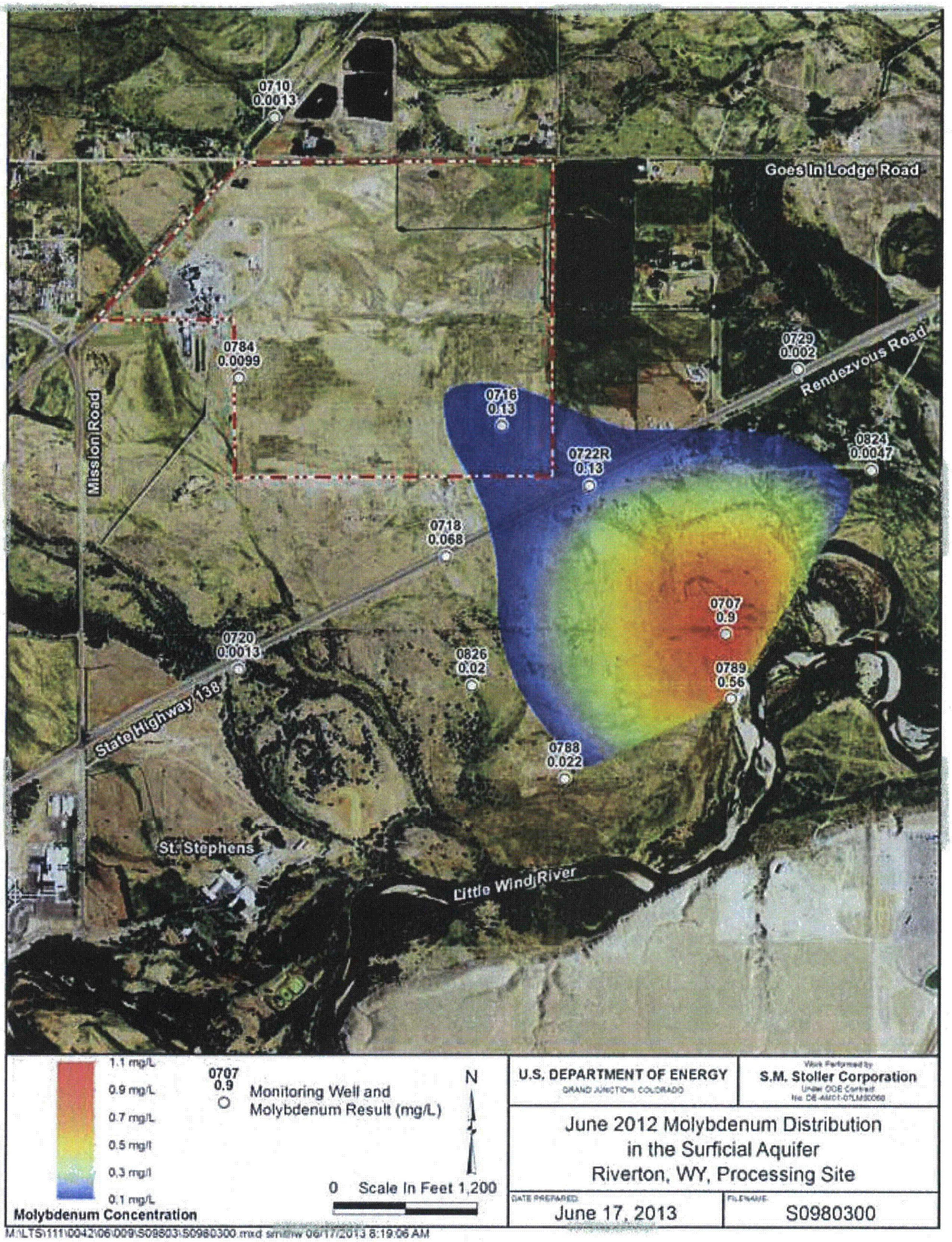


Figure 9. June 2012 Molybdenum Distribution in the Surficial Aquifer at the Riverton Site

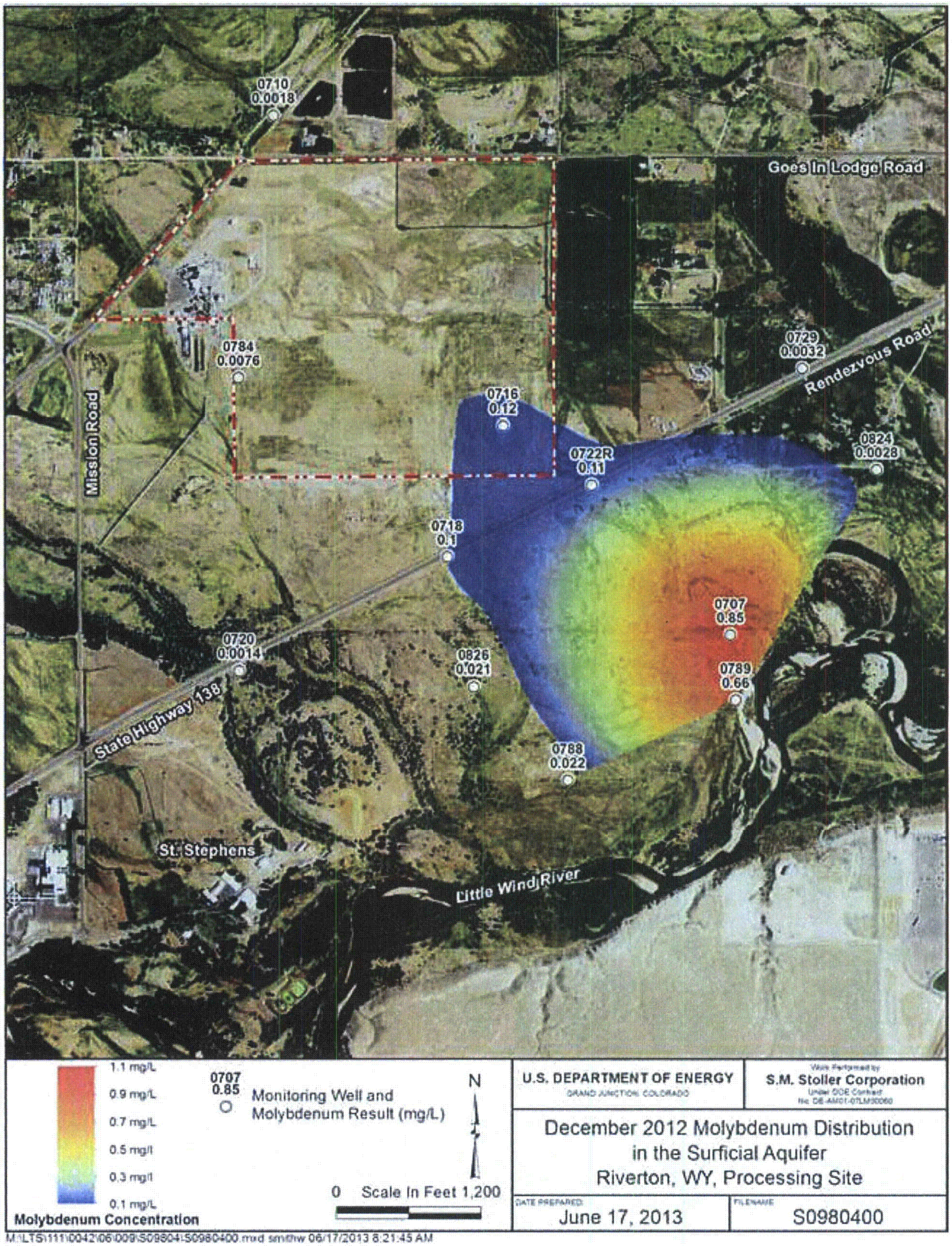


Figure 10. December 2012 Molybdenum Distribution in the Surficial Aquifer at the Riverton Site

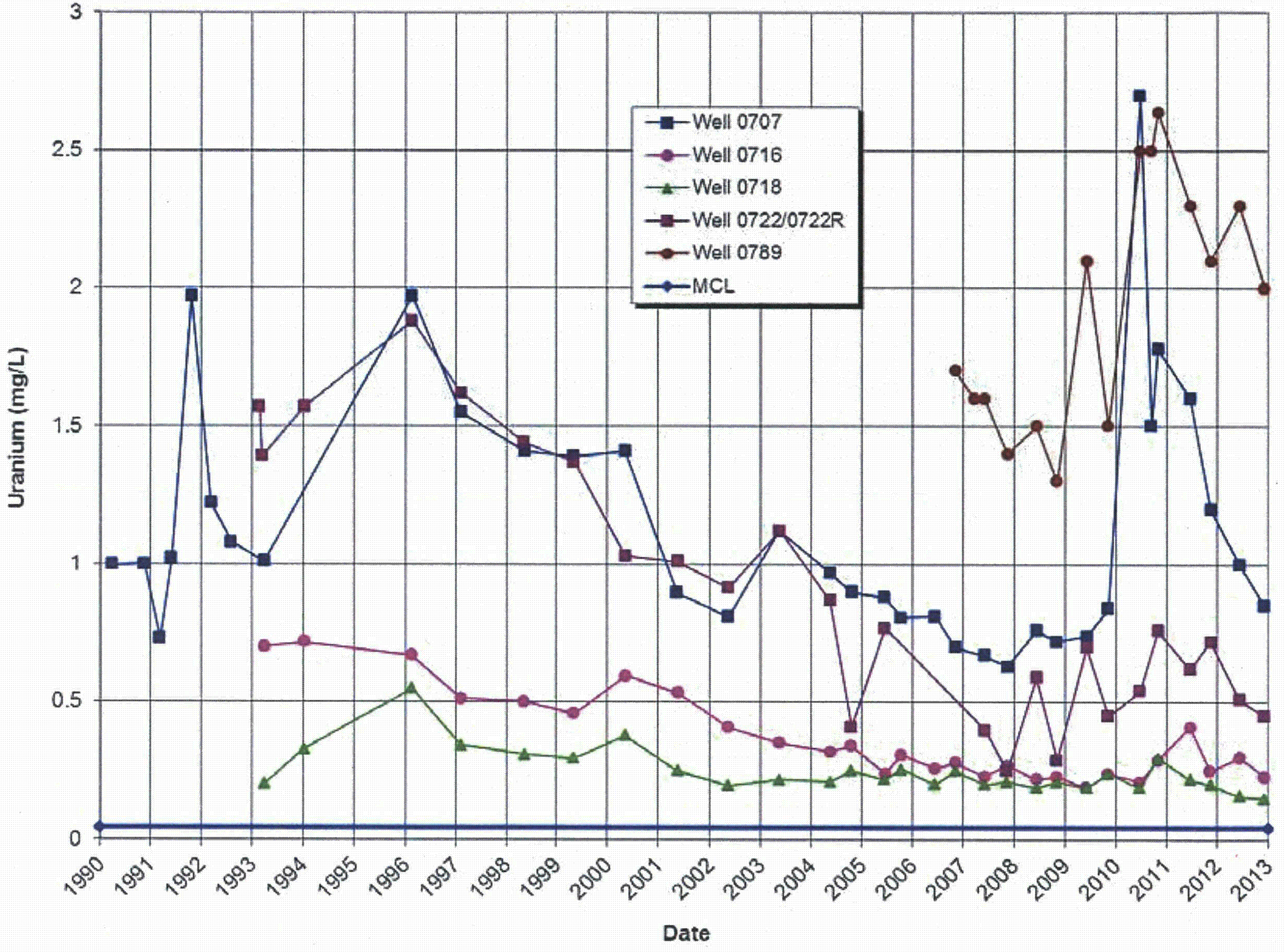
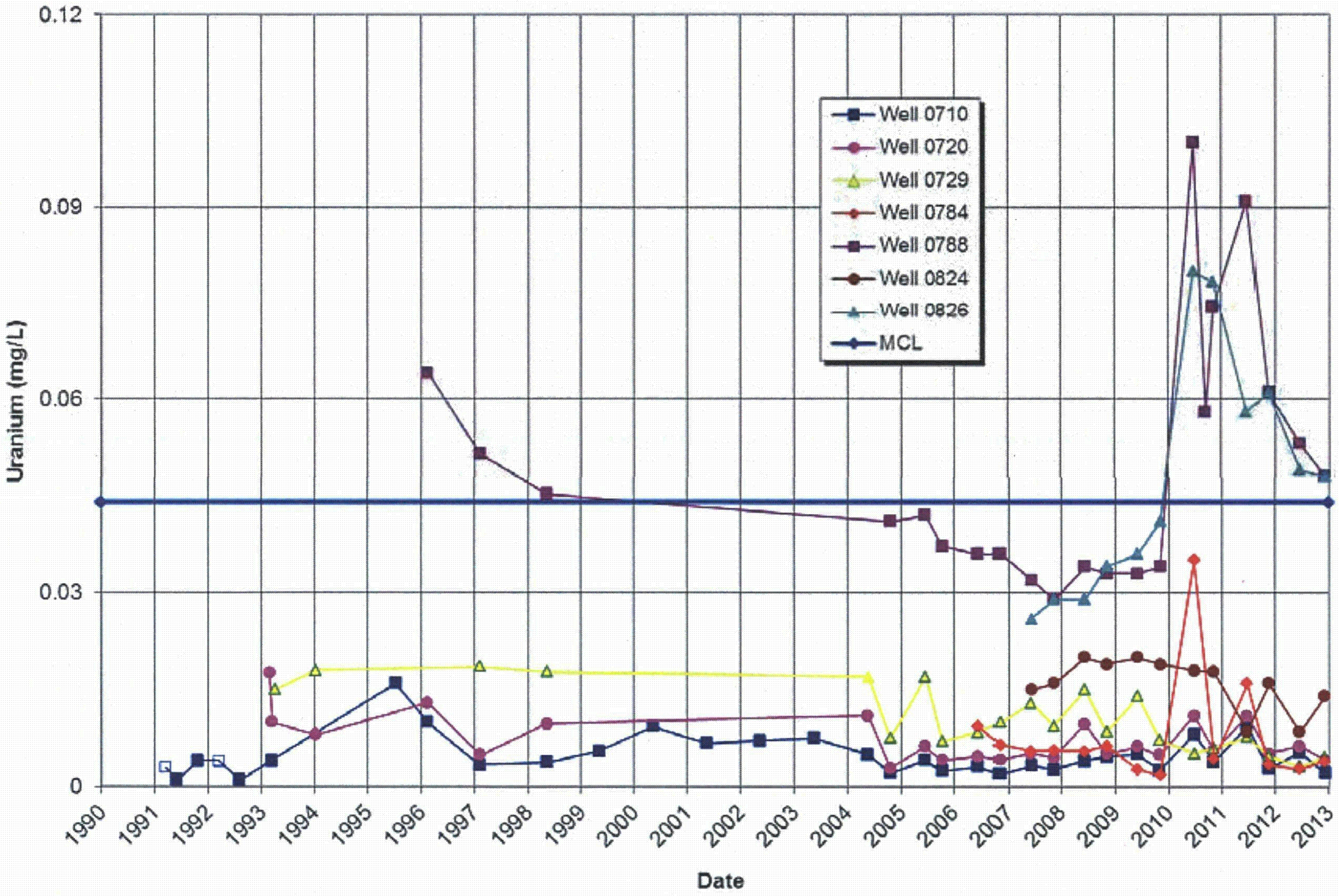


Figure 11. Uranium Concentrations in Surficial Aquifer Wells within the Contaminant Plume



Note: A hollow symbol denotes an analytical result below the detection limit.

Figure 12. Uranium Concentrations in Surficial Aquifer Wells on the Edge of the Contaminant Plume

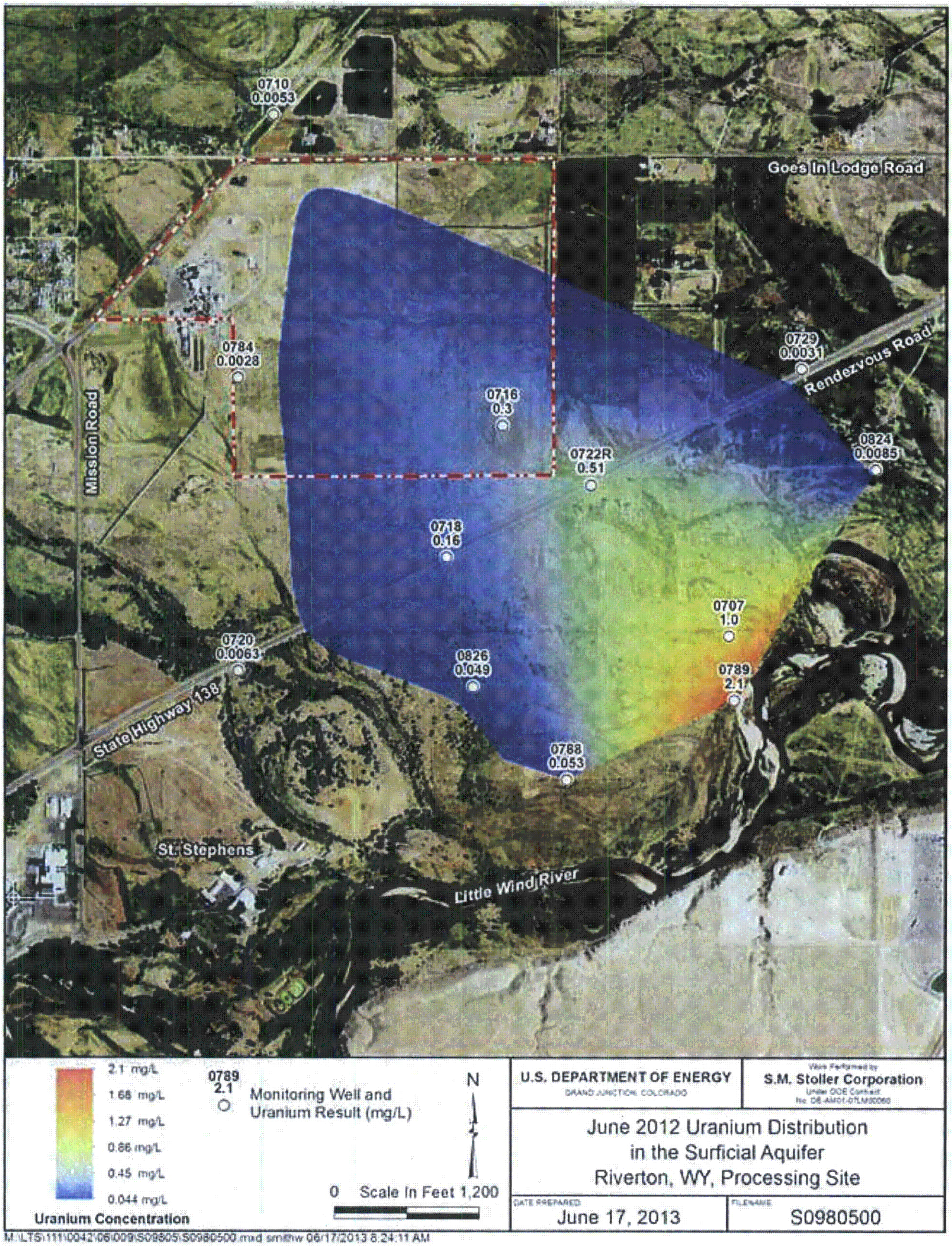


Figure 13. June 2012 Uranium Distribution in the Surficial Aquifer at the Riverton Site

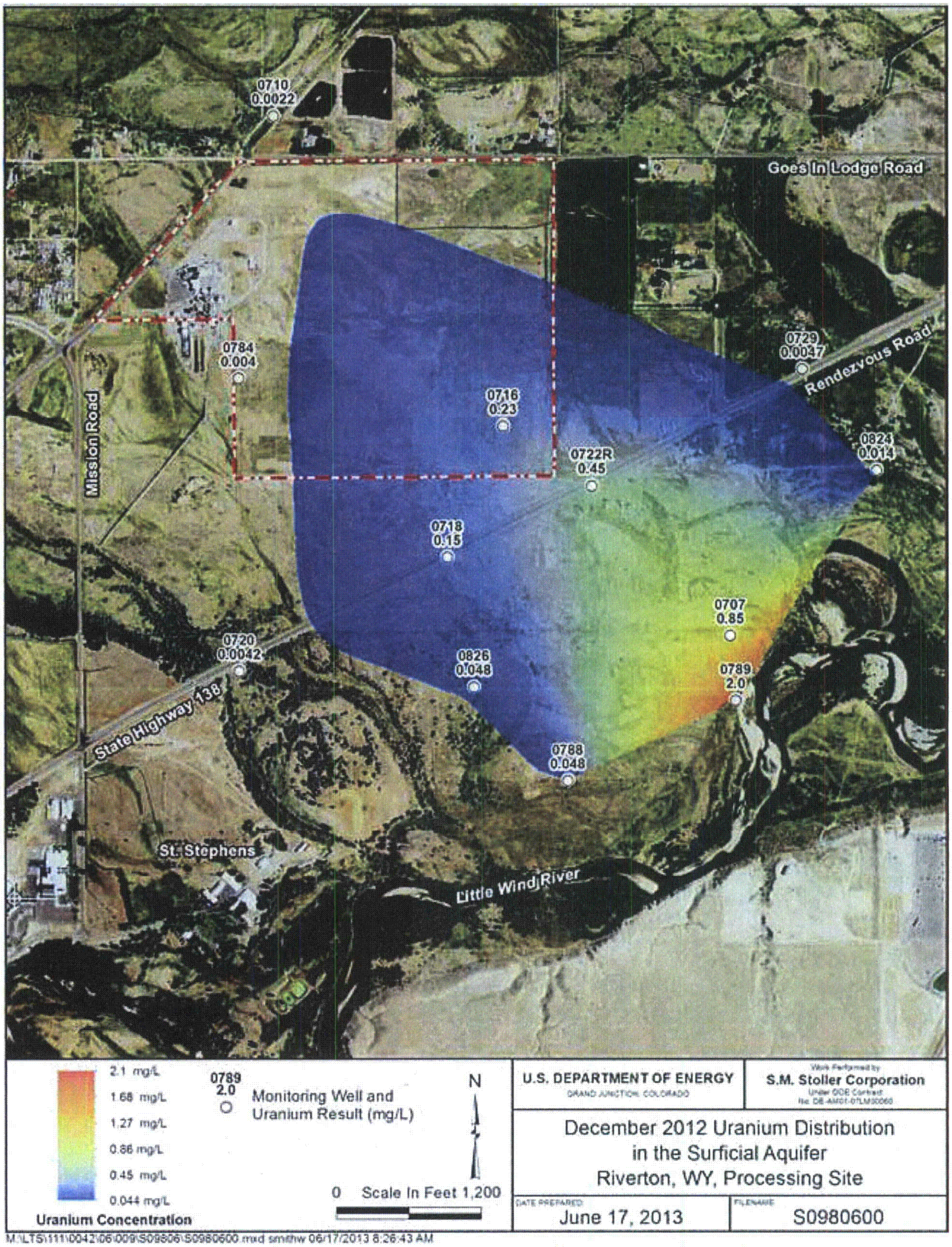
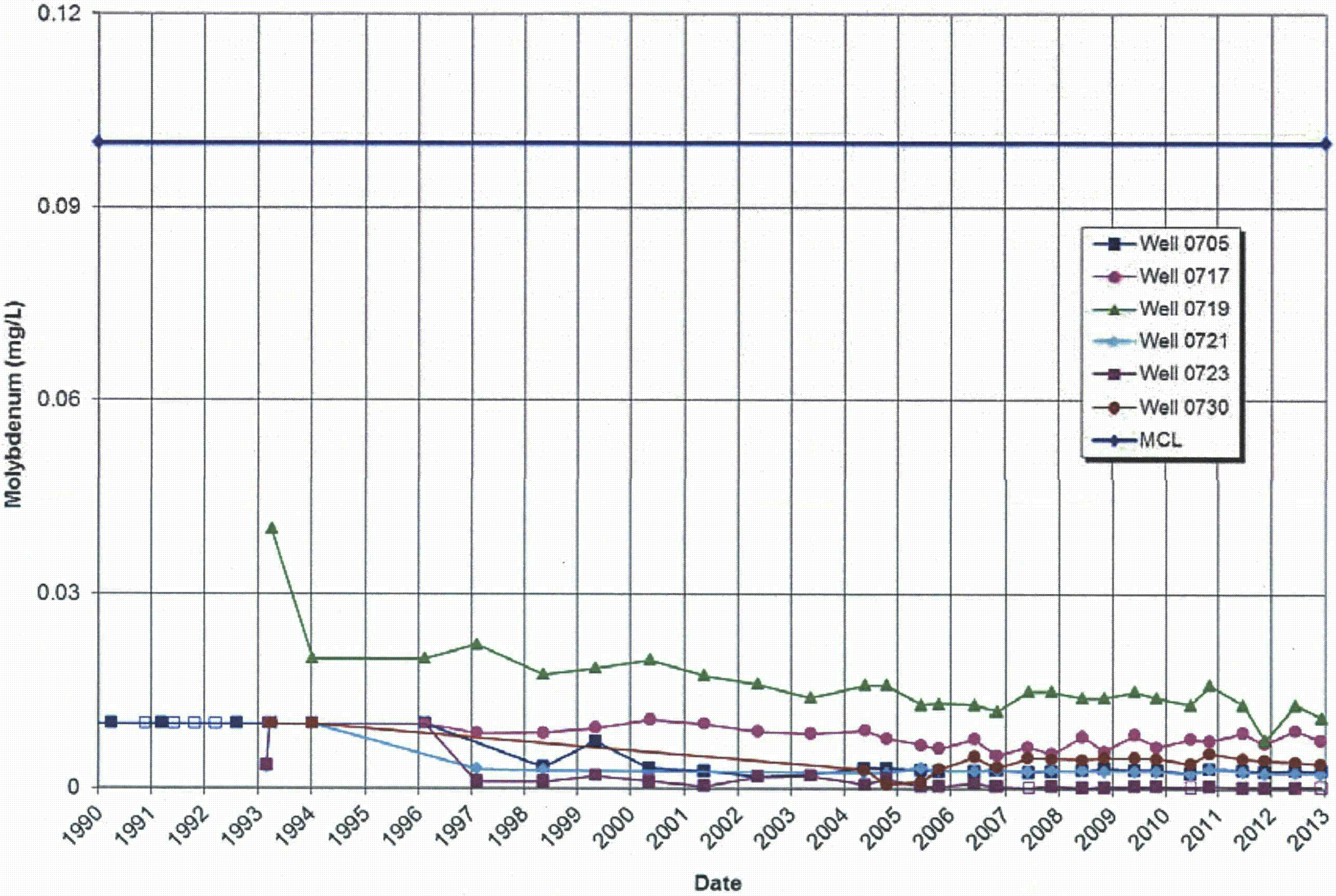
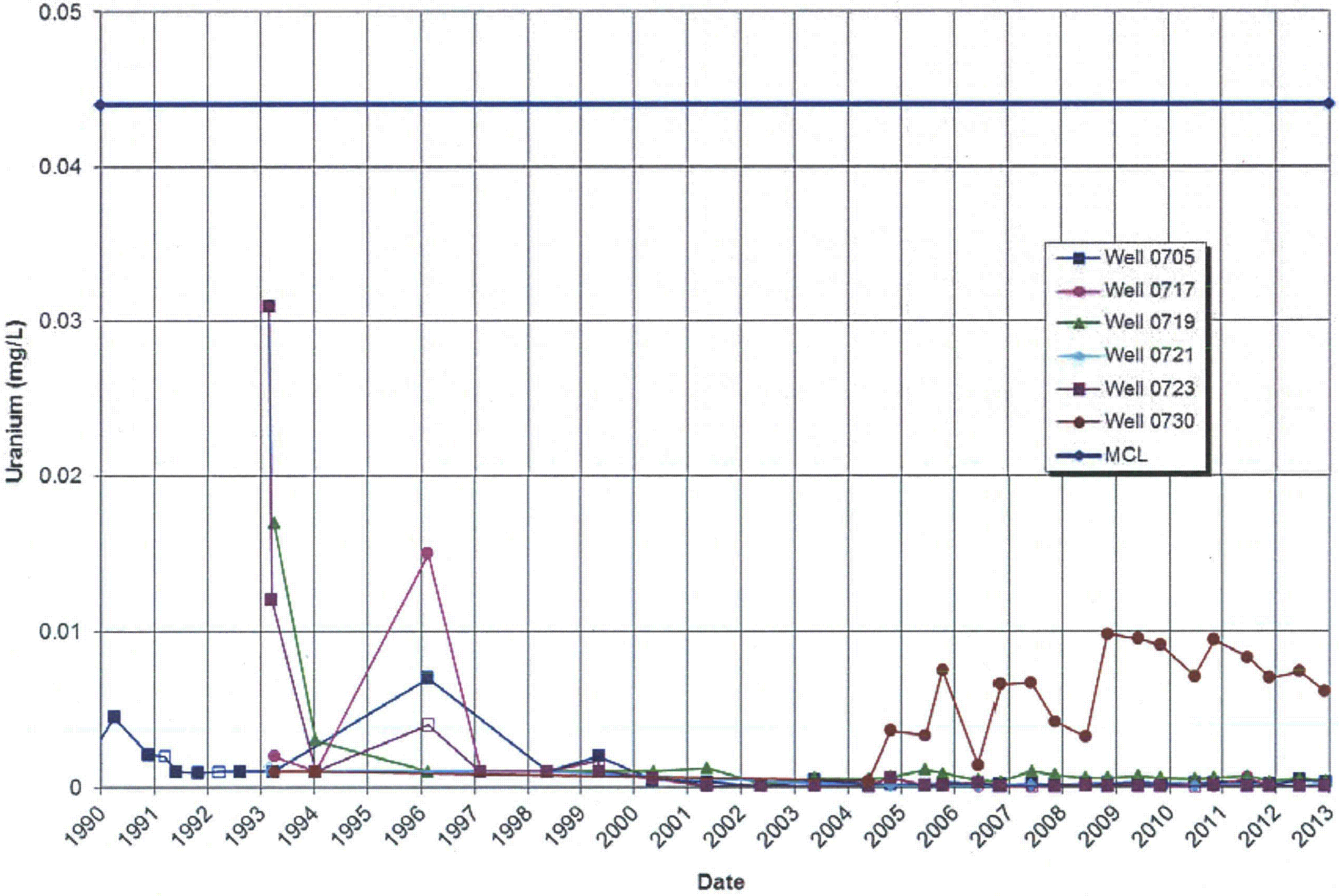


Figure 14. December 2012 Uranium Distribution in the Surficial Aquifer at the Riverton Site



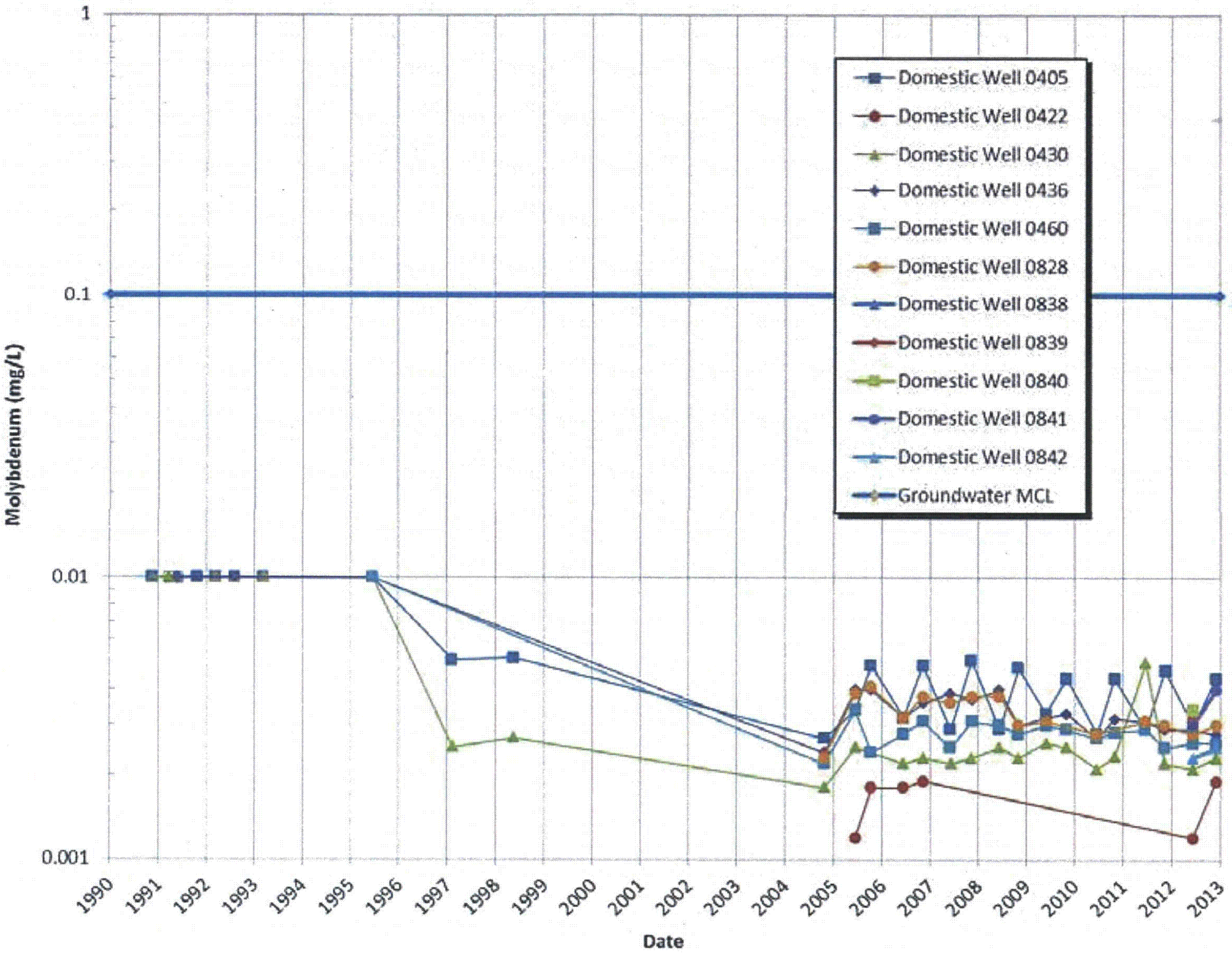
Note: A hollow symbol denotes an analytical result below the detection limit.

Figure 15. Molybdenum Concentrations in Semiconfined Aquifer Wells



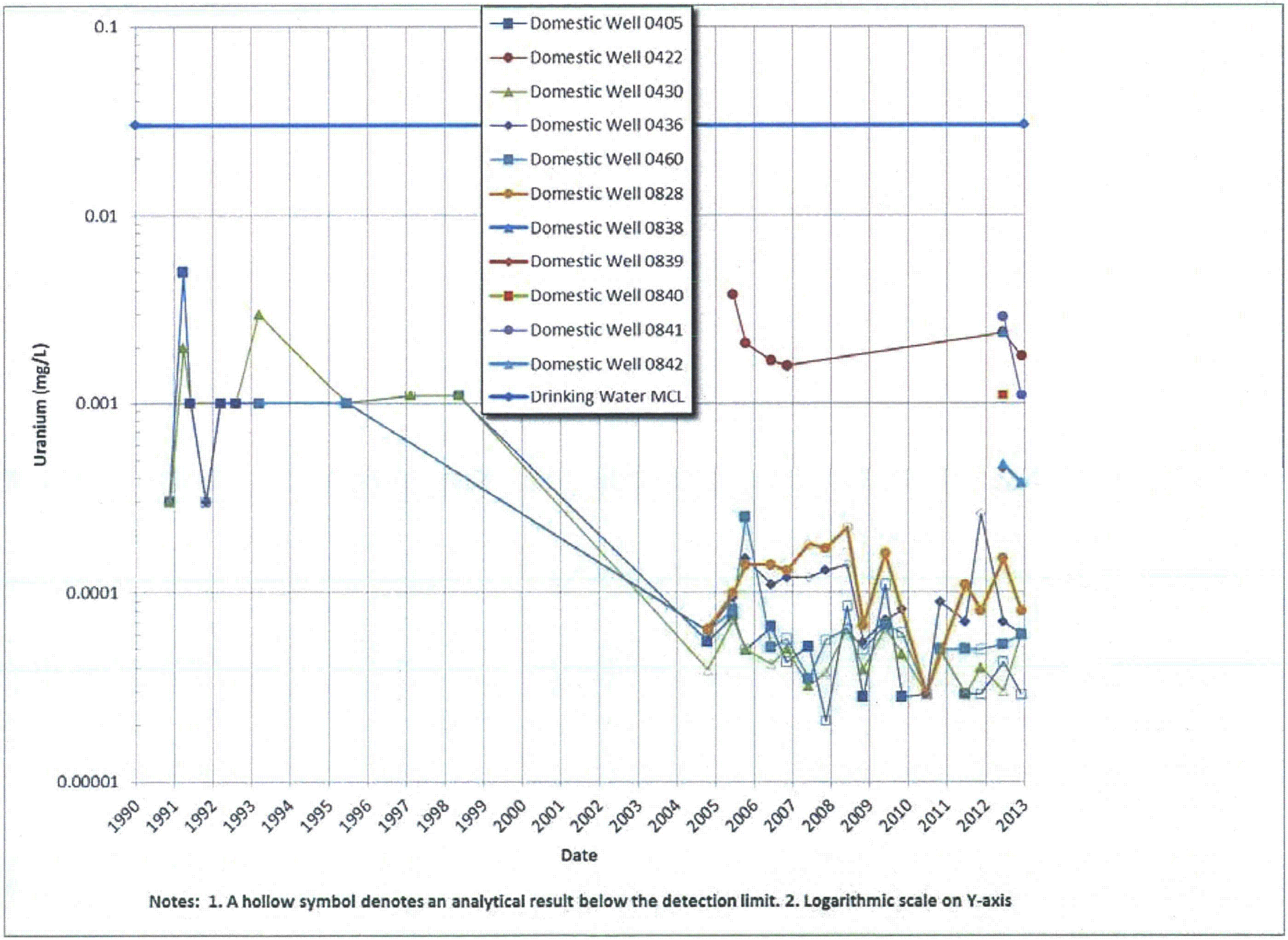
Note: A hollow symbol denotes an analytical result below the detection limit.

Figure 16. Uranium Concentrations in Semiconfined Aquifer Wells



Note: Logarithmic scale on Y-axis.

Figure 17. Molybdenum Concentrations in Domestic Wells



Notes: 1. A hollow symbol denotes an analytical result below the detection limit. 2. Logarithmic scale on Y-axis

Figure 18. Uranium Concentrations in Domestic Wells

2.3.2 Surface Water

2.3.2.1 Surface Water Flow

The 2010 flood of the Little Wind River demonstrated a direct correlation between high discharge in the Little Wind River and increased contaminant concentrations in the surficial aquifer; therefore, it is likely that pre-2010 flooding of the river affected the concentration and configuration of contaminants in the saturated and unsaturated zones of the surficial aquifer. Figure 19 shows the highest peak discharges recorded since the start of milling operations (1958) at the U.S. Geological Survey gaging station (USGS 2012a) located approximately 1.6 miles east of the former mill site (the gaging station location is shown in Figure 2). In 2012, the highest discharge for the year was measured on June 6 at 1,610 cfs and at a river stage of 3.34 feet below flood stage. Discharge in the Little Wind River is statistically the highest in June, which reflects spring runoff from the Wind River Range. Most of the recharge of the alluvial aquifer likely occurs during these higher flows in the river. An assessment of June Little Wind River discharge data indicates that spring runoff/flow in the river was below normal in 2012, after being above normal for the previous three years (Table 3). Prior to 2009, mean spring runoff/flow in the river had been below normal since 2000.

Table 3. Discharge Statistics[a] from the Little Wind River

Year	Mean June Discharge (cfs)	Deviation from Normal[b] June Discharge (cfs)	Maximum Discharge (cfs)
2000	1,089	-1,231	2,720
2001	233.2	-2,087	2,090
2001	740.6	-1,579	1,930
2003	861.7	-1,458	2,490
2004	1,591	-729	4,120
2005	2,272	-48	4,520
2006	642.4	-1,678	1,710
2007	738.9	-1,581	1,910
2008	2,175	-145	3,730
2009	3,012	692	4,190
2010	5,829	3,509	13,300
2011	2,861	541	7,210
2012	594	-1,726	1,610

[a] U.S. Geological Survey gaging station statistics.
[b] Based on a mean June discharge of 2,320 cfs since 1941.

2.3.2.2 Surface Water Quality

Samples were collected at four locations on the Little Wind River (Figure 2), which flows generally from the southwest to the northeast adjacent to the site. Contaminated groundwater likely discharges to the Little Wind River, but there is no evidence that it impacts surface water quality in the river. Molybdenum and uranium concentrations measured in samples collected from river locations adjacent to and downstream of the groundwater plume (locations 0811, 0812, and 0796) are comparable to concentrations from river samples collected upstream of the groundwater plume (location 0794), as shown in Figure 20 and Figure 21, respectively.

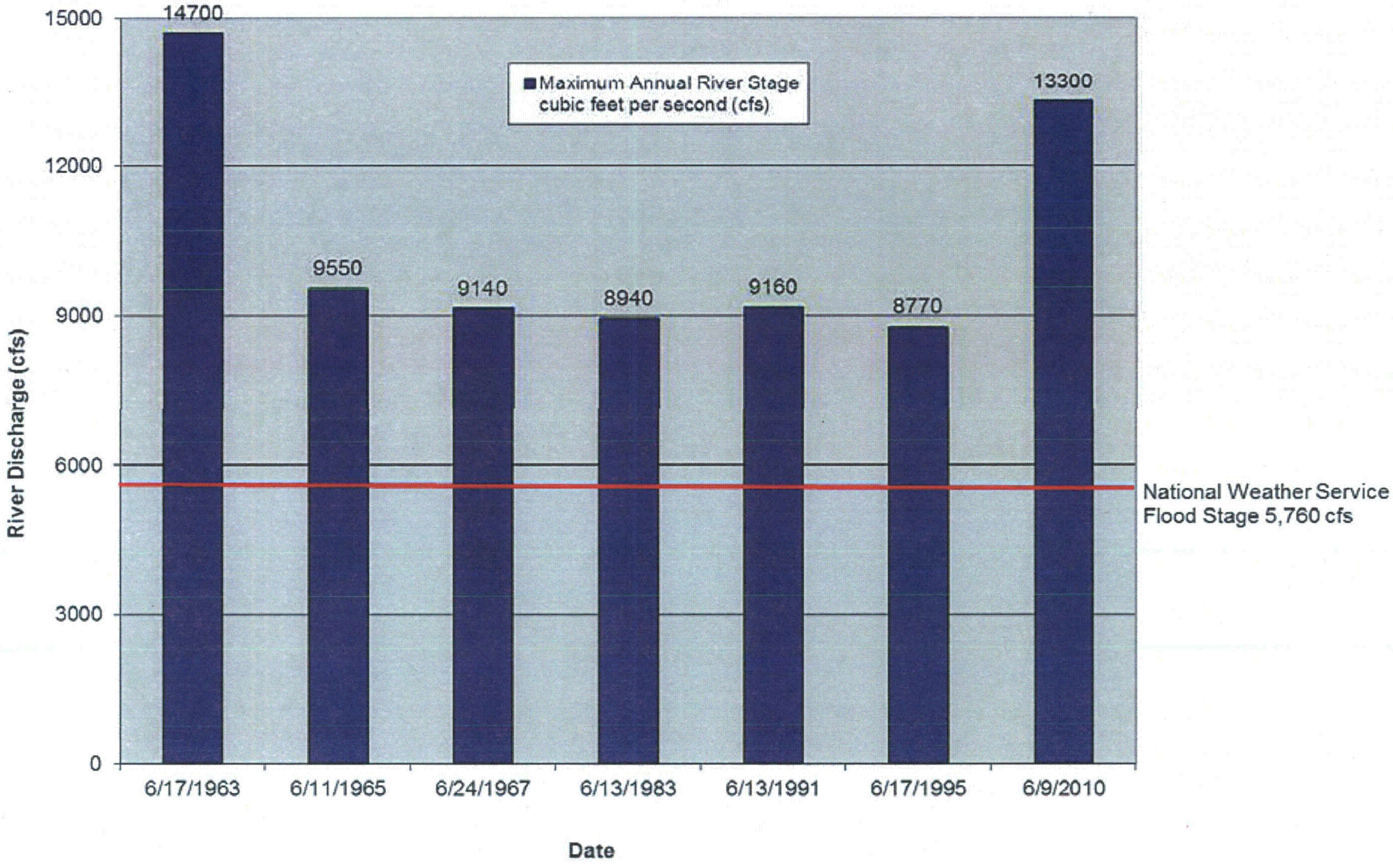
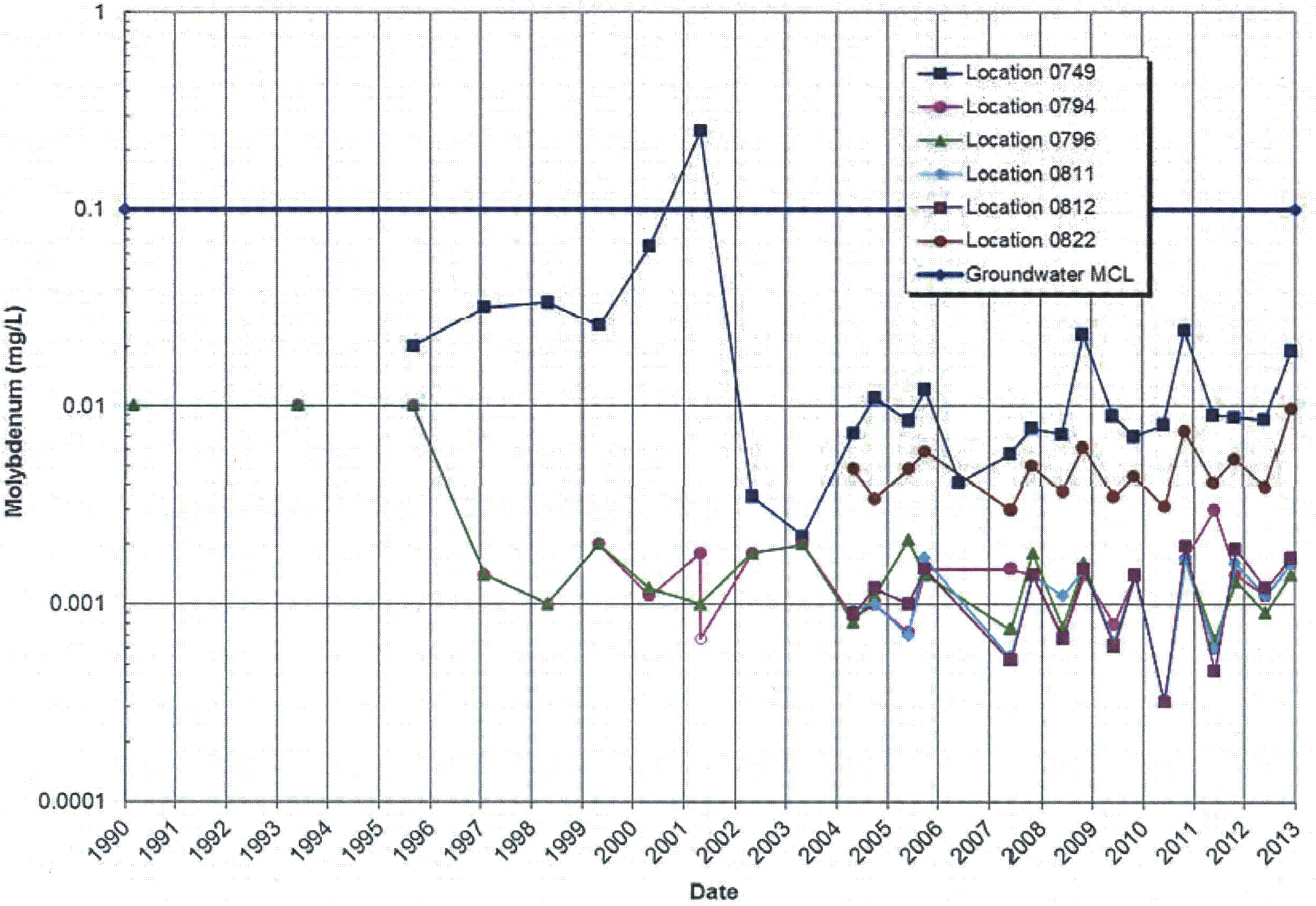
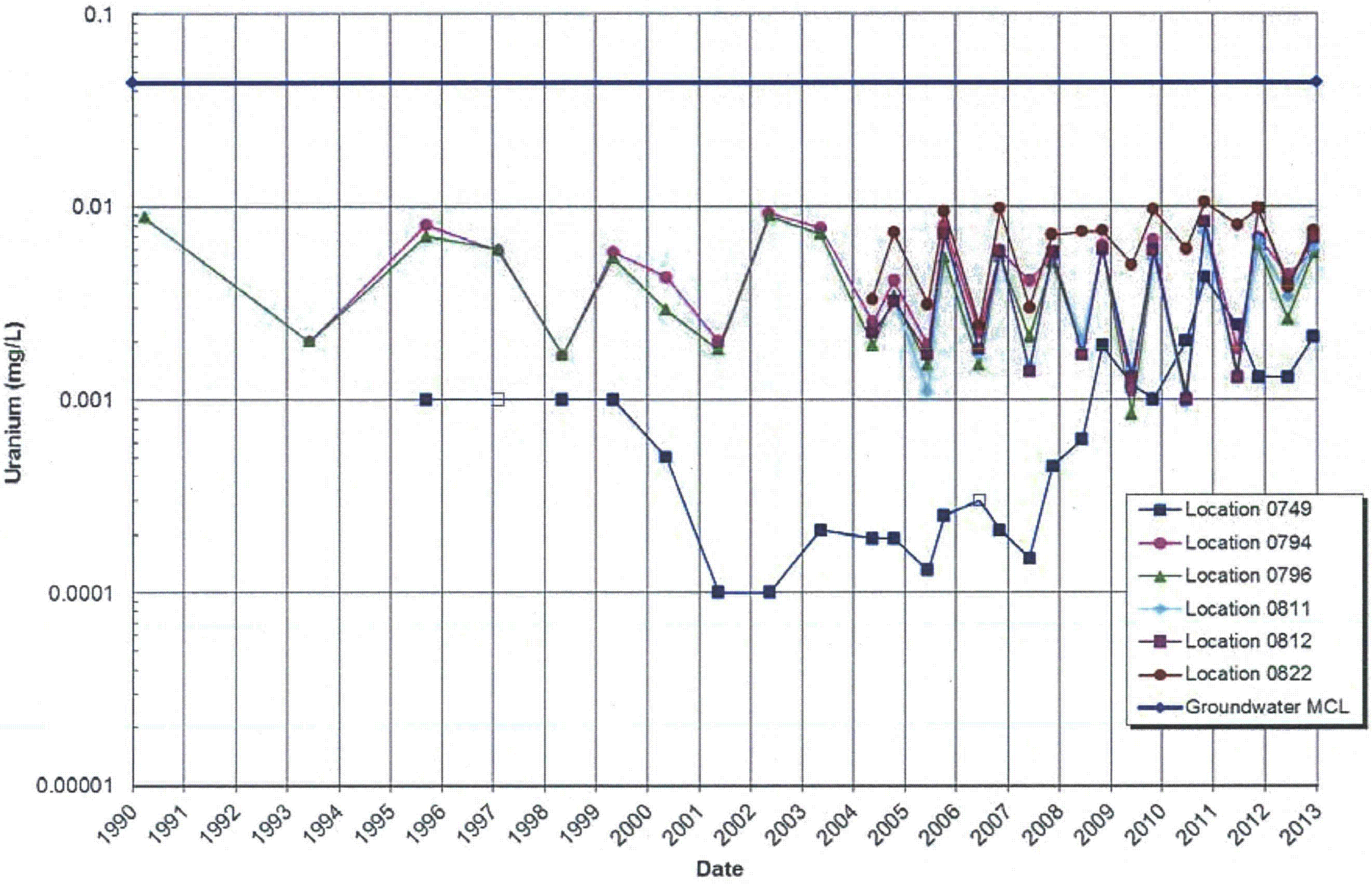


Figure 19. Historical Maximum Stages of the Little Wind River



Notes: 1. A hollow symbol denotes an analytical result below the detection limit. 2. Y-axis is a logarithmic scale.

Figure 20. Molybdenum Concentrations in Creek and River Locations



Notes: 1. A hollow symbol denotes an analytical result below the detection limit. 2. Y-axis is a logarithmic scale.

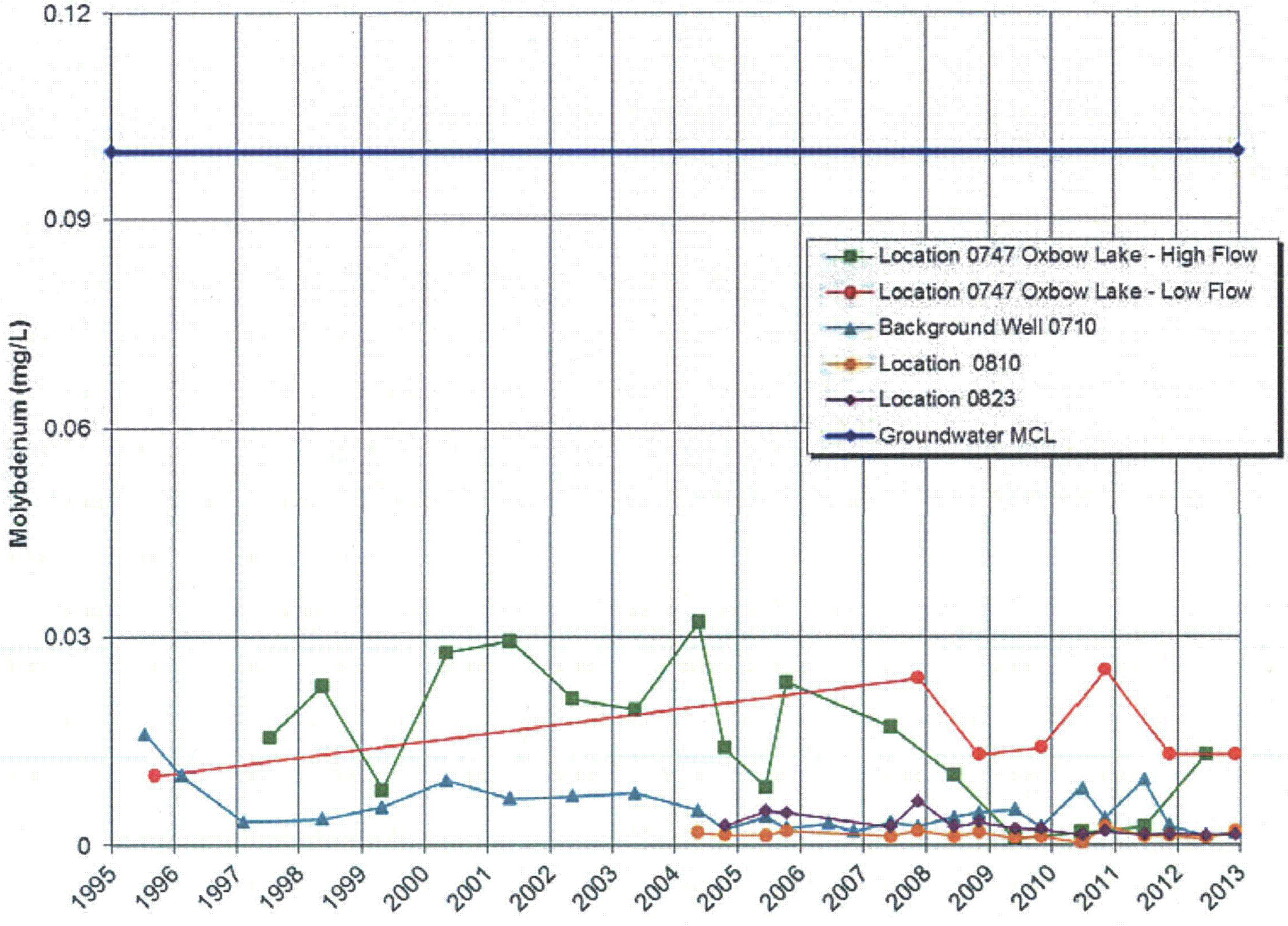
Figure 21. Uranium Concentrations in Creek and River Locations

Two ponds (locations 0810 and 0823) formed from groundwater discharge into former gravel pits were sampled as part of the long-term monitoring network. These ponds are primarily used for fishing and swimming. Samples collected from these ponds had concentrations of molybdenum and uranium that were below their respective groundwater MCLs and comparable to background, which indicates no discernible impacts from the site. Molybdenum and uranium concentrations over time in these pond locations are shown in Figure 22 and Figure 23, respectively.

The sample collected at the ditch that carries discharge water from the Chemtrade sulfuric acid refinery (location 0749) had elevated concentrations of sulfate in 2012 (2,000 mg/L in June). Discharge from the ditch is regulated through a National Pollutant Discharge Elimination System permit issued to Chemtrade and administered by EPA. Sulfate concentrations have been in the 1,800 to 3,000 mg/L range since 2004. The elevated sulfate concentrations in the Chemtrade ditch water have affected sulfate concentrations farther downstream in the west side irrigation ditch (e.g., 960 mg/L at location 0822 in June). Water samples from the west side irrigation ditch also have been analyzed for radium-226 and radium-228 in response to elevated concentrations of these contaminants in the sediments within the ditch. Radium concentrations in water samples collected from the ditch were low (<0.5 pCi/L) and either less than the detections limit (one sample) or near the detection limit (three samples), which indicates minimal impacts to water quality in the ditch from the sediments. Historically, radium concentrations have been below or near the detection limit, indicating no impact to water quality in the ditch. Uranium concentrations in samples collected from the west side irrigation ditch have been within the range of background uranium concentrations and correlate with uranium concentrations in the river (Figure 21), which indicates minimal site impacts to the water quality in the ditch.

Concentrations of molybdenum and uranium in the oxbow lake (location 0747) have varied over time. This variability is attributed to surface inflow (this does not occur every year; it depends on the river stage) to the lake from the Little Wind River during a high river stage, which causes a dilution of uranium concentrations. Hydraulic and water quality data indicate that the oxbow lake is fed by the discharge of contaminated groundwater; therefore, elevated concentrations are expected.

Figure 22 and Figure 23 split oxbow-lake sampling data into high-flow and low-flow events; the high-flow events reflect the potential for river inflow diluting analyte concentrations in the oxbow lake, and the low-flow events reflect a low potential for river inflow diluting analyte concentrations in the oxbow lake. In the June 2012 sampling event, the Little Wind River was not flowing into the oxbow lake and run-off was lower than normal; therefore, the uranium concentration in the sample collected from the oxbow lake was elevated. Uranium concentrations also were elevated in samples collected from the oxbow lake in December, as expected, because the river was not flowing into the lake at that time. Surface water quality data by parameter for locations sampled during 2012 are provided in Appendix D.



Note: A hollow symbol denotes an analytical result below the detection limit.

Figure 22. Molybdenum Concentrations in Ponds

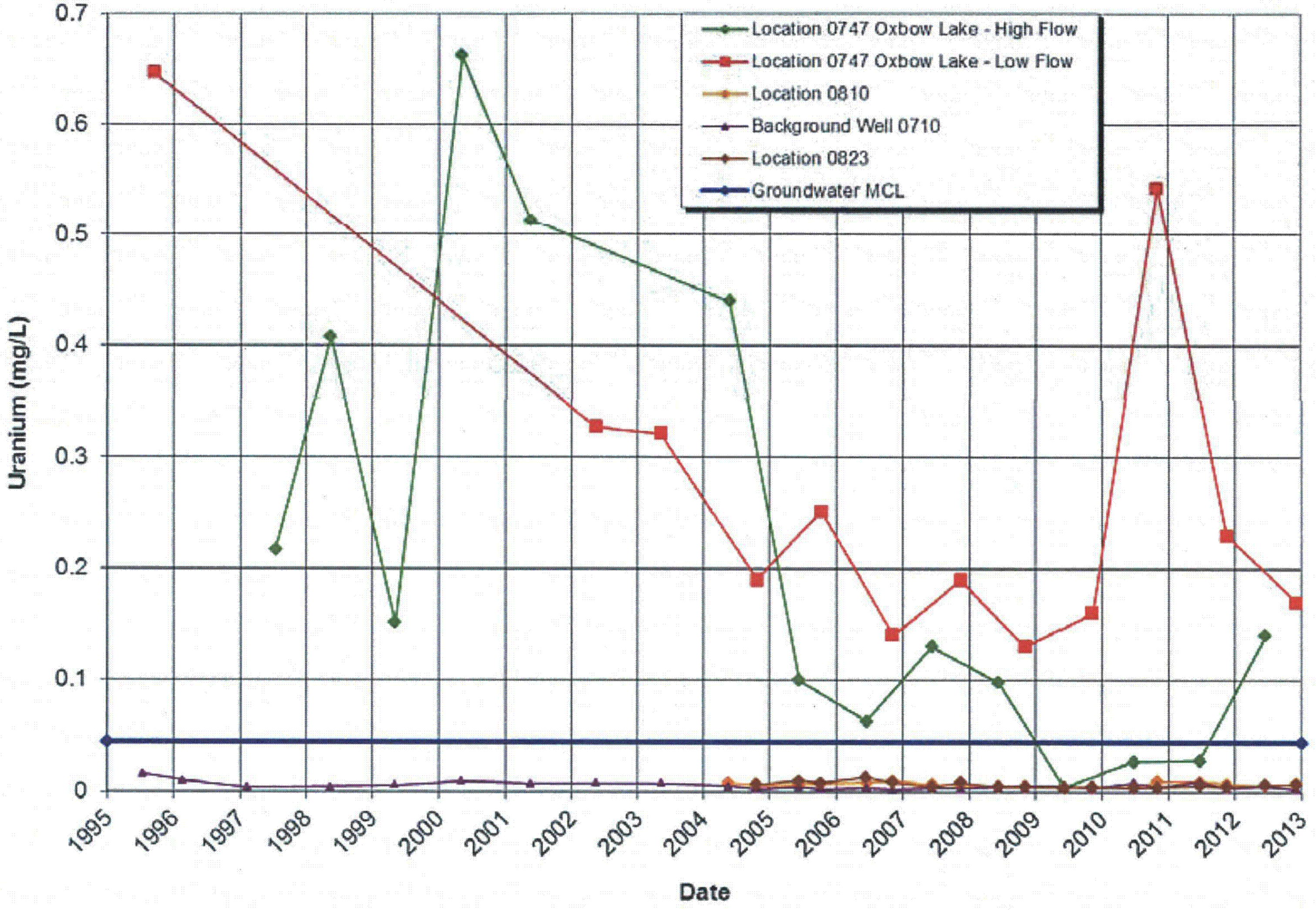


Figure 23. Uranium Concentrations in Ponds

2.3.3 AWSS Monitoring

The AWSS was installed in 1998 by the Indian Health Service. DOE provided $800,000 in funding, which included 25 percent of the cost of a new 1-million-gallon storage tank (Figure 24). As a component of ICs for the Riverton site, the AWSS is designed to supply drinking water to residents within the IC boundary in lieu of drinking groundwater that could potentially be impacted by the contaminated surficial aquifer. The AWSS is an addition to a pre-existing water supply system and consists of 8.5 miles of transmission pipeline running from the 1-million-gallon tank (Figure 25).

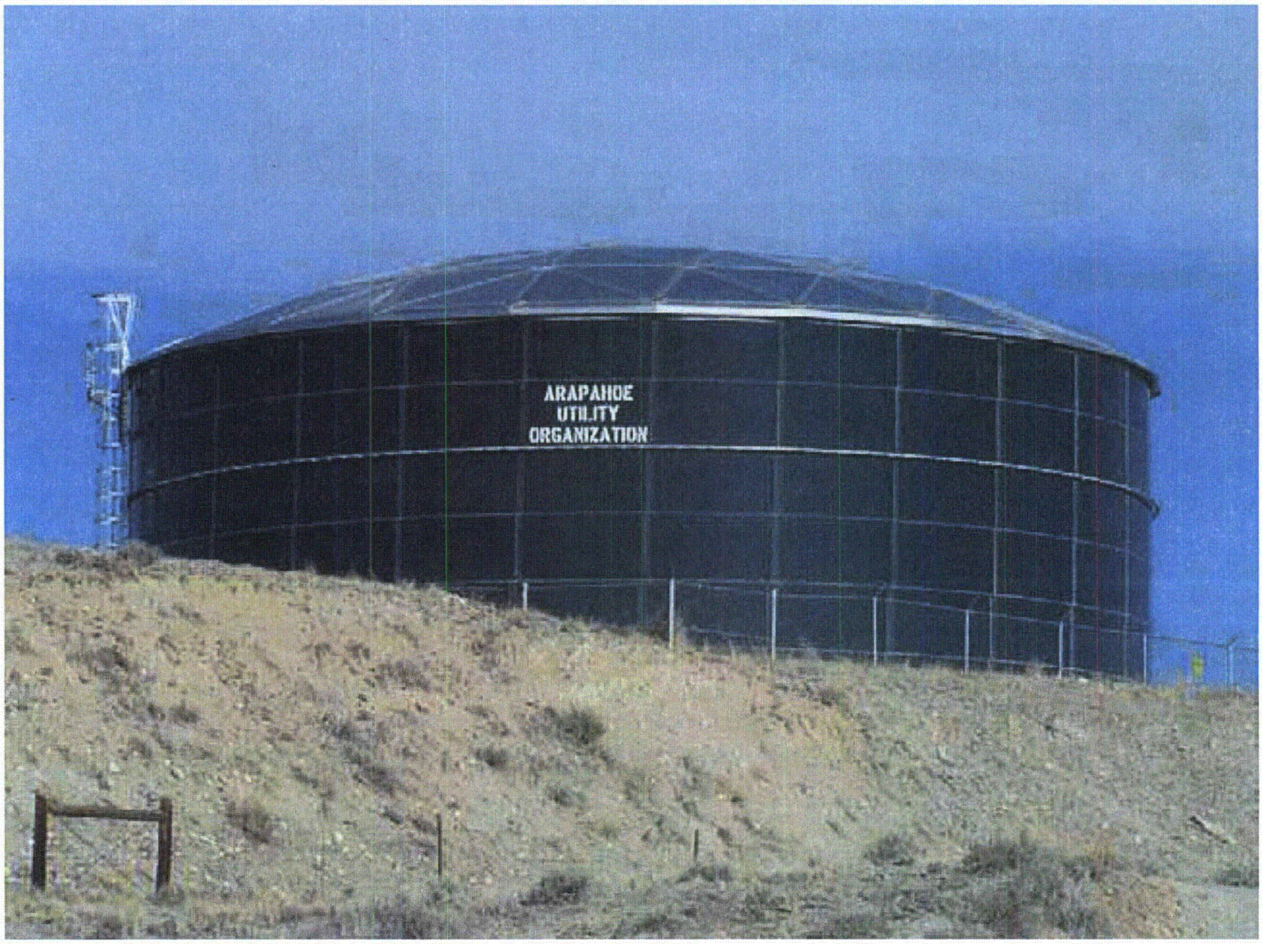


Figure 24. AWSS 1-Million-Gallon Tank

Elevated concentrations of radionuclides were identified in the AWSS in 2002 (Babits 2003), and these results were confirmed by DOE in 2004 (DOE 2005). In response to these findings, DOE funded an independent analysis of the AWSS, and the analysis recommended implementation of a flushing program to determine if flushing would reduce the radionuclide concentrations to acceptable levels (ASCG 2005). Based on the recommendation of the independent analysis, DOE implemented a 2-year flushing study to determine if flushing would reduce radionuclide concentrations and control radionuclide buildup in the AWSS (DOE 2006). Results of the study indicated that a unidirectional flushing program be implemented on a 6-month frequency (DOE 2008).

Flushing of the AWSS in 2012 consisted of two semiannual events. One event was conducted by the Great Plains Utility Organization and the Tribal Engineer's Office in April, and a second flushing event was conducted jointly among the Great Plains Utility Organization, the Tribal Engineer's Office, and DOE in October. Sampling was conducted in in accordance with the *Alternate Water Supply System Flushing Plan, Riverton, Wyoming* (DOE 2012b). Seven hydrant locations on the AWSS were flushed and sampled, and four tap locations were sampled. Two samples were collected at each of five hydrant locations – one sample 5 minutes into the flush and one sample at the end of the flush, as specified in the plan. Only end-of-flush samples were collected at hydrant locations 0820 and 0834 because of the short flushing time. A new hydrant (0843) was noted during the flushing event and added to the flushing network for subsequent events; a cursory flush was conducted on this hydrant during the October event, and samples were collected from this hydrant by the Wind River Environmental Quality Commission.

Monitoring of flow during each hydrant flush was required to ensure the calculated water volume of each section of pipe was removed. Flow meters were installed at each hydrant during flushing to measure the volume of water flushed from the pipe. Volume measurements also were used to calculate the velocity of the water moving through the pipe. Velocity data were used to determine if water movement within the pipeline was sufficient to remove sediment and debris, and to scour biofilm from the inside of the pipe. According to the independent analysis (ASCG 2005), flushing velocities of 2 to 3 feet per second (ft/s) are needed to remove sediment and loosely attached particles, while flushing velocities of greater than 5 ft/s are required to scour and remove buildup of biofilm and material adhering to the wall of the pipe. Water volume removed and velocities from each section are shown in Table 4.

Table 4. October 2012 Hydrant Flushing Summary

ID	Calculated Flushing Volume[a]	Section Volume Flushed (gallons)	Section Flush Time (minutes)	Section Average Flow Rate (gallons/minute)	Section Average Velocity (ft/s)
0829	20,252	20,400	41.5	492	3.14
0830	39,554	39,600	70	566	3.61
0818	20,738	20,800	42	495	5.62
0819	43,209	43,200	77	561	3.58
0821	13,973	14,000	33.6	417	4.73
0820	3,139	3,200	6.5	492	5.59
0834	918	1,000	2.13	469	5.33
		Total 142,200	**Total 273**	**Average 499**	**Average 4.51**

[a] Flushing volume calculated as 1.25 x pipe volume.

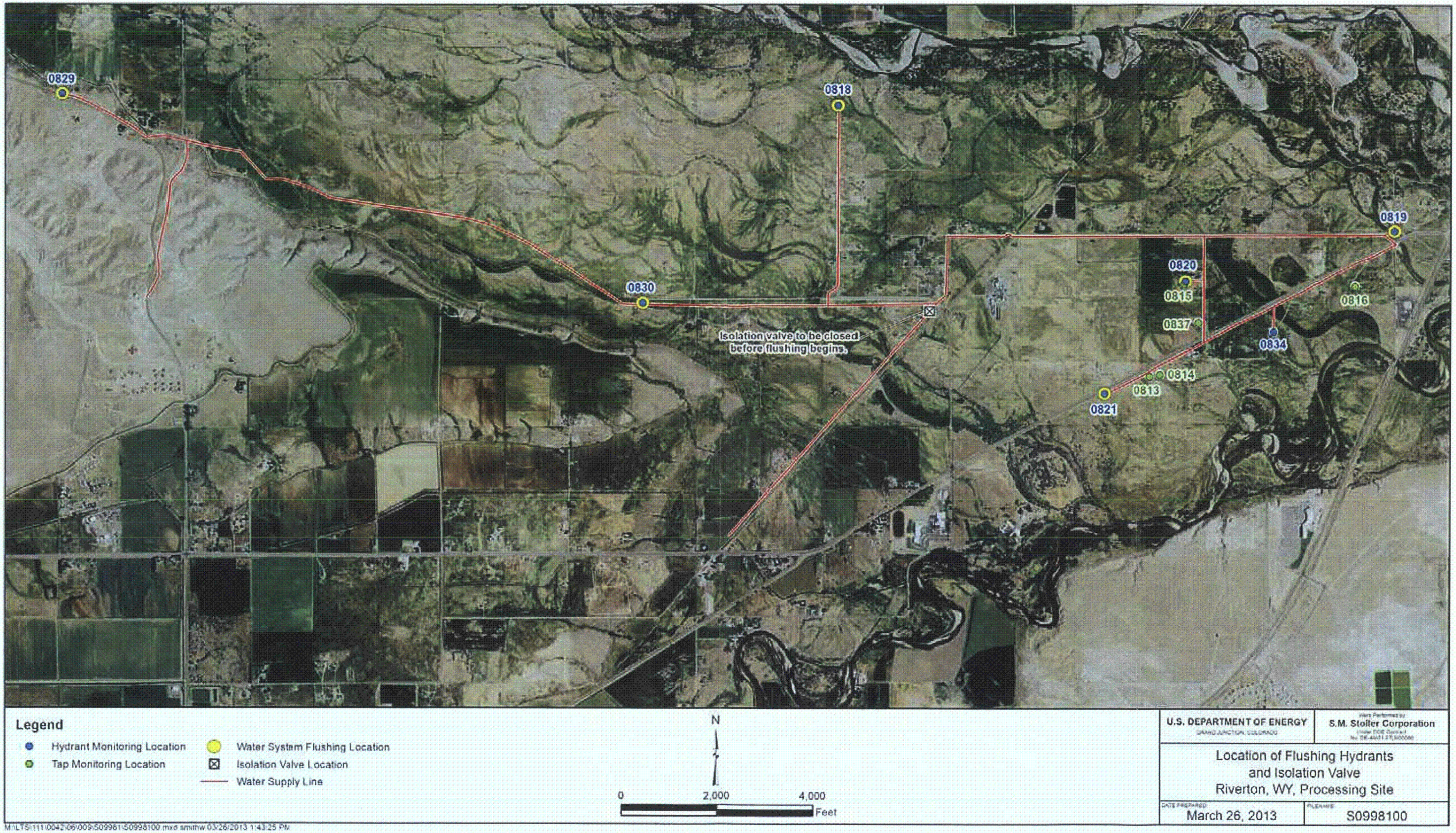


Figure 25. Location of Flushing Hydrants and Tap Monitoring Locations

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Monitoring of hydrant and tap locations was conducted to determine the effectiveness of the flushing program in reducing radionuclide concentrations and maintaining them at acceptable levels. The flushing program is successful when the combined radium-226 and radium-228 concentrations are below the federal drinking water MCL of 5 pCi/L, and the uranium concentrations are below the federal drinking water MCL of 0.03 mg/L. DOE was not involved in the April flushing event, so those results are not presented in this report; however, no issues were identified by the Great Plains Utility Organization or the Tribal Engineer's Office. Effectiveness of the flushing program was demonstrated in October with a maximum-observed combined radium-226 and radium-228 concentration of 2.52 pCi/L, and a maximum observed uranium concentration of 0.00011 mg/L. Results from samples collected from AWSS hydrant and tap locations in October are summarized in Table 5 and provided in Appendix E.

Table 5. Monitoring Results from the October 2012 AWSS Flushing Event

ID	Sample	Radium-226 +Radium-228 (pCi/L)	Radium-226 +Radium-228 MCL	Uranium (mg/L)	Uranium MCL (mg/L)
Hydrant Locations					
0818	5-minute	1.543	5 pCi/L	0.00011	0.03 mg/L
	End of flush	1.364		0.00009	
0819	5-minute	1.943		0.00009	
	End of flush	2.273		0.00009	
0820	5-minute	2.52		0.00011	
0821	5-minute	1.657		0.00008	
	End of flush	2.24		0.0001	
0829	5-minute	1.458		0.00009	
	End of flush	0.939		0.0001	
0830	5-minute	1.44		0.00008	
	End of flush	1.4		0.00008	
0834	5-minute	1.992		0.00008	
Tap Locations					
0813	After completion of flushing	0.776	5 pCi/L	0.0001	0.03 mg/L
0815	After completion of flushing	0.92		0.00009	
0816	After completion of flushing	0.771		0.00008	
0837	After completion of flushing	2.124		0.00009	

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