LMS/WEL/S31922

Weldon Spring Site

Sixth Five-Year Review

September 2021

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Weldon Spring Site Sixth Five-Year Review

September 2021

Approved by: Date:

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SIXTH FIVE-YEAR REVIEW REPORT
WELDON SPRING QUARRY/PLANT/PITS SITE
ST. CHARLES COUNTY, MISSOURI

Prepared by
U.S. Department of Energy

Reviewed and Approved by:
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Mary P. Peterson, Director
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Abbreviations

AEC	U.S. Atomic Energy Commission
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ASER	Annual Site Environmental Report
BLL	blood lead level
BTL	baseline tolerance limit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COC	contaminant of concern
CPOU	Chemical Plant Operable Unit
CSR	*Code of State Regulations*
DCE	dichloroethene
DNB	dinitrobenzene
DNT	dinitrotoluene
DOE	U.S. Department of Energy
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
FFA	Federal Facility Agreement
FIMS	Facilities Information Management System
ft	feet
FYR	Five-Year Review
GEMS	Geospatial Environmental Mapping System
gpa	gallons per acre
gpd	gallons per day
GWOU	Groundwater Operable Unit
HDPE	high-density polyethylene
HQ	hazard quotient
IC	institutional control
ICO	in situ chemical oxidation
IRA	Interim Response Action
kg	kilogram

lidar	light detection and ranging
LM	Office of Legacy Management
LMS	Legacy Management Support
LTS&M	long-term surveillance and maintenance
MCL	maximum contaminant level
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mg/kg-day	milligrams per kilogram per day
mg/L	milligrams per liter
µg/dL	micrograms per deciliter
µg/L	micrograms per liter
MNA	monitored natural attenuation
MoDOT	Missouri Department of Transportation
MOU	Memorandum of Understanding
mrem	millirem
MSD	Metropolitan St. Louis Sewer District
msl	mean sea level
NB	nitrobenzene
NCP	National Contingency Plan
NPL	National Priorities List
ORAU	Oak Ridge Associated Universities
ORP	oxidation-reduction potential
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi	picocuries
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PRG	preliminary remediation goal
PWSD	Public Water Supply District
QBWOU	Quarry Bulk Waste Operable Unit
QROU	Quarry Residuals Operable Unit
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective

RAR	relevant and appropriate requirement
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
ROD	Record of Decision
RSL	Regional Screening Level (EPA summary table)
SOARS	System Operation and Analysis at Remote Sites
STEM	science, technology, engineering, and mathematics
SWRAU	Sitewide Ready for Anticipated Use
TBC	to be considered
TCE	trichloroethene
TED	total effective dose
TNT	trinitrotoluene
TSA	Temporary Storage Area
USACE	U.S. Army Corps of Engineers
UU/UE	unlimited use and unrestricted exposure
VISL	vapor intrusion screening level
VOCs	volatile organic compounds

1.0 Introduction

The purpose of a Five-Year Review (FYR) is to evaluate the implementation and performance of a remedy in order to determine if the remedy is and will continue to be protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in FYR reports such as this one. In addition, FYR reports identify issues found during the review, if any, and document recommendations to address them.

The U.S. Department of Energy (DOE) Office of Legacy Management (LM) is preparing this FYR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 121, consistent with the National Contingency Plan (Title 40 *Code of Federal Regulations* Section 300.430(f)(4)(ii) [40 CFR 300.430(f)(4)(ii]) and considering U.S. Environmental Protection Agency (EPA) policy.

This is the sixth FYR for the Weldon Spring Quarry/Plant/Pits site. The due date is September 30, 2021. The FYR has been prepared due to the fact that hazardous substances, pollutants, or contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure (UU/UE).

Remediation of the Weldon Spring Site was administratively divided into four Operable Units (OUs): the Chemical Plant Operable Unit (CPOU), the Groundwater Operable Unit (GWOU), the Quarry Bulk Waste Operable Unit (QBWOU), and the Quarry Residuals Operable Unit (QROU). All four OUs will be addressed in the FYR. The Southeast Drainage will be addressed as part of the CPOU.

DOE, with the assistance of the Legacy Management Support (LMS) contractor (Navarro Research and Engineering, Inc.), conducted the FYR of the remedies implemented at the Weldon Spring Site in St. Charles, Missouri. The review began on September 15, 2020.

1.1 Site Background

The Weldon Spring Site is in St. Charles County, Missouri, about 30 miles west of St. Louis (Figure 1). The site comprises two geographically distinct DOE-owned properties: the Weldon Spring former Chemical Plant and Raffinate Pit areas (Chemical Plant) and the Weldon Spring Quarry (Quarry). The former Chemical Plant is about 2 miles southwest of the junction of Missouri State Route 94 and Interstate 64. The Quarry is about 4 miles southwest of the former Chemical Plant. Both sites are accessible from Missouri State Route 94.

During the early 1940s, the Department of the Army acquired 17,232 acres of private land in St. Charles County for construction of the Weldon Spring Ordnance Works facility. The former Ordnance Works site has since been divided into several contiguous areas under different ownership, as depicted in Figure 2. Current land use of the former Ordnance Works site includes the former Chemical Plant and Quarry, the U.S. Army Reserve Weldon Spring Training Area, Missouri Department of Conservation (MDC) and Missouri Department of Natural Resources (MDNR) Division of State Parks, Francis Howell High School, a St. Charles County highway maintenance facility (formerly Missouri Department of Transportation [MoDOT]), the Public Water Supply District (PWSD) No. 2 water treatment facility, the St. Charles County law-enforcement training center, the village of Weldon Spring Heights, and the University of Missouri research park.

The Chemical Plant and Quarry Areas total 228.16 acres; the former Chemical Plant property occupies 219.50 acres, and the Quarry occupies 8.66 acres.

1.2 Land Use and Demography

According to the U.S. Census Bureau, the estimated population of St. Charles County in 2019 was 402,022. The three largest communities in St. Charles County are O'Fallon (population: approximately 88,673), St. Charles (population: approximately 71,028), and St. Peters (population: approximately 58,212) (Figure 1). The two communities closest to the site are Weldon Spring and Weldon Spring Heights, about 2 miles to the northeast. The combined population of these two communities is about 5700. No private residences exist between Weldon Spring Heights and the site. Urban areas occupy about 6% of county land, and nonurban areas occupy 90%; the remaining 4% is dedicated to transportation and water uses.

Francis Howell High School is about 0.6 mile northeast of the site along Missouri State Route 94 (Figure 2). The school employs approximately 150 faculty and staff, and about 1780 students attend.

The St. Charles County highway maintenance facility (formerly MoDOT), located adjacent to the north side of the Chemical Plant, is unmanned. The Army Reserve Training Area is west of the Chemical Plant. The Army has constructed a large Reserve center on the Army property. About 741 acres (300 hectares) of land east and southeast of the high school is owned by the University of Missouri. The northern third of this land has been developed into a high-technology research park. The conservation areas adjacent to the Chemical Plant are operated by MDC and employ about 50 people.

1.3 History of Contamination

1.3.1 Operations History

In 1941, the U.S. government acquired 17,232 acres of rural land in St. Charles County to establish the Weldon Spring Ordnance Works. In the process, the towns of Hamburg, Howell, and Toonerville and 576 citizens of the area were displaced. From 1941 to 1945, the Army manufactured trinitrotoluene (TNT) and dinitrotoluene (DNT) at the Ordnance Works site. Four TNT production lines were situated on what was to be the Chemical Plant. These operations resulted in nitroaromatic contamination of soil, sediments, and some offsite springs ("offsite" in this document refers to those adjacent or nearby properties not located within the physical boundaries of the Weldon Spring Chemical Plant and Quarry, this definition of "offsite" deviates from the definition in CERCLA).

Following a considerable amount of explosives decontamination of the facility by the Army, 205 acres of the former Ordnance Works property were transferred to the U.S. Atomic Energy Commission (AEC) in 1956 for construction of the Weldon Spring Uranium Feed Materials Plant, now referred to as the Weldon Spring Chemical Plant. An additional 14.88 acres were transferred to AEC in 1964. The plant converted processed uranium ore concentrates to pure uranium trioxide, intermediate compounds, and uranium metal. A small amount of thorium was also processed. Wastes generated during these operations were stored in four Raffinate Pits located on the Chemical Plant property. Uranium processing operations resulted in radiological contamination of the same general locations previously contaminated by former Army operations.

The Quarry was mined for limestone aggregate used in construction of the Ordnance Works. The Army also used the Quarry for burning wastes from explosives manufacturing and disposal of TNT-contaminated rubble during operation of the Ordnance Works. These activities resulted in nitroaromatic contamination of the soil and groundwater at the Quarry. In 1960, the Army transferred the Quarry to AEC, who used it from 1963 to 1969 as a disposal area for uranium and thorium residues (both drummed and uncontained) from the former Chemical Plant and other AEC locations.

Uranium processing operations ceased in 1966, and on December 31, 1967, AEC returned the facility to the Army for use as a defoliant production plant. In preparation for the defoliant-production process, the Army removed equipment and materials from some of the buildings and disposed of them principally in Raffinate Pit 4. The defoliant project was cancelled before any defoliant was manufactured, and the Army transferred 50.65 acres of land encompassing the Raffinate Pits back to AEC while retaining the Chemical Plant. AEC, and subsequently DOE, managed the site, including the Army-owned Chemical Plant, under caretaker status from 1968 through 1985. Caretaker activities included site security oversight, fence maintenance, grass cutting, and other incidental maintenance. In 1984, the Army repaired several of the buildings at the Chemical Plant, decontaminated some of the floors, walls, and ceilings, and isolated some equipment. In 1985, the Army transferred full custody of the Chemical Plant to DOE.

1.3.2 Nature and Extent of Contamination

Except for the limited decontamination effort by the Army in 1984, the Chemical Plant had been closed for 20 years when the remediation project began at the site. During this period, the infrastructure had deteriorated considerably. Many windows were broken, walls were separated from floors, floors had begun to break apart, and roofs had holes and had deteriorated to the extent that many leaked badly. Radioactive contamination existed on various surfaces, polychlorinated biphenyls (PCBs) contaminated floors, and protective coverings for asbestos-containing insulation had deteriorated.

On the Chemical Plant grounds, 300 utility poles supporting 150,000 linear feet (ft) of wiring were rotten, and many had fallen to the ground. There was an additional 33,000 linear ft of piping, some with deteriorating asbestos containing insulation. Active water mains leaked extensively and added to contaminated water leaving the site.

In addition to the buildings, four Raffinate Pits contained several hundred to several thousand picocuries per gram (pCi/g) of uranium, radium, and thorium isotopes. Chemical analysis of the sludge showed relatively homogeneous material in all of the pits except Pit 4, which also contained a large number of discarded drums, containers, and debris from the Army’s earlier partial decontamination. The sludge contained concentrations greater than background for all of the metals and anions included in the analysis. The pH of greater than 7 maintained low concentrations of heavy metals in the water. These four pits, Frog Pond, and Ash Pond all contained radionuclides, primarily thorium and uranium, metals such as arsenic and chromium, and inorganic anions such as nitrate and sulfate (Figure 3).

Chemical Plant soils generally contained low levels of radionuclides such as uranium, thorium, and radium; some heavy metals such as arsenic and lead; and inorganic ions such as sulfate. Characterization data indicated that uranium (uranium-238) was generally distributed at low levels across the Chemical Plant surface soils, but with a few discrete areas of relatively high concentrations.

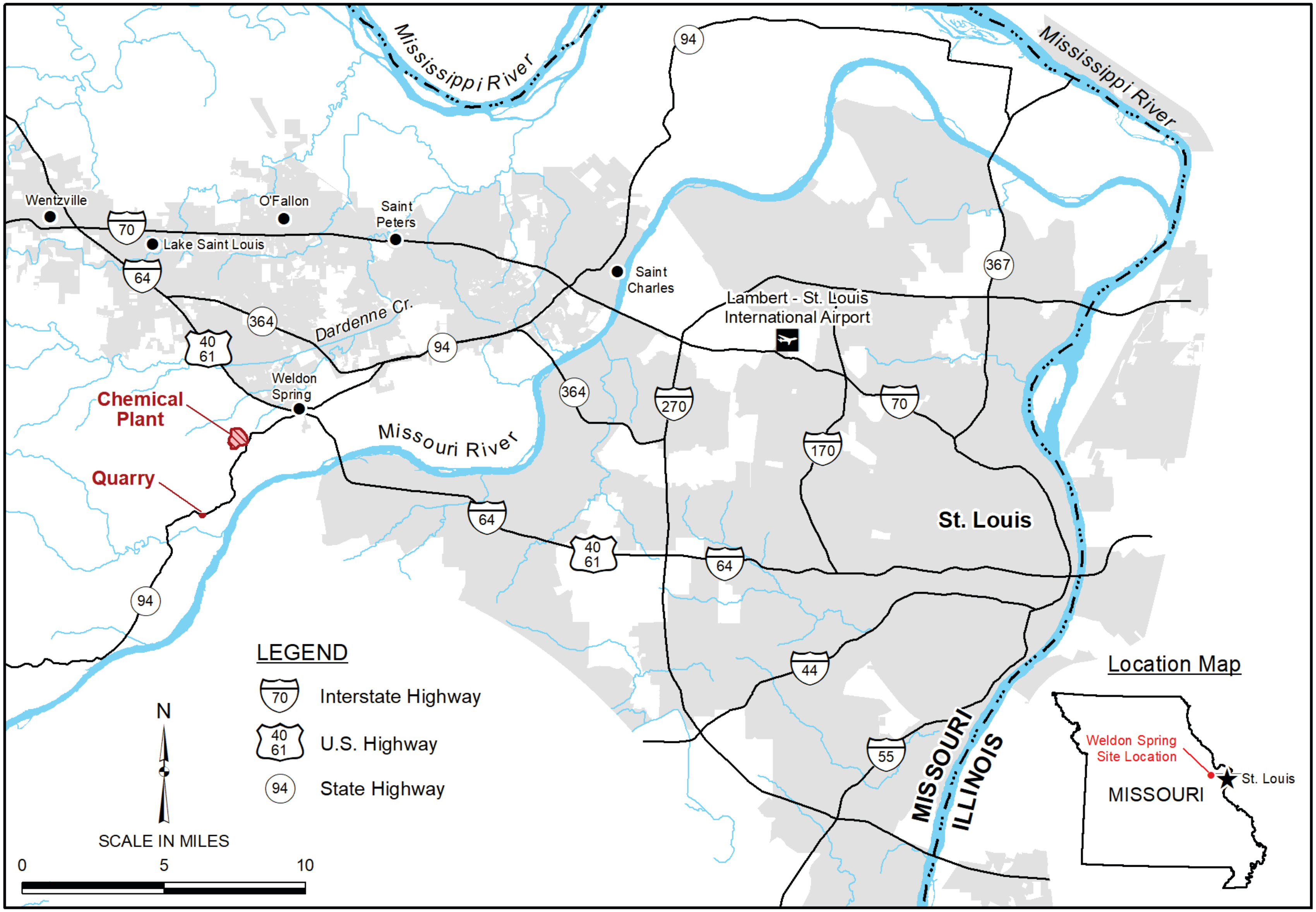

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Figure 1. Location of the Weldon Spring, Missouri, Site

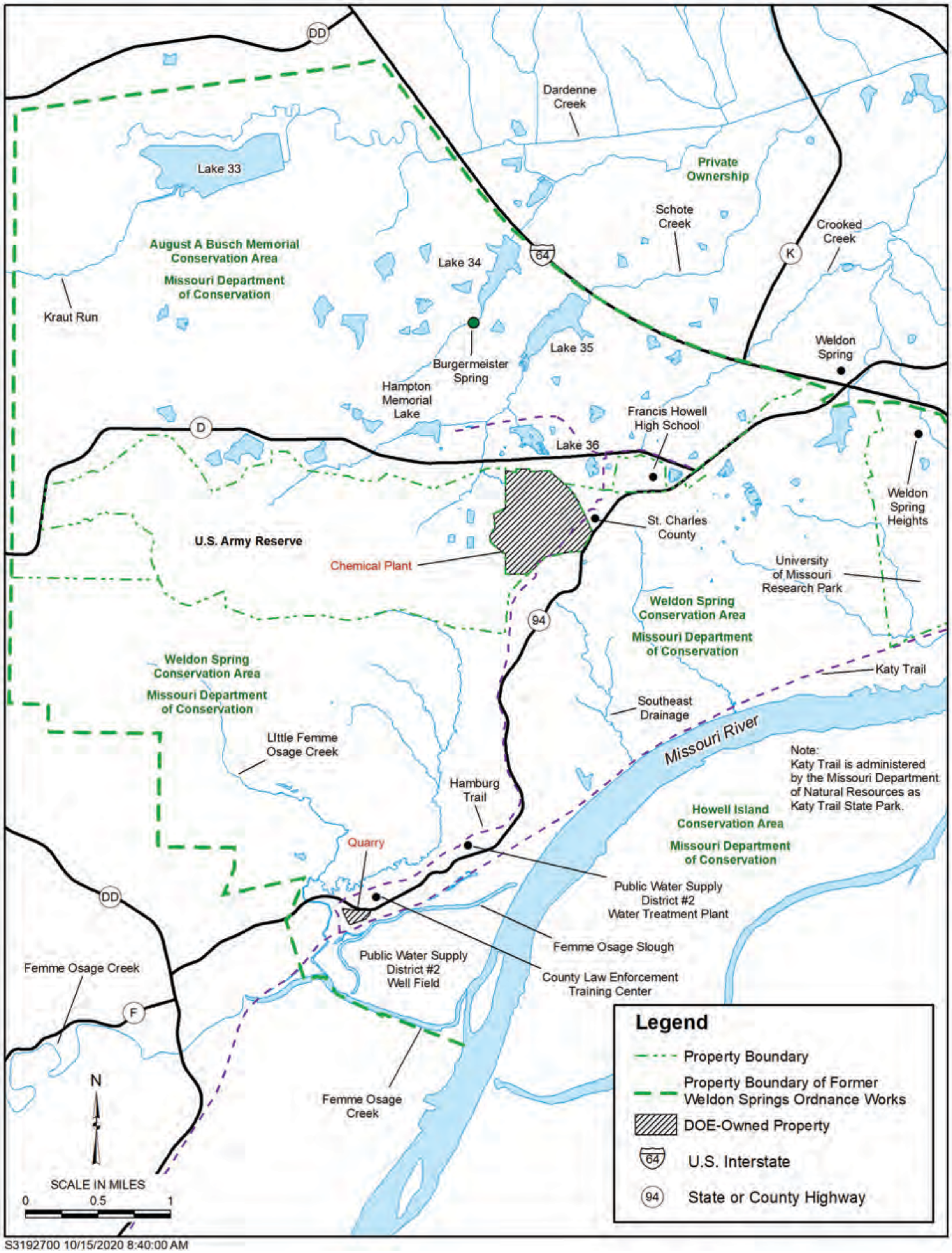

Figure 2. Vicinity Map of the Weldon Spring, Missouri, Site

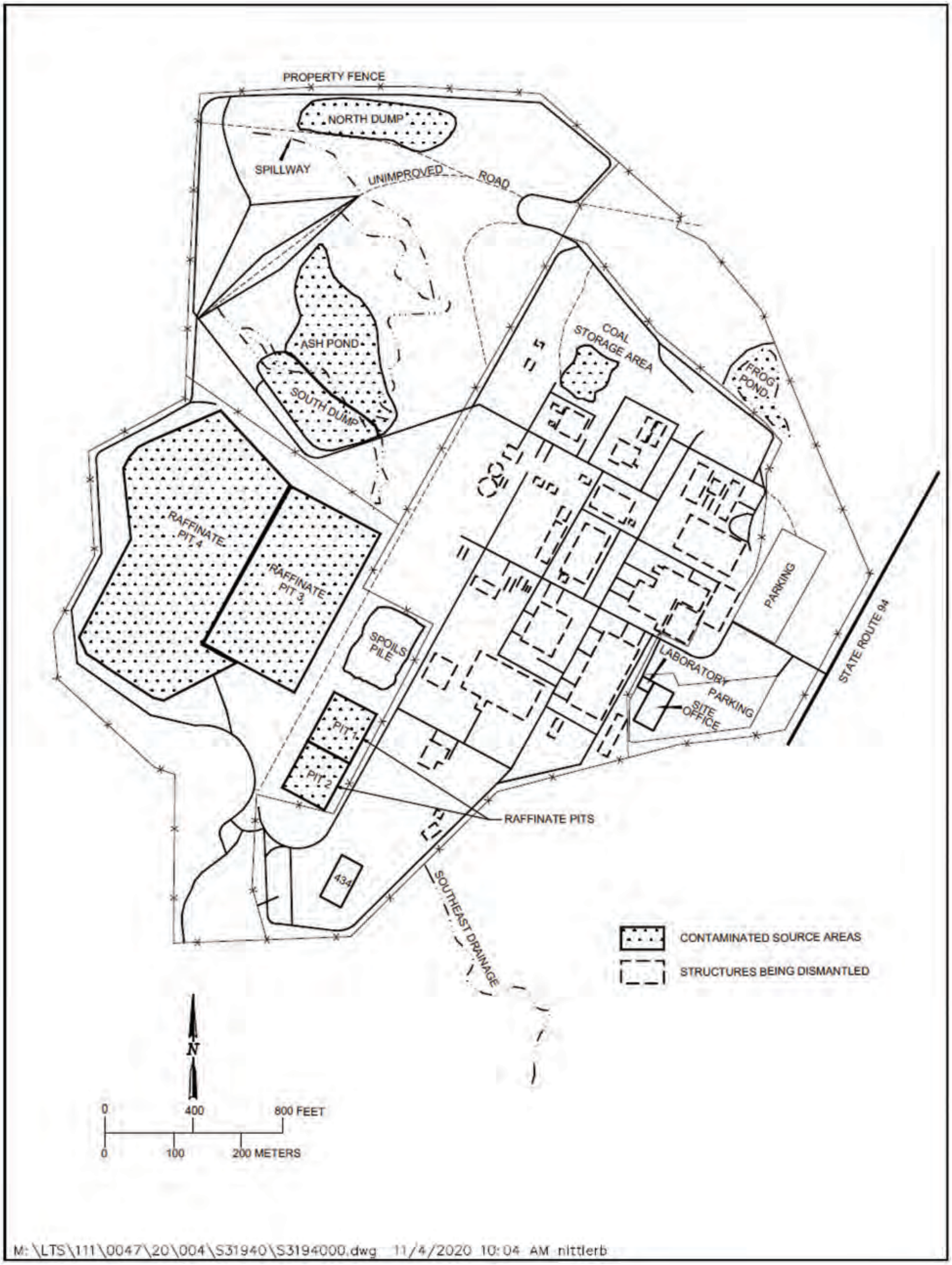

Figure 3. Location of Raffinate Pits, Frog Pond, and Ash Pond

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site Name: Weldon Spring Quarry/Plant/Pits		
EPA ID: MO3210090004		
Region: 7	**State:** MO	**City/County:** St. Charles/St. Charles
SITE STATUS		
NPL Status: Final		
Multiple OUs? Yes	**Has the site achieved construction completion?** Yes	
REVIEW STATUS		
Lead agency: Other Federal Agency ***[If "Other Federal Agency", enter Agency name]*:** Department of Energy		
Author name (Federal or State Project Manager): Rebecca Roberts		
Author affiliation: DOE Project Manager		
Review period: 9/15/2020–9/30/2021		
Date of site inspection: 12/1/2020		
Type of review: Statutory		
Review number: 6		
Triggering action date: 9/30/2016		
Due date *(five years after triggering action date)*: 9/30/2021		

2.0 Response Action Summary

2.1 Basis for Taking Action

2.1.1 Chemical Plant Concentration Ranges of Major Chemical Contaminants Prior to Remediation

Table 1 lists the CPOU concentration ranges of major chemical contaminants prior to remediation as discussed in the CPOU Record of Decision (ROD).

Table 1. Concentration Ranges of Chemical Contaminants Prior to Remediation at the Chemical Plant

	Onsite Concentration Range[a]			Offsite Concentration Range[b]	
Contaminant	**Soil (mg/kg)**	**Surface Water (µg/L)**	**Raffinate Pit Sludge (mg/kg)**	**Surface Water (µg/L)**	**Sediment (mg/kg)**
Antimony	6.4–110	65–400	6.0–87	70–76	ND
Arsenic	1.3–130	12–120	3.1–1100	12–29	3.0–19
Barium	25–5200	ND	20–7700	78–110	10–330
Beryllium	0.51–5.5	7.0–9.0	0.59–25	ND	ND
Cadmium	0.51–11	37	0.94–14	ND	ND
Chromium(III)	2.0–280	28–170	4.5–150	13–23	6.3–23
Chromium(VI)	0.22–31	3.1–19	0.5–17	1.4–2.6	0.7–2.5
Cobalt	2.8–110	ND	5.1–44	ND	7.0–37
Copper	3.6–460	30–45	3.7–510	ND	5.0–170
Lead	1.3–1900	22–450	2.1–640	9.5–15	9.0–48
Lithium	5.3–71	61–4500	5.0–120	ND	–
Manganese	3.3–13,000	16–33	25–3000	18–870	280–6500
Mercury	0.11–2.1	0.29–0.36	0.10–15	0.35–1.3	ND
Molybdenum	4.1–120	690–4100	16–1600	22–42	–
Nickel	5.6–270	47–170	3.3–8800	ND	8.0–66
Selenium	0.63–47	7.5–220	2.7–81	ND	ND
Silver	0.92–13	25–40	1.0–5.0	4.0–6.0	ND
Thallium	1.0–80	ND	1.1–58	33	ND
Vanadium	7.2–380	90–2100	26–8700	ND	14–75
Zinc	6.1–1100	26–60	7.9–1600	21–78	24–220
Fluoride	1.3–45	230–19,000	3.2–170	170–600	–
Nitrate	0.54–3800	190–200,000	0.6–160,000	300–260,000	–
Nitrite	1.5–29	–	1.0–1,600	–	–
Acenaphthene	1.9	–	ND	–	ND
Anthracene	3.4	–	ND	–	ND
Benz[*a*]anthracene	0.41–8.2	–	ND	–	ND
Benzo[*b*]fluoranthene	4.6	–	ND	–	ND
Benzo[*k*]fluoranthene	3.9	–	ND	–	ND
Benzo[*g,h,i*]perylene	2.1	–	ND	–	ND

Table 1. Concentration Ranges of Chemical Contaminants Prior to Remediation at the Chemical Plant (continued)

	Onsite Concentration Range[a]			Offsite Concentration Range[b]	
Contaminant	**Soil (mg/kg)**	**Surface Water (µg/L)**	**Raffinate Pit Sludge (mg/kg)**	**Surface Water (µg/L)**	**Sediment (mg/kg)**
Benzo[*a*]pyrene	5.1	–	ND	–	ND
Chrysene	0.39–8.0	–	ND	–	ND
Fluoranthene	0.58–11	–	ND	–	ND
Fluorene	1.6	–	ND	–	ND
Indeno[1,2,3,-*d*]pyrene	3.2	–	ND	–	ND
2-Methylnaphthalene	0.52–4.6	–	ND	–	ND
Naphthalene	1.8	–	ND	–	ND
Phenanthrene	0.42–11	–	ND	–	ND
Pyrene	0.35–19	–	ND	–	ND
PCBs	0.28–12	–	0.15–11	ND	0.2
DNB	1.0–3.8	ND	ND	0.18–0.81	ND
2,4-DNT	0.83–6.3	ND	ND	0.3–11	ND
2,6-DNT	1.6–3.5	ND	ND	0.19–18	ND
NB	1.6–3.8	ND	ND	0.87	ND
TNB	0.63–5.7	0.04–1.4	ND	0.02–0.84	ND
TNT	1.3–32	0.80–7.5	ND	0.05–110	ND

Source: *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1993)

Notes:
[a] The term “onsite” refers to all areas, contaminated or otherwise, within the physical boundaries of the Chemical Plant and Quarry.
[b] The term “offsite” refers to Busch Conservation Area vicinity properties, Weldon Spring Training Area vicinity properties, Weldon Spring Conservation Area vicinity properties, Burgermeister Spring, and the Southeast Drainage.

Abbreviations:
DNB = dinitrobenzene
mg/kg = milligrams per kilogram
µg/L = micrograms per liter
NB = nitrobenzene
ND = not detected
TNB = trinitrobenzene

Table 2 shows the concentration ranges and locations of the radioactive contaminants for the CPOU prior to remediation.

Table 2. Concentration Ranges and Locations of CPOU Radioactive Contaminants Prior to Remediation

Contaminant	Onsite Concentration Range[a]			Offsite Concentration Range[b]	
	Soil (pCi/g)	Surface Water (pCi/L)	Raffinate Pit Sludge (pCi/g)	Surface Water (pCi/L)	Sediment (pCi/g)
Lead-210	0.4–450	–	1.0–1700	–	–
Radium-226	0.4–450	3.4–130	1.0–1700	ND	0.7–220
Radium-228	0.4–450	1.5–25	4.0–1400	ND	0.4–480
Radon-220 progeny	–	–	–	–	–
Radon-222 progeny	–	–	–	–	–
Thorium-228	0.4–450	1.5–25	4.0–1400	ND	0.4–480
Thorium-230	0.3–97	1.4–760	8.0–34,000	1.0–8.0	1.5–10,000
Thorium-232	0.4–150	0.2–7.6	3.0–1400	ND	0.7–2.5
Uranium-234[c]	0.3–2300	28–1300	4.9–1700	2.0–590	0.5–720
Uranium-235	0.01–110	1.3–60	0.2–78	0.09–27	0.02–33
Uranium-238	0.3–2300	28–1300	4.9–1700	2.0–590	0.5–720

Source: (DOE 1993)

Notes:

[a] The term “onsite” refers to all areas, contaminated or otherwise, within the physical boundaries of the Chemical Plant and Quarry.

[b] The term “offsite” refers to Busch Conservation Area vicinity properties, Weldon Spring Training Area vicinity properties, Weldon Spring Conservation Area vicinity properties, Burgermeister Spring, and the Southeast Drainage.

[c] Estimated on the basis of expected equilibrium conditions.

Abbreviations: ND = not detected pCi/L = picocuries per liter

2.1.2 Quarry Concentration Ranges of Major Chemical Contaminants Prior to Remediation

Table 3 lists concentration ranges of major radiological contaminants prior to remediation as discussed in the QBWOU ROD.

Table 3. Concentration Ranges of Radionuclides at the Quarry Prior to Remediation

Radionuclide	Bulk Waste Concentration (pCi/g)		Average Surficial Concentration[a] (pCi/g)	Average Background Concentration (pCi/g)
	Range	Average		
Uranium-238	1.4–2400	200	170	1.3
Thorium-232	0.7–36	26	NDA	1.0
Thorium-230	0.7–6800	330	150	1.3
Radium-228	0.1–2200	96	20	1.0
Radium-226	0.2–2800	110	110	0.9

Source: *Record of Decision for Management of Bulk Wastes at the Weldon Spring Quarry* (DOE 1990b)

Note:

[a] Samples obtained from the top 6 inches (15 centimeters) of the Quarry bulk wastes.

Abbreviation: NDA = No data available

Table 4 lists the concentration ranges of major chemical contaminants prior to remediation as discussed in the QBWOU ROD.

Table 4. Concentration Ranges of Chemicals Detected in the Quarry Bulk Wastes in the 1984–1985 Characterization Study and Background Concentrations in Missouri Soils

Chemical[a]	Composite Borehole Sample Concentration (mg/kg)		Number of Boreholes in Which Chemical Detected	Surface Sample Concentration (mg/kg)	Average Background Concentration[c] (mg/kg)
	Range[b]	Average[b]			
Antimony	<20[d]	–	0	71	<200[d]
Arsenic	73–120	100	6	100	8.7
Beryllium	0.45–0.83	0.62	6	0.61	0.8
Cadmium	1.8–98	19	6	2.0	<1
Chromium	19–49	30	6	24	54
Copper	38–160	100	6	140	13
Lead	130–410	280	6	950	20
Mercury	0.18–6.3	2.0	6	0.7	0.039
Nickel	19–120	43	6	300	14
Selenium	17–28	23	6	22	0.28
Silver	5.8–8.3	7.0	3	7.5	0.7
Thallium	3.0–6.2	4.7	6	5.1	<50[d]
Zinc	68–870	340	6	39	49
Cyanide	0.2–0.6	0.38	5	0.2	NA
PCBs (Aroclor 1254)	0.56–46	12	5	1.00	NA
PCBs (Aroclor 1260)	9.0	9.0	1	–	NA

Source: *Record of Decision for Management of Bulk Wastes at the Weldon Spring Quarry* (DOE 1990b)

Notes:

[a] All compounds that had one or more positive results above detection limits are listed; concentrations are rounded to two significant figures. Samples were taken from six boreholes in the bulk wastes and from a surface waste pile.

[b] Ranges and averages are for detected values only and do not necessarily indicate the average concentrations for the entire waste material.

[c] Concentration in Missouri agricultural soils.

[d] Lower limit of detection.

Abbreviations:

mg/kg = milligrams per kilogram

NA = not applicable

2.1.3 Quarry Residuals Concentration Ranges of Major Chemical Contaminants Prior to Remediation

Table 5 lists concentration ranges of major radiological contaminants prior to remediation as discussed in the QROU ROD.

Table 5. Summary of Contaminant Data Collected for the QROU Prior to Remediation[a]

Contaminant	Quarry Proper		Femme Osage Slough/Creeks		Groundwater	Background			
	Soil	Fractures	Surface Water	Sediment		Soil	Surface Water	Sediment	Groundwater
Radionuclides	*(pCi/g)*[b]	*(pCi/g)*[b]	*(pCi/L)*	*(pCi/g)*	*(pCi/L)*	*(pCi/g)*	*(pCi/L)*	*(pCi/g)*	*(pCi/L)*
Radium-226	0.28–50	0.20–96	–[c]	–	–	0.69–1.2	0.060–0.24	0.56–1.2	0.040–1.4
Radium-228	0.16–23	0.22–84	–	–	–	0.70–1.4	0.060–0.86	0.28–2.1	0.20–7.3
Thorium-230	0.81–570	0.77–630	–	–	–	0.72–1.2	0.080–1.3	0.54–2.2	0.040–9.7
Thorium-232	0.45–25	0.21–60	–	–	–	0.60–1.2	0.040–0.32	8.2–1.1	0.010–1.0
Uranium-238[d]	0.44–21	1.3–200	0.47–53	1.0–180	0.020–4200	0.94–1.6	2.5–2.9	0.64–0.69	0.20–11
Chemicals	*(mg/kg)*	*(mg/kg)*	*(µg/L)*	*(mg/kg)*	*(µg/L)*	*(mg/kg)*	*(µg/L)*	*(mg/kg)*	*(µg/L)*
Metals									
Aluminum	4200–20,000	4000–31,000	67–200	1100–20,000	22–26,000	1300–12,000	67–200	1100–13,000	18–4800
Antimony	–	–	–	6.9–36	–	ND	33	ND	86
Arsenic	–	–	3.1–6.8	–	–	3.5–15	ND	2.5–6.8	2.0–8.8
Barium	–	–	–	–	29–1,200	9.3–210	56–97	27–150	75–700
Beryllium	–	–	–	0.27–1.6	–	0.44–0.74	ND	0.27–0.85	0.7–1.7
Cadmium	–	–	–	0.20–3.5	0.26–4.3	0.46–0.98	ND	ND	ND
Chromium	–	–	ND	2.8–24	0.72–150	3.3–13	ND	2.8–16	3.0–54
Cobalt	–	–	–	–	1.4–15	2.0–9.1	ND	2.2–9.5	4.3–6.6
Copper	–	–	–	2.9–30	2.2–120	11–19	16–17	2.9–14	2.2–49
Lead	–	–	ND	–	–	9.2–27	ND	2.7–15	1.0–77
Manganese	–	–	240–1300	58–1100	4.3–5000	170–1000	270–370	58–810	16–790
Mercury	–	–	–	0.060–0.10	0.16–2.4	0.090–0.10	ND	0.10	0.040–0.40
Molybdenum	–	–	–	0.80–3.9	–	0.59–1.3	ND	ND	17–19
Nickel	–	–	ND	12.3–28	4.2–66	15–28	ND	12–22	12–43
Selenium	0.21–6.0	23–150	–	0.77–2.7	–	0.62–2.0	ND	0.99	2.6–8.9
Silver	0.36–11	10–39	ND	–	–	0.97	ND	ND	22
Strontium	–	–	120–260	–	–	ND	100–110	5.5–17	250–1200

Table 5. Summary of Contaminant Data Collected for the QROU Prior to Remediation (continued)

Contaminant	Quarry Proper		Femme Osage Slough/Creeks		Groundwater	Background			
	Soil	Fractures	Surface Water	Sediment		Soil	Surface Water	Sediment	Groundwater
Thallium	–	–	–	–	1.1–8.3	0.61–2.0	ND	1.5–14	2.9–6.1
Uranium, total	1.4–63	3.9–600	0.70–80	3.0–540	0.03–10,000	0.72–3.0	3.7–4.3	1.6–3.7	0.45–17
Vanadium	–	–	–	4.8–44	1.2–67	6.2–20	10–14	4.8–31	3.2–41
Zinc	24–810	60–820	8.9–78	–	2.4–160	18–66	8.9–13	8.9–69	4.7–53
Organic Compounds									
1,3,5-TNB	0.0030–3.8	1.3	ND	0.14	0.015–270	NA	NA	NA	NA
1,3-DNB	0.002	ND	ND	ND	0.045–3.5	NA	NA	NA	NA
2,4,6-TNT	0.00020–0.69	0.0010–1.2	ND	ND	0.014–60	NA	NA	NA	NA
2,4-DNT	0.0003–0.05	0.00040–1.2	ND	0.0070	0.011–4.6	NA	NA	NA	NA
Nitrobenzene	–	ND	ND	ND	ND	NA	NA	NA	NA
PAHs	0.0075–1.4	0.009–1.4	ND	ND	ND	NA	NA	NA	NA
PCBs	0.031–4.5	0.036–1.5	ND	ND	ND	NA	NA	NA	NA

Source*:* *Record of Decision for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site* (DOE 1998a)

Notes:

[a] The range of detected concentrations for contaminants of potential concern identified for each medium is provided. Contaminants identified as COPCs are those contaminants with concentrations exceeding the statistically determined background concentration. The identification of COPCs was performed by using all the data collected for each medium (i.e., since 1987). For groundwater and surface water, the ranges of reported concentrations are for recent data collected from 1995 to 1997. These recent data are considered more representative of current conditions and indicate a decreasing trend as a result of bulk waste removal from the Quarry. Sources: Weldon Spring Remedial Action Project Database 1997; DOE 1998d.

[b] The majority of the samples from Quarry soil and fractures indicate low concentrations for radionuclides, as reflected by low mean concentrations. Mean Quarry concentrations for Quarry soil and fractures are as follows:

Soil	Mean	Fractures	Mean
Radium-226	2.4	Radium-226	4.5
Radium-228	2.3	Radium-228	4.6
Thorium-230	30	Thorium-230	58
Thorium-232	1.5	Thorium-232	5.7
Uranium-238	4.8	Uranium-238	17

[c] A dash denotes that the contaminant was not identified as a COPC.

[d] For groundwater and surface water, reported concentrations are for total uranium.

Abbreviations:

COPCs = contaminants of potential concern; NA = not applicable (background concentrations of organic compounds that are considered anthropogenic are assumed to be zero); ND = not detected; PAHs = polycyclic aromatic hydrocarbons; TNB = trinitrobenzene

2.1.4 Southeast Drainage Concentration Ranges of Radionuclide Contaminants Prior to Remediation

Initial soil characterization for the Southeast Drainage was conducted by Oak Ridge Associated Universities (ORAU) from July 1984 through September 1985. During the survey, surface beta and gamma measurements, surface and subsurface soil samples, water samples, and sediment samples were collected. Both vicinity properties that make up the Southeast Drainage (DA 4 and MDC 7) were surveyed separately. During the soil and sediment sampling of MDC 7, five samples were analyzed for thorium-230, in addition to radium-226, thorium-232, and uranium-238. The ORAU data for the Southeast Drainage (both surface and subsurface sediment and soil) are summarized in Table 6. Remediation of the Southeast Drainage was administratively under the CPOU.

Table 6. Summary of ORAU Data for Southeast Drainage Prior to Remediation

Southeast Drainage Area	^{226}Ra Concentration Range (pCi/g)	^{230}Th Concentration Range (pCi/g)	^{232}Th Concentration Range (pCi/g)	^{238}U Concentration Range (pCi/g)	Primary Contaminant	Estimated Volume (yd^3)
DA 4	0.76–210	Not analyzed	0.43–69.1	<1.56–1010	^{226}Ra ^{232}Th ^{238}U	3270
MDC 7	2.57–130	570–10,100	0.51–240	9.58–810	^{226}Ra ^{230}Th ^{232}Th ^{238}U	6997

Source: Southeast Drainage Closeout Report Vicinity Properties DA-4 and MDC-7 (DOE 1999a)

Abbreviations:
DA = Department of the Army
^{226}Ra = radium-226
^{230}Th = thorium-230
^{232}Th = thorium-232
^{238}U = uranium-238
yd^3 = cubic yards

2.1.5 Groundwater Operable Unit Concentration Ranges of Chemical Contaminants Prior to Remediation

The GWOU ROD discussed concentration ranges of contaminants of concern in the groundwater. Data collected in 2002 showed TCE concentrations ranging from 1.6 to 580 µg/L. Nitrate concentration ranges were from 0.4 to 826 mg/L. Data for 2002 indicated nitrate concentration ranging from 0.94 to 11 mg/L in Burgermeister Spring. A nitrate concentration of 1.9 mg/L was also detected at a Southeast Drainage spring (SP-5304) in 2002. Data on uranium concentrations collected in 2002 showed ranges of 0.1 to 60 pCi/L. Uranium was detected at Burgermeister Spring and at SP-5304. In 2002, uranium ranged from 8.6 to 100 pCi/L and from 9.4 to 103 pCi/L at the two springs, respectively.

For nitroaromatics, maximum concentrations of 1,600 µg/L for 2,4-DNT, 1,300 µg/L for 2,6-DNT, 290 µg/L for 2,4,6-TNT, 1.7 µg/L for 1,3-DNB, and 69 µg/L for NB were detected in 2002. These maximums were reported for one particular well, MW-2012. Of the nitroaromatic compounds sampled for Burgermeister Spring in 2002, only 2,6-DNT was detected, at an average concentration of 0.12 µg/L. At spring SP-5303, the average 2,4,6-TNT concentration in

2002 was 26 µg/L. There was also a single 0.35 µg/L detect of 2,6-DNT at SP-5303 with four other nondetects in 2002. Farther downstream at SP-5304 only 2,4,6-TNT was detected, at an average concentration of 0.13 µg/L.

2.2 Interim Response Actions

Initial remedial activities at the Chemical Plant, a series of Interim Response Actions (IRAs) authorized through the use of the engineering evaluation/cost analysis (EE/CA) process, included:

- Removal of electrical transformers, electrical poles and lines, and overhead piping and asbestos that presented an immediate threat to workers and the environment.
- Construction of an isolation dike to divert runoff around the Ash Pond area to reduce the concentration of contaminants going offsite in surface water.
- Detailed characterization of onsite debris, separation of radiological and nonradiological debris, and transport of materials to designated staging areas for interim storage.
- Dismantling of 44 Chemical Plant buildings under four separate IRAs.
- Treatment of contaminated water at the Chemical Plant and the Quarry.

Originally, 23 IRAs (Table 7) were scoped, but some of these were cancelled and others combined so that 14 were completed. All IRAs that were cancelled were covered by other environmental documentation.

EPA placed the Quarry and Chemical Plant areas on the National Priorities List (NPL) on July 30, 1987, and March 30, 1989, respectively.

A Federal Facility Agreement (FFA) was signed by EPA and DOE in 1986, and it was amended in 1992. The main purpose of this FFA was to establish a procedural framework and schedule for developing, implementing, and monitoring appropriate response actions at the site in accordance with CERCLA.

A revised FFA between EPA, DOE, and MDNR was signed by all parties by March 31, 2006. Long-term surveillance and maintenance (LTS&M) activities are the focus of the new FFA.

Remediation of the Weldon Spring Site was administratively divided into the four OUs: the QBWOU, QROU, CPOU, and GWOU. The Southeast Drainage was remediated as a separate action through the *Engineering Evaluation/Cost Analysis for the Proposed Removal Action at the Southeast Drainage near the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1996), hereafter called the EE/CA report and was administratively covered under the CPOU. The selected remedies are described in Section 2.3.

Table 7. Weldon Spring Site IRAs

Number	Description	Status
1	Electrical Transformer Removal	Complete
2	Ash Pond Isolation System	Complete
3	Material Staging Area (Moved to IRA 15)	Cancelled
4	Army Property 7	Complete
5	August A. Busch and Weldon Spring Wildlife Areas 3, 4, 5, and 6	Cancelled
6	Overhead Piping/Asbestos Removal	Complete
7	Containerized Chemicals	Complete
8	Electrical Pole/Overhead Line Removal	Complete
9	Debris Consolidation	Complete
10	Building 409 Dismantlement	Complete
11	Building 401 Dismantlement	Complete
12	Isolation Dike for Surface Water Management on the Southeast Drainage	Cancelled
13	Army Reserve Properties 1, 2, 3, and 7	Cancelled
14	Dismantlement and Removal of Non-Process Buildings, Structures, and Equipment (Moved to IRA 15-19)	Cancelled
15	Non-Process Building Dismantlement Task 1	Complete
16	Remaining Process and Non-Process Building Dismantlement (Moved to IRA 18)	Cancelled
17	Water Tower Removal (Moved to IRA 18)	Cancelled
18	Process (Contaminated Structures) Building Dismantlement	Complete
19	Decontamination Facility	Cancelled
20	Site Water Treatment Plant	Complete
21	Quarry Water Treatment Plant	Complete
22	Quarry Construction Staging Area (Incorporated into Quarry Bulk Waste ROD)	Cancelled
23	Southeast Drainage Soil Removal	Complete

2.3 Remedial Actions

2.3.1 Chemical Plant Operable Unit

2.3.1.1 CPOU Remedy Selection

The Remedial Investigation/Feasibility Study (RI/FS) process was conducted for the Weldon Spring CPOU in accordance with the requirements of CERCLA, as amended, to document the proposed management of the Chemical Plant area as an OU for overall site remediation and to support the comprehensive disposal options for the entire cleanup. Documents developed during the RI/FS process included the following:

- *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site* (DOE 1992a)
- *Baseline Assessment for the Chemical Plant Area of the Weldon Spring Site* (DOE 1992c)
- *Feasibility Study for the Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1992b)
- *Proposed Plan for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1992d)

In September 1993, DOE finalized the *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1993) for managing contaminated materials (except groundwater) at the Chemical Plant. The CPOU addressed the various sources of contamination in the Chemical Plant, including soils, sludge, sediment, and materials placed in short-term storage as a result of previous response actions. The remedial action included in the Chemical Plant ROD was the major component of site cleanup and addressed comprehensive disposal options for the project. The primary focus was the contaminated material in the Chemical Plant, including that generated as a result of previous response actions, but it also addressed the disposal of materials generated by the other OUs to facilitate a disposal decision that would integrate all of the OUs. The three key components of the remedy were the following:

- Remove the contaminated materials
- Treat the wastes as appropriate by chemical stabilization or solidification
- Dispose of the wastes in an engineered disposal facility constructed onsite

These components were not specifically referred to as remedial action objectives in the ROD. These components of the remedy were all met as discussed below and documented in the *Chemical Plant Operable Unit Remedial Action Report* (DOE 2004b).

The remedy included remediation of 17 vicinity properties affected by Chemical Plant operations. The vicinity properties were remediated in accordance with Chemical Plant ROD cleanup criteria. Appendix A to the *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri, Site* (2008a), hereafter called the LTS&M Plan, includes a summary of the vicinity property remediation projects and references to the closeout reports. Contaminant of concern (COC) information is discussed in Section 2.0.

2.3.1.2 CPOU Remedy Implementation

The *Conceptual Design Report for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1994) was issued in December 1994 and comprised the Remedial Design Work Plan. The *Remedial Action Work Plan of the Chemical Plant Area of the Weldon Spring Site* (DOE 1995b) was issued in November 1995.

The majority of the activities and components of the Chemical Plant remedial action were discussed in the second FYR (DOE 2001). The cell was close to completion at the time of the report, which was dated August 2001. The cell cover was completed in October 2001. The components of the remedy that have been ongoing since the time of the second, third, fourth, and fifth reviews are the Leachate Collection and Removal System (LCRS); leachate monitoring; disposal cell groundwater monitoring; and LTS&M activities, such as inspections, monitoring and maintenance, and institutional controls (ICs). The description of the remedial action is detailed in the *Chemical Plant Operable Unit Remedial Action Report* (DOE 2004b).

The *Post-Remediation Risk Assessment for the Chemical Plant Operable Unit Weldon Spring Site, St. Charles, Missouri* (DOE 2002b) documents the risk estimates for residual soil after the remedial action was completed. The document concluded that on the basis of the results presented in this report, the remediation performed for the Chemical Plant and its vicinity properties has resulted in residual chemical risks that are well within the acceptable risk range for the hypothetical resident and recreational visitor scenarios evaluated. Future use of these areas or properties in a manner similar to the scenarios assumed in the report should be protective of human health. The hazard indexes estimated also indicate that potential systemic toxicity would not be a concern in these areas.

The site reached construction completion under CERCLA on August 22, 2005. The site also received the EPA Superfund Sitewide Ready for Anticipated Use (SWRAU) designation from EPA in a letter dated March 20, 2013. The SWRAU performance measure reports sites documented as ready for reuse when the entire construction-completed NPL site meets the following requirements:

- All cleanup goals in the RODs or other remedy decision documents have been achieved for media that may affect current and reasonably anticipated future land uses of the site, so that there are no unacceptable risks
- All ICs or other controls required in the RODs or other remedy decision documents have been put in place

After a review of all relevant site documents (including the RODs, the LTS&M Plan, FYRs, annual inspections and monitoring data, and ICs documentation), EPA determined that DOE has achieved the SWRAU performance measure for all DOE-owned land at the site. This includes the former Chemical Plant and Quarry areas and totals approximately 229 acres. The SWRAU measure was recorded as completed in the EPA Comprehensive Environmental Response, Compensation, and Liability Information System database on February 13, 2013.

2.3.1.3 Disposal Cell Design and Leachate Collection and Removal System

The disposal cell is located on the northeastern portion of the Chemical Plant property, and the overall cell encompasses an area of approximately 41 acres. The five-sided cell has 4:1 side slopes over the clean-fill dike and cover slopes of approximately 13:1 over the waste. The maximum width of the cell footprint, including the rock-covered apron, is approximately 1500 ft, and the maximum height above grade is approximately 91 ft. The cell contains approximately 1.48 million cubic yards of contaminated waste, with an estimated total activity of 6570 curies. The waste column has a maximum thickness of 63 ft, and the waste footprint, including the lower interior dike slopes, is approximately 24 acres.

Six primary systems were incorporated into the cell design: the cover, the waste, a surrounding clean-fill dike, a geochemical barrier, a basal liner system, and the LCRS.

Leachate from the cell is collected in primary and secondary collection systems. The primary collection system consists of 4-inch-diameter perforated high-density polyethylene (HDPE) pipes located in the drainage material on top of the primary liner. The pipes convey leachate by gravity to a sump north of the disposal cell. The sump consists of a 60-inch-diameter HDPE manhole with an attached HDPE storage pipe measuring 200 ft long and 42 inches in diameter.

A secondary collection system consists of an HDPE geonet placed between layers of geotextile (high-tensile-strength filter fabric), which is placed between the primary and secondary liners. This system collects any leachate that leaks through the primary liner. Leakage flows through the secondary collection system to two gravel-filled sumps, one for each bay (east and west), located along the north edge of the cell. This secondary leachate is then conveyed by HDPE pipe through the same gravel-filled secondary containment as the primary leachate piping to the HDPE sump north of the cell. Flows from secondary collection system pipes can be monitored individually at the sump.

Leachate level is uploaded electronically into the System Operation and Analysis at Remote Sites (SOARS). By using SOARS, these data can be remotely monitored and tracked instead of having to be downloaded at the LCRS.

In accordance with 40 CFR 264.303(c)2, after the final cover was installed on the disposal cell, the amount of liquids removed from each secondary leak detection system sump was required to be recorded at least monthly. As a reliable database continues to be generated, DOE may modify the sump level monitoring frequency in accordance with regulations in 40 CFR 264.303(c)2. Flow rates are reported in units of gallons per day (gpd) and compared to the action leakage rate of 100 gallons per acre (gpa) per day established for the leachate collection system.

In 2020, the total primary and secondary leachate production, including secondary containment water, was approximately 22,446 gallons. In 2016, the total primary and secondary leachate production was approximately 25,087 gallons. This is a 10.5% reduction and the trend is slowing down, but is expected to continue.

Figure 4 shows the primary leachate monthly average flow rates for 2016 through 2020. The average monthly discharge from the primary leachate collection system has gone from an average of 59.4 gpd in 2016 to 50.9 gpd in 2020. This represents a 14.3% decrease in 5 years and shows that leachate production has decreased more slowly since the previous 5-year period (24%) but continues to decrease as designed.

The combined leachate from the secondary leachate collection system (east, west secondary collection and secondary containment) averaged approximately 9.2 gpd for 2016 to 9.7 gpd in 2020. This is a slight increase (5.4%) in the flow rate since 2016, and the increase is from the secondary containment flow rate, which includes perched water infiltration. The average leak rate for the entire secondary leachate collection system for 2001 was approximately 0.96 gpa per day. The average leak rate in 2020 was approximately 0.44 gpa per day. The trend is expected to remain flat as the secondary containment flow rate continues to include infiltration. This annual flow rate continues to be much less than 1% of the action leakage rate (100 gpa per day).

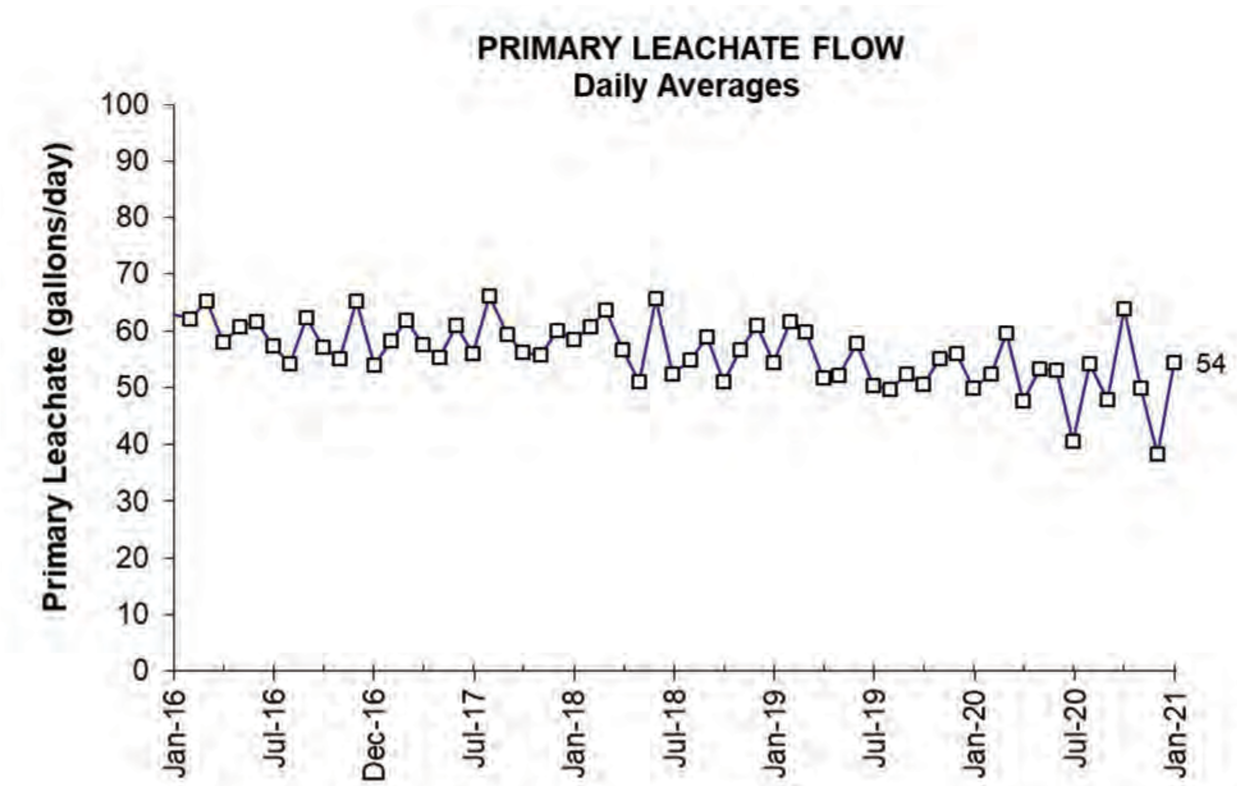

Figure 4. Primary Leachate Trends

The untreated leachate is sampled semiannually in accordance with Appendix K, “Disposal Cell Monitoring Plan,” of the LTS&M Plan (DOE 2008a). The analytical results for untreated leachate samples collected between 2016 and 2020 are summarized in Table 8.

Untreated combined leachate uranium activity during 2002 ranged from 16 to 57 picocuries per liter (pCi/L) and averaged 38.3 pCi/L. From 2016 to 2020 untreated leachate averaged 24.9 pCi/L.

The leachate is pretreated for uranium and then disposed of by hauling to the Metropolitan St. Louis Sewer District (MSD) Bissell Point Plant. MSD and DOE established an agreement in 2001 for MSD to receive the leachate, perform the final treatment on it, and discharge it. DOE maintains a National Pollutant Discharge Elimination System permit that authorizes discharge from the LCRS to the Missouri River as a contingency option for the leachate. No water has been discharged under this permit since 2002.

Table 8. Leachate Analytical Data (LW-DC10)

Parameter	Jun 2016	Dec 2016	Jun 2017	Dec 2017	Jun 2018	Dec 2018	Jun 2019	Dec 2019	Jun 2020	Dec 2020
Chloride (mg/L)	44	41	44	48	44	37	45	44	48	44
Fluoride (mg/L)	0.19	0.60	0.24	0.20	0.19	0.29	0.16	0.15	0.26	0.16
Nitrate (mg/L)	6.0	3.4	4.7	3.8	4.6	5.5	5.5	5.4	4.5	7.6
Sulfate (mg/L)	109	96	119	118	121	117	101	115	116	105
Arsenic (µg/L)	3.5	2.2	3.9	2.8	3.2	3.3	4.7	3.4	3.6	3.1
Barium (µg/L)	349	216	300	343	216	126	320	299	255	271
Chromium (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt (µg/L)	ND	ND	ND	ND	ND	ND	ND	0.35	ND	ND
Iron (µg/L)	33	143	33	53	74	73	41	24	ND	ND
Lead (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese (µg/L)	225	16	114	132	278	2	50	39	78	52
Nickel (µg/L)	4.2	3.7	3.4	3.3	3.0 (J)	ND	2.4	5.0	3.0	2.6
Selenium (µg/L)	1.8	7.3	ND	ND	ND	ND	ND	ND	ND	ND
Thallium (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
COD (mg/L)	32.6	60.5	30.8	35	ND	40.7	21.9	21.9	33	41
TDS (mg/L)	653	639	851	779	846	834	849	809	811	827
TOC (mg/L)	12.2	9.8	12.7	12	10.5	11.1	11.3	11.0	11.6	10.8
1,3,5-TNB (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-DNB (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-TNT (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-DNT (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-DNT (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Radium-226 (pCi/L)	0.52	ND	0.32	0.45	ND	ND	ND	ND	0.72 (J)	0.9
Radium-228 (pCi/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-228 (pCi/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-230 (pCi/L)	ND	ND	ND	ND	ND	0.38	ND	ND	ND	ND
Thorium-232 (pCi/L)	ND	ND	ND	ND	0.39	0.17	ND	ND	ND	ND
Uranium (pCi/L)	27.5	27.9	28.6	25.6	23.9	21.9	20	30	25	24.3
PCBs/PAHs (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Abbreviations:
COD = chemical oxygen demand
DNB = dinitrobenzene
J = estimated value
µg/L = micrograms per liter
ND = analyte not detected above method detection limit indicated in parentheses
PAHs = polycyclic aromatic hydrocarbons
TDS = total dissolved solids
TOC = total organic carbon
TNB = trinitrobenzene

2.3.1.4 Disposal Cell Groundwater Monitoring

DOE established a groundwater detection monitoring network around the disposal cell to monitor cell performance, as required under 40 CFR 264 Subpart F and Title 10 *Missouri Code of State Regulations* Division 25–7.264(2)(F) (10 CSR 25–7.264(2)(F)). The network originally consisted of five wells (MW-2048, MW-2032, MW-2045, MW-2046, and MW-2047) and Burgermeister Spring. All wells are completed in the weathered portion of the Burlington-Keokuk Limestone. In 2001, monitoring well MW-2048 was damaged and replaced with well MW-2055. Also, well MW-2051 was installed to replace well MW-2045, where anomalous, elevated metal concentrations were attributed to poor hydraulic performance. Burgermeister Spring (SP-6301) is a perennial downgradient point of emergence for groundwater from the Chemical Plant area. The current wells (MW-2032, MW-2046, MW-2047, MW-2051, and MW-2055), spring, and leachate are sampled semiannually (June and December) for a specific suite of analytes. Specific procedures for evaluating monitoring results and required responses are presented in the LTS&M Plan, Appendix K, "Disposal Cell Groundwater Monitoring Plan."

2.3.1.5 CPOU Long -Term Monitoring and Maintenance Activities

The project transferred LTS&M responsibility for the Weldon Spring Site from the DOE Oak Ridge Office to the DOE LTS&M program on October 1, 2002, and then to LM in December 2003. The LTS&M Plan for the Weldon Spring Site was finalized in July 2005 and revised in December 2008. The following is a discussion of the LTS&M activities that took place during the last FYR period.

Interpretive Center

The Weldon Spring Site Interpretive Center is part of DOE's LTS&M activities at the Weldon Spring Site. The purpose of this facility is to inform the public of the site's history, remedial action activities, and final conditions. The Center provides information about the LTS&M program for the site, provides access to surveillance and maintenance information, and supports community involvement activities.

Current exhibits in the Interpretive Center have presented:

- The history of the towns that once occupied the area.
- A timeline of significant events at the Weldon Spring Site from 1900 to the present.
- The legacy of the Weldon Spring Ordnance Plant and Uranium Feed Material Plant and the manufacturing wastes.
- The events and community efforts to clean up the site, and the people that made it happen.
- The multifaceted phases of the Weldon Spring Site Remedial Action Project.

The Interpretive Center's hours of operation are posted at the site. The current hours of operation are:

- Monday through Friday: 9 a.m. to 5 p.m.
- Saturday: 10 a.m. to 4 p.m. (10 a.m. to 2 p.m. November 1 through March 31).
- Sunday: Noon to 4 p.m.

The Interpretive Center is closed on federal holidays.

Attendance is tracked (Table 9) through the following types of public activities:

- Individuals who walk into the Interpretive Center during normal hours of operation.
- Scheduled groups that participate in Interpretive Center educational programs.
- Community-based organizations that use the Paul T. Mydler and Howell-Hamburg meeting rooms to conduct business meetings.
- Community-based groups that host public events onsite, using the building and resources.
- Scheduled groups that cannot visit the site but receive Interpretive Center outreach presentations.
- Attendees of programs and presentation provided during various school and community events.

A significant number of individuals also use site features for recreation and education (e.g., the Hamburg Trail, the disposal cell perimeter road, the disposal cell viewing platform, the Native Plant Education Garden); however, because this use does not involve entering the Interpretive Center and is often outside of normal hours of operation, it is not consistently tracked.

Attendance at the Interpretive Center has been steadily increasing (Table 9). School and youth groups ranging from prekindergarten through collegiate levels continue to have significant interest in Interpretive Center programs. Field trips are usually scheduled at least several months in advance, and available calendar dates fill up quickly. At times, this requires reservations to be made for the following school year. School groups usually spend 1 to 3 hours at the site in the exhibit gallery, in programming, and on the disposal cell trail. Outreach programming is provided for schools that cannot send students to the site due to funding or distance. Outreach activities usually involve one program provided to multiple classrooms in the grade level.

The attendance was adversely affected in 2013 during the government shutdown and when the facility was shut down following tornado damage. Attendance also decreased in 2019 during construction of the new building. The Interpretive Center closed in March 2020 as a public safety response to the coronavirus pandemic.

On September 12, 2015, the Weldon Spring Site teamed with the Missouri Pollinator Network (formerly Missourians for Monarchs) to cohost the first Monarch Madness special event. The event was also supported with volunteers and funding by the Missouri Master Naturalists, MDC, and Great Rivers Greenway. Attendance at the event included 550 visitors from the public and 60 volunteers and exhibitors. The event hosted pollinator identification activities, kids’ crafts, hikes to the top of the disposal cell, hikes through the prairie, native plant sales, and even making muddy, native seed bombs for families to plant at home. The most popular activity of the event was to catch and tag live monarch butterflies as part of an international research project. An incredible 43 monarchs were captured and tagged during the event, all to fly off and continue their 3000-mile journey to the mountains of central Mexico. A primary purpose of the event was to empower visitors to support pollinators. Monarch Madness was held at the Weldon Spring Site in 2016–2018. The event was cancelled in 2019 because of construction and again in 2020 because of the pandemic-related closure, which began on March 16, 2020.

Table 9. Interpretive Center Attendance

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2002								301	224	190	40	31	786
2003	6	44	44	85	174	191	161	233	251	350	125	122	1786
2004	52	61	166	182	104	324	192	353	379	850	556	354	3573
2005	123	605	1056	2048	1888	1408	1370	1091	1511	1663	1739	903	15,405
2006	542	1136	1595	1874	1685	1226	1465	1431	1176	2215	1735	692	16,772
2007	1157	1022	2786	2479	2192	1960	1703	1129	1843	2811	1569	882	21,524
2008	1132	1445	2261	3086	2489	1734	1556	1395	2412	2624	1705	1142	22,981
2009	1418	1987	3183	2181	2036	1928	1299	1492	2591	2857	1522	1106	23,600
2010	1440	1441	2465	2378	2968	2002	1904	1117	2615	2696	2396	1534	24,956
2011	1631	1958	2593	3036	2938	2182	1441	1165	2455	2848	2087	2111	26,445
2012	1986	1687	2556	2663	2025	2107	1085	1787	2150	2041	1771	1360	23,218
2013	1663	1581	1871	2471	2209	1205	1201	1197	2207	1057	1981	1207	19,850
2014	1168	1401	2478	2298	2891	1379	1491	696	2026	3187	1951	1056	22,022
2015	1491	1746	2524	3592	2169	1308	934	1099	3417	5403	1747	1649	27,079
2016	1355	1791	2663	4367	1994	2329	1196	1076	1494	3000	1748	1191	24,204
2017	1201	1980	2086	3998	2031	2265	1085	1797	1682	3086	1575	1068	23,854
2018	1657	1907	2184	3047	1784	2061	1102	1041	2491	3504	1448	1316	23,560
2019	1713	1275	1803	3428	1887	1279	904	912	1571	3995	1286	790	20,843
2020	1436	2032	972	0	0	0	0	0	0	23	0	0	4463
													346,921

LM is an important contributor to pollinator restoration. In May of 2015, the White House released a Pollinator Research Action Plan, which outlined several efforts to support and restore pollinator populations on public lands and through public and private partnerships. Specifically, the plan calls for increasing monarch butterfly populations to 225 million butterflies, a significant increase from the current 60 million butterflies. DOE lands, like the Weldon Spring Site, are crucial success stories in conversion of lands from World War II- and Cold War-era activities and factories to native habitat.

On May 9, 2019, LM and the U.S. Army Corps of Engineers (USACE) St. Louis District celebrated the start of construction of a new Interpretive Center and administrative office space at the Weldon Spring Site. The design of the new Interpretive Center adheres to the Guiding Principles for Sustainable Federal Buildings established by EPA in 2006; these principles promote energy optimization, improved water conservation, enhanced use of natural daylight, and compliance with many other ecologically conscious standards. In the spirit of an ongoing commitment to stewardship, even the materials used to build the new Interpretive Center have been chosen to reduce their environmental impact. The exhibit gallery planning took a new thematic approach to better express Weldon Spring Site's history and sustained use to a wider audience. Exhibit design and interpretive methods are also more effective and contemporary than those used at the current center. The new Interpretive Center will have more meeting room space to accommodate more student groups; this permits more science, technology, engineering, and mathematics (STEM) learning and information sharing about environmental stewardship and provides additional meeting space for community groups. The new Weldon Spring Site Interpretive Center is scheduled to open in 2021.

On October 3, 2020 (during the Interpretive Center closure), the Weldon Spring Site Interpretive Center staff provided virtual programming on rock and rock collecting for the Girl Scouts of Eastern Missouri’s annual Roundup, which was a virtual event. This resulted in the 23 attendees included in Table 9 for October 2020.

On October 28, 2020, EPA awarded the 2020 Federal Facility Excellence in Site Reuse Award to the Weldon Spring Site. This award recognizes noteworthy restoration and reuse of federal facility sites through innovative thinking and cooperation among federal agencies, states, tribes, local partners, and developers.

Since opening in 2001, the Interpretive Center has served more than 346,000 visitors, program attendees, meeting room users, and event attendees. Interpretive Center staff engage with students throughout the school year, providing innovative STEM educational programs. As an additional service to the community, meeting room space is made available to groups, including naturalists, hobbyists, crafters, special interest and civic groups, trail users, and many others.

Howell Prairie/Native Plant Education Garden

The 150 acres surrounding the disposal cell have been planted with over 80 species of native prairie grasses and wildflowers. Plants such as prairie blazing star, little bluestem, and wild bergamot will once again dominate this area, which was a large native prairie before European settlement. Howell Prairie is one of the largest plantings of its kind in the St. Louis metropolitan area. Prairie maintenance included spot-spraying individual small trees and *Sericea lespedeza* plants with herbicide as part of ongoing efforts to reduce numbers and control the encroachment of invasive weed and woody tree species throughout the prairie area. In mid-December 2017, approximately 65 acres of the prairie were burned under controlled conditions over the course of 2 days, and in mid-March 2018, approximately 72 acres were burned under controlled conditions.

A garden of plants native to Missouri was designed and constructed to surround the Interpretive Center and build awareness about the Weldon Spring Site. Garden maintenance consisting of manual weeding and occasional irrigation was performed throughout the growing season. Corn gluten, a cereal industry byproduct with preemergent herbicide qualities, was broadcast on garden beds throughout the spring to assist in weed control efforts and act as an organic fertilizer. Dried seed heads from forbs were harvested and utilized for hand overseeding in the prairie area. Locations in the prairie with erosion and less plant establishment were targeted.

Erosion

Erosion channels within the entire prairie have been mapped with GPS annually since 2007. It has been noted during recent inspections that the erosion and plant growth conditions in the erosion areas have improved over conditions of past years and are not considered an issue at this time.

Institutional Controls

ICs for the CPOU are discussed in Section 5.1.1.5.

Aerial Lidar Survey

Aerial surveys are required by the LTS&M Plan to be performed in conjunction with the CERCLA FYRs. The survey is required to be conducted with a vertical resolution no less precise than 0.5 ft and map and survey data to be produced with the cell surface represented by 1 ft contour intervals. The data are reviewed for indications of possible settlement. The first survey was performed in 2003 as a baseline, and subsequent surveys were performed in 2005, 2010, 2014, and 2020 in conjunction with the CERCLA FYRs. Flights were also flown in November 2016 and November 2018 in conjunction with the annual inspections. DOE decided that starting with the 2016 inspection aerial light detection and ranging (lidar) surveys would be flown every 2 years (at least initially) to replace walking transects on the disposal cell. This plan was discussed and agreed upon with EPA and MDNR during the 2015 annual inspection. Results of visually delineating surface anomalies on the disposal cell transect walk had historically been subjective and had not added quantitative value. The lidar survey is more objective and supported by technological data; its use also reduces hazards to personnel performing the disposal cell inspection.

An aerial survey of the disposal cell was flown in January 2020 (Figure 5). This aerial survey utilized the lidar technology. Six-inch contours were generated from the lidar survey. The previous surveys generated 1 ft contours using photogrammetric methods. The results show that no settlement is occurring on the disposal cell.

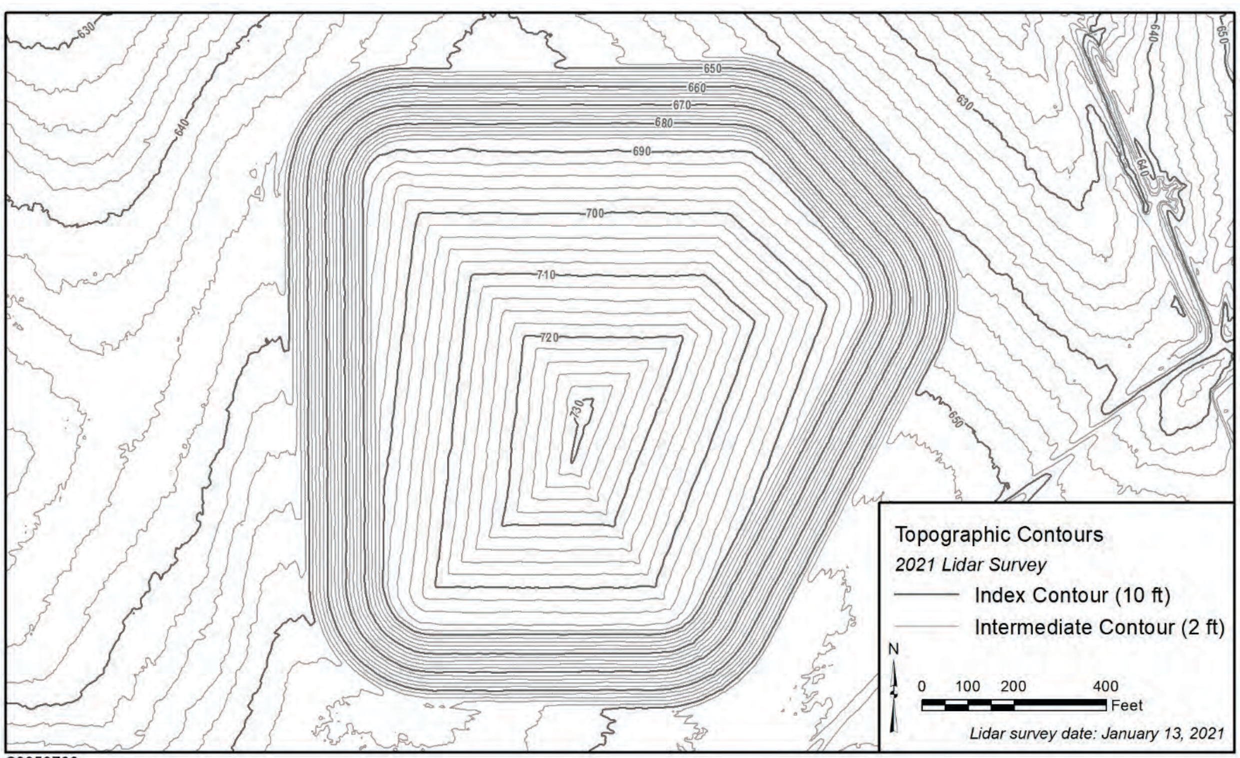

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Figure 5. Lidar Aerial Survey

Other Monitoring and Maintenance Activities

Other monitoring and maintenance activities for the CPOU include disposal cell monitoring and the collection and monitoring of the leachate, which are both previously discussed in this section.

2.3.2 Groundwater Operable Unit

2.3.2.1 GWOU Remedy Selection

In 1993, it was decided to prepare separate environmental documentation regarding remediation of groundwater beneath the Chemical Plant site. Prior to that decision, the groundwater was being addressed as part of the CPOU. It also was decided then that DOE and the Army would work jointly to address the groundwater issues for both sites. The remedial investigation was conducted in 1995 and included a joint sampling effort by DOE and the Army of all wells in the Chemical Plant and Ordnance Works areas. The *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1997a) and the *Baseline Risk Assessment for the Groundwater Operable Units at the Chemical Plant Area and Ordnance Works Area, Weldon Spring, Missouri* (DOE 1997c) were finalized in July 1997. The contaminants of potential concern were identified as nitrate, sulfate, chloride, lithium, molybdenum, nitroaromatic compounds, uranium, trichloroethene (TCE), and 1,2-dichloroethene (DCE). The RI report concluded that contamination in groundwater is generally confined to the shallow, weathered portion of the uppermost bedrock unit, the Burlington-Keokuk Limestone.

The *Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area at the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998c) was initiated in 1997. This study evaluated potential options for addressing groundwater contamination at both sites. The preferred alternative was long-term monitoring of groundwater in conjunction with in situ treatment of portions of the shallow aquifer impacted by TCE. In 1998, a long-term pumping test was performed at the Chemical Plant to evaluate potential groundwater remediation methods for TCE-contaminated groundwater. Results indicated that the transmissivity of the aquifer in the area of TCE impact was higher than expected; however, due to the geology in the area, dewatering of the aquifer occurred. Evaluation of conventional pump-and-treat technologies indicated that this would not be the most effective method for possible remediation of this area. These data were evaluated in the *Supplemental Feasibility Study for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1999c) and utilized in preparation of the *Proposed Plan for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1999d).

DOE proposed active remediation of the TCE-impacted groundwater at the Chemical Plant site as presented in the proposed plan and to conduct further field studies to reexamine the effectiveness and practicability of further active remediation for the remaining COCs. An interim ROD related to the remediation for TCE-contaminated groundwater at the Chemical Plant site was signed by DOE and EPA on September 29, 2000. This *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon*

Spring Site (DOE 2000a), also called the Interim ROD, authorized treatment of TCE in groundwater utilizing in situ chemical oxidation (ICO) methods.

In 2003, the document *Supporting Evaluation for the Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2003c) was prepared in conjunction with the *Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2003d). The purpose of the Supporting Evaluation was to reevaluate the feasibility of groundwater removal, in situ ICO, and monitored natural attenuation (MNA) technologies and options on the basis of recent information collected from the ICO pilot-phase treatment and the additional groundwater field studies.

The *Record of Decision for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2004a) was signed by DOE in January 2004 and by EPA on February 20, 2004. The selected remedy of MNA with ICs to limit groundwater use during the period of remediation addresses the cleanup of all COCs in groundwater and springs at the Chemical Plant Area. MNA relies on the effectiveness of naturally occurring processes to reduce contaminant concentrations over time. The GWOU ROD establishes remedial goals and performance standards for MNA. The selected remedy also serves as a change to the Interim ROD, which addressed TCE groundwater contamination. In situ treatment of TCE did not perform adequately in the field, and MNA is now considered the appropriate final remedy for TCE as well as the other groundwater contaminants.

The GWOU remedy and status is further described in Section 4.2.

The RAO listed in the GWOU ROD is to restore contaminated groundwater in the shallow aquifer to its beneficial use by attaining the cleanup standards. Sections 2.3.2.2 and 5.2.2.3 update the status of attaining this RAO. COC information is included in Section 2.0.

2.3.2.2 GWOU Remedy Implementation

In July 2004, DOE initiated monitoring for MNA as outlined in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004d). This network was modified as presented in the *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site* (DOE 2005c) and is described below.

Monitoring Program

The objectives specified in the GWOU ROD (DOE 2004a) for the MNA monitoring network are as follows:

- Objective 1 is to monitor the unimpacted water quality at upgradient locations in order to maintain a baseline of naturally occurring constituents from which to evaluate changes in downgradient locations. This objective will be met by using wells upgradient of the contaminant plume.
- Objective 2 is to verify that contaminant concentrations are declining with time at a rate and in a manner that cleanup standards will be met in approximately 100 years as established by predictive modeling. This objective will be met using wells at or near the locations with the highest concentrations of contaminants, both near the former source areas and along

expected migration pathways. The objective will be to evaluate the most contaminated zones. Long-term trend analysis will be performed to confirm downward trends in contaminant concentrations over time. Performance will be gauged against long-term trends. It is anticipated that some locations could show temporary upward trends due to the recent source control remediation, ongoing dispersion, seasonal fluctuations, analytical variability, or other factors. However, concentrations are not expected to exceed historical maximums.

- Objective 3 is to ensure that lateral migration remains confined to the current area of impact. Contaminants are expected to continue to disperse within known preferential flow paths associated with bedrock lows (paleochannels) in the upper Burlington-Keokuk Limestone and become more dilute over time as rain events continue to recharge the area. This objective will be met by monitoring various downgradient fringe locations that either are not impacted or are minimally impacted. Contaminant impacts in these locations are expected to remain minimal or nonexistent.
- Objective 4 is to monitor locations underlying the impacted groundwater system to confirm that there is no significant vertical migration of contaminants. This will be evaluated using deeper wells screened and influenced by the unweathered zone. No significant impacts at these locations should be observed.
- Objective 5 is to monitor contaminant levels at the impacted springs that are the only potential points of exposure under current land use conditions. The springs discharge groundwater that includes contaminated groundwater originating at the Chemical Plant area. Presently, contaminant concentrations at these locations are protective of human health and the environment under current recreational land uses. Continued improvement of the water quality in the affected springs should be observed.
- Objective 6 is to monitor for hydrologic conditions at the site over time in order to identify any changes in groundwater flow that might affect the protectiveness of the selected remedy. The static groundwater elevation of the monitoring network will be measured to establish that groundwater flow is not changing significantly and resulting in changes in contaminant migration.

The monitoring network is designed to collect data to either show that natural attenuation processes are acting as predicted or trigger the implementation of contingencies when these processes are not acting as predicted (i.e., unexpected expansion of the plume or sustained increases in concentrations within the area of impact). The data analysis and interpretation will satisfy the following:

- Baseline conditions (Objective 1) have remained unchanged
- Performance monitoring locations (Objective 2) indicate that concentrations within the area of impact are decreasing or remaining stable, as expected
- Detection monitoring locations (Objectives 3, 4, and 5) indicate when a trigger has been exceeded, indicating unacceptable expansion of the area of impact
- Hydrogeologic monitoring locations (Objectives 1, 2, 3, 4, and 6) indicate any changes in groundwater flow that might affect the protectiveness of the MNA remedy at the site over time

The guidance documents *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks Sites* (EPA 1999) and the *Technical Guidance for the*

Long-Term Monitoring of Natural Attenuation Remedies at Department of Energy Sites (DOE 1999b) were used during the development of this monitoring program. The guidance documents *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water* (EPA 2010) and *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites* (EPA 2015b) were used during this five-year review process.

The monitoring network consists of wells screened in the weathered and unweathered units of the Burlington-Keokuk Formation and surface water locations (springs, ponds, and streams). The subset of locations that evaluate the MNA remedy and the objectives they satisfy are summarized in Table 10 and are depicted in Figure 6. As many as 20 additional wells and surface locations are sampled each year to support the site conceptual model and to address the uranium contamination identified in the unweathered unit near the Raffinate Pits. COCs for groundwater and springs in the Chemical Plant area are TCE, nitrate, uranium, and nitroaromatic compounds. The set of COCs measured for each of the monitoring locations presented in Table 10 depends on the proximity of the particular well or spring to the contaminant plumes.

Baseline Concentrations and Data Evaluation

The report *Baseline Concentrations of the Chemical Plant Groundwater Operable Unit Monitored Natural Attenuation Network at the Weldon Spring Site* (DOE 2008b), hereafter called the Baseline Concentrations Report, was updated and revised in July 2008. The primary objective of the report was to evaluate monitoring data collected from the baseline monitoring period of July 2006 through May 2008 to establish baseline concentrations for the COCs for each well and spring in the MNA network. Baseline monitoring was performed as outlined in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004d) to acquire a comprehensive set of data to reevaluate the MNA remediation time frames developed in 2002 during the remedial design phase of the GWOU and assess the long-term monitoring program. Also, this report presented the methodology for review and evaluation of future MNA data. Contingency actions associated with upward trends and trigger exceedances are outlined in the LTS&M Plan and were developed in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004d).

The initial modeling to evaluate remediation time frames using MNA was performed in 2002 and is documented in the *Supporting Evaluation for the Proposed Plan for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2003c). It was estimated that the desired concentrations of COCs in groundwater could be attained within 100 years. A comparison of the initial concentrations used in 2002 and the baseline concentrations indicates that the values were relatively similar for most of the COCs. A review of the contaminant distribution in the shallow groundwater at the Chemical Plant from 2002 and the baseline period (2004–2006) shows that the areal distribution of the COCs is essentially unchanged. The modeling performed in 2002 to evaluate MNA was not revised, and the projected cleanup times resulting from that earlier evaluation were considered applicable. The projected cleanup time for most contaminants in the GWOU is less than 100 years. The exception is the stable uranium concentrations in the unweathered bedrock in the former Raffinate Pits area that have not begun to decrease. Until the stable trend begins to decrease, it is not possible to project a cleanup time for this area.

Table 10. Monitoring Locations Retained for MNA Monitoring for the GWOU

Location	Objective	Unit	TCE	Nitrate	Uranium	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB
MW-2017	1	Weathered				✓	✓	✓	✓	✓
MW-2035	1	Weathered	✓	✓	✓			✓		
MW-4022	1	Unweathered		✓	✓					
MW-4023	1	Weathered		✓	✓					
MW-2012	2	Weathered				✓	✓	✓	✓	✓
MW-2014	2	Weathered						✓	✓	
MW-2038	2	Weathered		✓				✓		
MW-2040	2	Weathered		✓						
MW-2046	2	Weathered					✓			
MW-2050	2	Weathered						✓	✓	
MW-2052	2	Weathered						✓	✓	
MW-2053	2	Weathered					✓	✓	✓	
MW-2054	2	Weathered						✓	✓	
MW-3003	2	Weathered		✓	✓					
MW-3024	2	Unweathered			✓					
MW-3026	2	Unweathered								
MW-3030	2	Weathered	✓		✓			✓		
MW-3034	2	Weathered	✓	✓				✓		
MW-3039	2	Weathered						✓		
MW-3040	2	Unweathered		✓	✓					
MW-4013	2	Weathered		✓						
MW-4029	2	Weathered	✓	✓						
MW-4031	2	Weathered		✓						
MW-4040	2	Unweathered		✓	✓					
MW-2032	3	Weathered				✓	✓	✓	✓	✓
MW-2051	3	Weathered				✓	✓	✓	✓	✓
MW-3037	3	Weathered	✓		✓			✓		
MW-4013	3	Weathered						✓	✓	✓
MW-4014	3	Weathered		✓		✓	✓	✓	✓	✓
MW-4015	3	Weathered						✓	✓	✓

Table 10. Monitoring Locations Retained for MNA Monitoring for the GWO (continued)

Location	Objective	Unit	TCE	Nitrate	Uranium	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB
MW-4026	3	Alluvium/SED			✓					
MW-4036	3	Weathered	✓	✓	✓					
MW-4039	3	Weathered				✓	✓	✓	✓	✓
MW-4040	3	Unweathered	✓					✓		
MW-4041	3	Weathered	✓	✓	✓	✓	✓	✓	✓	✓
MWS-1	3	Weathered	✓	✓	✓			✓		
MWS-4	3	Weathered	✓	✓	✓					
MW-2021	4	Unweathered		✓						
MW-2022	4	Unweathered				✓	✓			
MW-2023	4	Unweathered				✓	✓	✓	✓	✓
MW-2056	4	Unweathered				✓	✓	✓	✓	✓
MW-3006	4	Unweathered	✓	✓	✓			✓		
MW-4007	4	Unweathered	✓	✓						
MW-4042	4	Unweathered		✓	✓					
MW-4043	4	Unweathered	✓	✓	✓		✓	✓		✓
MWD-2	4	Unweathered		✓	✓					
SP-5303	5	Spring/SED			✓					
SP-5304	5	Spring/SED			✓					
SP-6301	5	Spring	✓	✓	✓	✓	✓	✓	✓	✓
SP-6303	5	Spring	✓	✓	✓	✓	✓	✓	✓	✓
SW-2007	5	Stream			✓					

Notes:
Objective 1 = Upgradient locations.
Objective 2 = Area of groundwater impact.
Objective 3 = Downgradient and lateral locations.
Objective 4 = Locations beneath the area of groundwater impact.
Objective 5 = Springs or surface water locations.
Note that wells MW-4013 and MW-4040 have different objectives for different analytes.

Abbreviations:
DNB = dinitrobenzene
NB = nitrobenzene
SED = Southeast Drainage

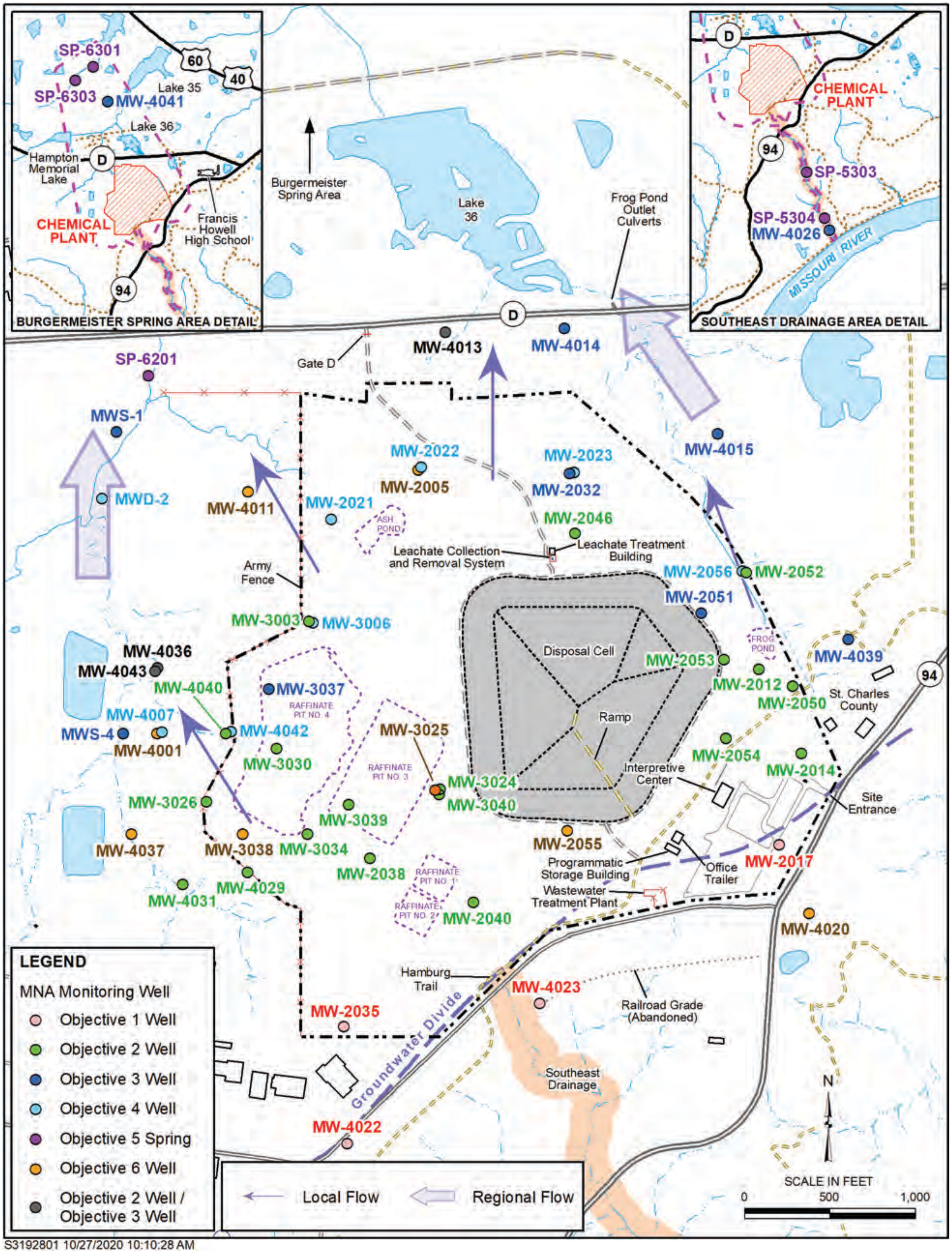


Figure 6. GWOU MNA Monitoring Locations

The monitoring network was designed to provide data to show that natural attenuation processes are acting as predicted or to trigger the implementation of contingencies. Methods to review and interpret data that will satisfy the monitoring objectives were defined in the revised Baseline Concentrations Report (DOE 2008b). Performance of the MNA remedy will be gauged against long-term trends in the Objective 2 wells and the continuation of low contaminant levels at Objective 3 and 4 locations. This progress is reviewed on a regular basis and documented every 5 years in conjunction with the CERCLA FYR. This review includes trending analysis for the past 5 years of data at performance monitoring locations.

Uranium Concentrations in the Unweathered Bedrock

Uranium levels in three impacted area unweathered unit wells (MW-4040, MW-3040, and MW3024) currently exceed the uranium fixed trigger level for Objective 2 wells. In response to the persistent elevated uranium levels at wells MW-4040 and MW-3024/MW-3040 the wells were reclassified from Objective 4 wells to Objective 2 (impacted area) wells in the 2005 Interim Remedial Action Report (DOE 2005c). The change in objectives was included in the LTS&M Plan. Uranium levels in these wells initially demonstrated a gradual increasing trend after installation but have since been stable for the last 7 to 12 years. A 2-year special study conducted from February 2012 to February 2014 (DOE 2014) evaluated historical data along with data collected at an increased frequency during the special study sampling period to establish an MNA monitoring program for the unweathered bedrock unit of the Burlington-Keokuk Limestone at the site. The study recommended establishing a separate uranium fixed trigger value for the unweathered unit impacted area (i.e., former source/raffinate pit areas). It was determined that the 100 pCi/L fixed trigger level for uranium in Objective 2 wells was established prematurely, before data from recently installed unweathered unit wells MW-4040 and MW-3040 was available. The stable uranium concentrations in the unweathered unit over the last 7 to 12 years support this recommendation however, both EPA and MDNR have not agreed to this DOE recommended fixed trigger level modification due to concerns with uranium plume delineation within and near the source area.

Sampling frequencies of monitoring network wells were determined to be adequate to detect any significant changes that might occur. The relatively high unweathered unit uranium concentrations will attenuate much more slowly than contamination in the weathered unit. Subsequent to the study, the unweathered unit monitoring network was expanded to include the 16 wells screened in the unweathered unit, advantageously located weathered unit wells, and three downgradient springs in the unweathered unit uranium monitoring network. The inclusion of historically low concentration downgradient wells expands the monitoring network to detect potential future migration in the unweathered unit.

Modification to Sampling Frequencies

As part of the Baseline Concentrations Report (DOE 2008b), an evaluation was performed to determine the appropriateness of the network to fulfill the intended objectives and the adequacy of the sampling frequencies that were initially specified for the MNA monitoring program. The following changes were recommended in the Baseline Concentrations Report and implemented through the LTS&M Plan in 2009:

- Objective 1: Reduced the sampling frequency to annual because concentrations in these upgradient wells were stable

- Objective 2: Maintained semiannual sampling in the Objective 2 wells due to continued variability in the data
- Objective 3: Reduced the sampling frequency to annual because concentrations have been behaving as expected
- Objective 4: Reduced the sampling frequency to annual because concentrations have been behaving as expected
- Objective 5: Increased the sampling frequency to quarterly due to variability in the springs and in some Objective 2 wells

Additional samples are sometimes collected at reduced-frequency sampling locations when results are unexpected, even if they have not exceeded a trigger level.

2.3.2.3 GWOU System Operation and Maintenance

The long-term monitoring and maintenance activities discussed in the CPOU section also apply to the GWOU. This includes the LTS&M Plan (DOE 2008a), inspections, and ICs. Other maintenance activities include maintenance of the wells, which are inspected during each sampling event and maintained regularly. ICs for the GWOU are discussed in Section 5.2.1.5.

2.3.3 Quarry Bulk Waste Operable Unit

2.3.3.1 QBWOU Remedy Selection

The RI/FS process was conducted for the Weldon Spring QBWOU in accordance with the requirements of CERCLA, as amended, to document the proposed management of the Chemical Plant area as an OU for management of the bulk wastes from the Quarry. Documents developed during the RI/FS process included (1) *Remedial Investigation for Quarry Bulk Wastes* (DOE 1989); (2) *Baseline Risk Evaluation for Exposure to Bulk Wastes at the Weldon Spring Quarry* (DOE 1990d); (3) *Feasibility Study for the Management of the Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri* (DOE 1990c); and (4) *Proposed Plan for the Management of Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri* (DOE 1990a).

Remedial activities under the QBWOU were performed under the *Record of Decision for Management of Bulk Wastes at the Weldon Spring Quarry* (QBWOU ROD) (DOE 1990b). The QBWOU ROD was signed by EPA on September 28, 1990, and by DOE on March 7, 1991. The primary components of the remedy established were to:

- Excavate and remove bulk waste (i.e., structural debris, drummed and uncontained waste, process equipment, sludge, soil).
- Transport the waste along a dedicated haul road to the Temporary Storage Area (TSA), which was within the boundary of the CPOU.
- Stage bulk wastes at the TSA for ultimate disposal in the onsite disposal cell.

These components were not specifically referred to as remedial action objectives in the ROD. These components were completed as discussed below.

2.3.3.2 QBWOU Remedy Implementation

Removal of the bulk waste was performed in a multitiered process similar to the one used at the Chemical Plant. In the first tier, the Quarry Water Treatment Plant, which was designed to treat contaminated water from the Quarry sump, was constructed. In the second tier, the basic infrastructure, including decontamination facilities, a haul road, and the utilities needed to excavate and transport the waste from the Quarry to the Chemical Plant, was built. In the final tier, the waste was excavated.

The waste was removed with conventional equipment and excavation techniques, placed in covered trucks, and hauled via the haul road to the TSA at the Chemical Plant. The waste was retained in the TSA until it could be placed in the disposal cell. From May 1993 to October 1995, approximately 144,000 cubic yards of soil and waste material were removed from the Quarry, transported to the Chemical Plant area, and placed in the TSA. All the wastes were directly placed, or treated and placed, in the disposal cell by March 1999.

The QBWOU activities are documented in the *Quarry Bulk Waste Excavation Remedial Action Report* (DOE 1997d). The QBWOU acted as an interim remedial action and the QROU discussed below acted as the final remedial action for the Quarry.

2.3.3.3 QBWOU System Operation and Maintenance

The QROU addresses residual contamination and long-term monitoring and maintenance for the Quarry.

2.3.4 Quarry Residuals Operable Unit

2.3.4.1 QROU Remedy Selection

The QROU was the second of two OUs established for the Quarry Area of the Weldon Spring Site. An RI/FS process was conducted for the QROU in accordance with the requirements of CERCLA, as amended, to document the proposed management of the Quarry proper, the Femme Osage Slough and nearby creeks, and groundwater north of the Femme Osage Slough. Documents developed during the RI/FS process included the following:

- *Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998b)
- *Baseline Risk Assessment for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1997b)
- *Feasibility Study for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998d)
- *Proposed Plan for Remedial Action at the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri* (DOE 1998e)

The QROU remedy was described in the *Record of Decision for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri* (QROU ROD) (DOE 1998a). The QROU addressed residual soil contamination in the Quarry proper, surface water and sediments in the Femme Osage Slough and nearby creeks, and contaminated groundwater.

The primary components of the remedy included:

- Long-term monitoring of groundwater in the Missouri River alluvium to ensure that water quality in the public water supply remains protective of human health and the environment.
- Long-term monitoring of contaminated groundwater north of the Femme Osage Slough until levels are attained that pose a negligible potential impact on the groundwater in the Missouri River alluvium.
- ICs to prevent exposure to the contaminated groundwater north of the Femme Osage Slough.

These components were not specifically referred to as remedial action objectives in the ROD. The components were completed as below.

The long-term monitoring status is discussed in Sections 4.2 and 5.3. The ICs for the QROU are discussed in Section 5.3.1.5.

The selected remedy in the QROU ROD (DOE 1998a) outlined the performance of two field studies to support the decision for long-term monitoring of groundwater and reliance on natural conditions to limit potential migration of uranium south of the slough. These field studies consisted of the installation and operation of an interceptor trench and hydrologic/geochemical sampling within the area of uranium impact to verify the effectiveness of uranium removal by groundwater extraction methods and support the conceptual fate and transport model for the Quarry. The interceptor trench study was performed from 2000 through 2002, and results indicated that modeled prediction for active removal of uranium from groundwater was optimistic and that further evaluation of groundwater treatment was not warranted (DOE 2003b). The result of the hydrologic and geochemical field studies performed from 2000 through 2002 provided a better understanding of the natural geochemistry of the alluvial aquifer north of the slough and led to the inclusion of this area in the ICs for the QROU (DOE 2002a).

Reclamation of the Quarry was completed on September 6, 2002. Backfilling of the Quarry was designed to reduce physical hazards associated with an open Quarry, eliminate the ponding of water, and reduce infiltration of precipitation into the groundwater system. Fill material was placed and compacted to design elevations within the Quarry proper. During backfilling of the Quarry, selected wall and floor fractures were sealed to prevent infiltration of water and reduce the likelihood of later subsidence of the backfill. COC information is discussed in Section 2.1.

2.3.4.2 QROU Remedy Implementation

DOE implemented long-term monitoring at the Quarry in October 2002. Monitoring is conducted in accordance with the *Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit* (DOE 2000b), which was finalized in January 2000. Long-term groundwater monitoring for the QROU consists of two separate programs. The first program details the monitoring of uranium and 2,4-DNT south of the slough to ensure that levels remain protective of human health and the environment. The second program consists of monitoring groundwater contaminant levels within the area north of the slough until a predetermined target level indicating negligible potential to affect groundwater south of the slough is attained.

Groundwater monitoring is necessary to continue to ensure that uranium-contaminated groundwater has a negligible potential to affect the PWSD No. 2 well field. Under current conditions, groundwater north of the slough poses no imminent risk to human health from water obtained from the well field. A target level of 300 pCi/L for uranium (10% of the maximum measured in 1999) was established to represent a significant reduction in the contaminant levels north of the slough. The target level for 2,4-DNT has been set at 0.11 microgram per liter (µg/L), the Missouri Water Quality Standard. Upon attainment of these target levels, it will be determined that the goal for the monitoring program has been met, and the long-term monitoring activities for the QROU will be concluded. Following attainment of the long-term monitoring target levels in groundwater north of the slough, an assessment of the residual risks based on actual groundwater concentrations will be performed to determine the need for future ICs.

To implement the two monitoring objectives, the wells were categorized into monitoring lines (Figure 7). Each line provides specific information relevant to long-term goals at the Quarry:

- The first line of wells (Line 1) monitors the area of impact within the bedrock rim of the Quarry proper. These wells (MW-1002, MW-1004, MW-1005, MW-1027, MW-1030) are sampled to establish trends in contaminant concentrations within the areas of higher impact. Well MW-1012 is monitored as a background location.
- The second line of wells monitors the area of impact within the alluvial materials and shallow bedrock north of the slough. These wells (MW-1006, MW-1007, MW-1008, MW 1009, MW-1013, MW-1014, MW-1015, MW-1016, MW-1028, MW-1031, MW-1032, MW-1045, MW-1046, MW-1047, MW-1048, MW-1049, MW-1051, MW-1052) are also sampled to establish trends in contaminant concentrations within the areas of higher impact and to monitor the oxidizing and reducing environments present within this area.
- The third line of wells monitors the alluvial material directly south of the slough. These wells (MW-1017, MW-1018, MW-1019, MW-1021, MW-1044, MW-1050) have shown no impact from Quarry contaminants and are monitored as the first line of warning for potential migration of uranium south of the slough.
- The fourth line of wells monitors the same portion of the alluvial aquifer that supplies the well field. These wells (RMW-1, RMW-2, RMW-3, RMW-4) are sampled to monitor the groundwater quality of the productive portions of the alluvial aquifer and determine the occurrence of uranium outside the range of natural variation.

The sampling frequency for each location was selected to provide adequate reaction time on the basis of travel times from the residual sources and areas of impact to potential receptors. Monitoring wells on the Quarry rim (Line 1) are sampled semiannually, and wells north of the Femme Osage Slough (Line 2) are sampled quarterly. Locations south of the slough are sampled semiannually (Line 3) or annually (Line 4). All locations in the Quarry Area are sampled for uranium, sulfate, and dissolved iron. A selected group of wells north of the slough are sampled for nitroaromatic compounds. Nitroaromatics have steadily decreased and a reduced sampling frequency is being recommended after calendar year 2021.

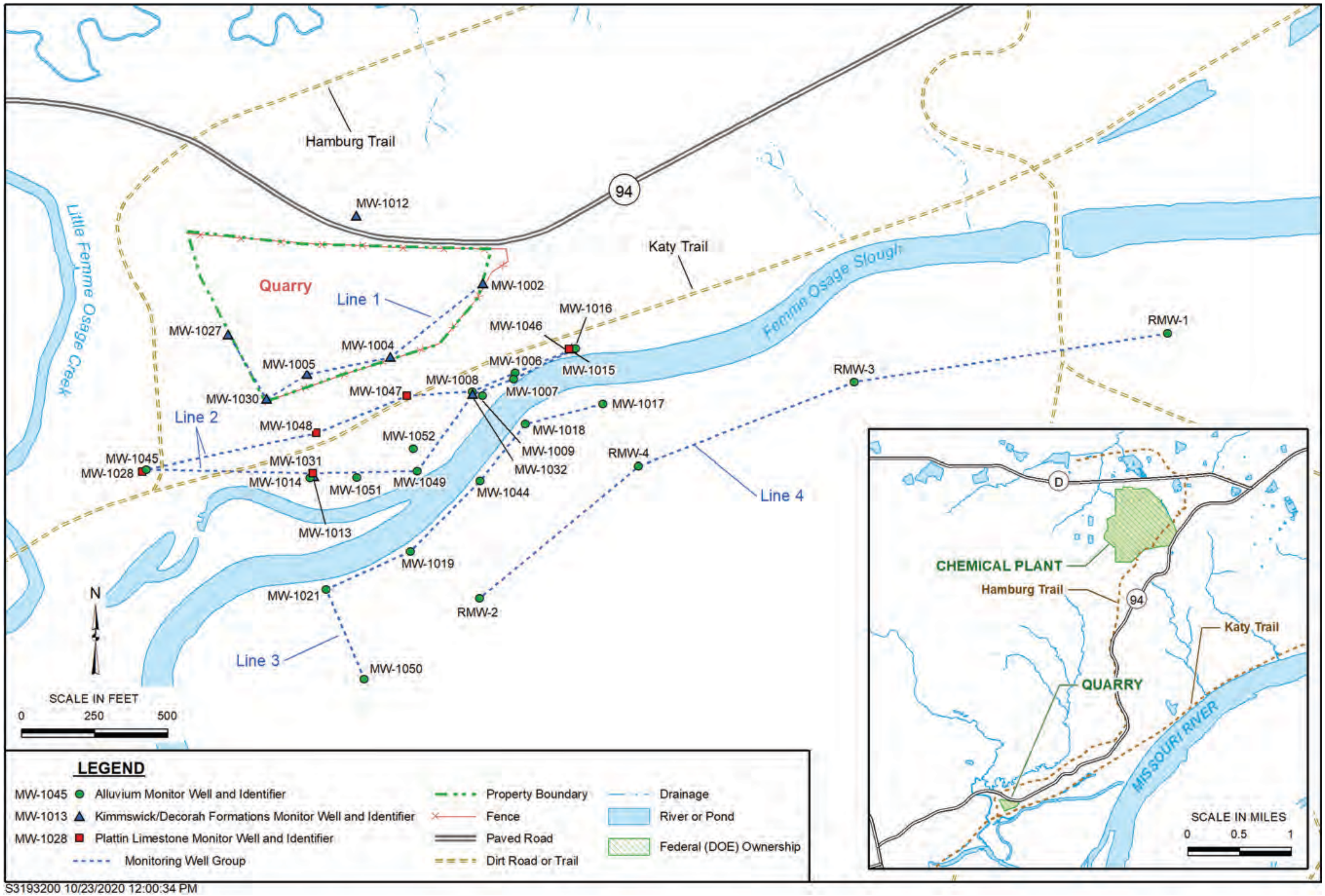


Figure 7. QROU Monitoring Locations

The production wells south of the Quarry Area have had a separate well field monitoring program, initiated in 1989, as a result of cooperative efforts between DOE, St. Charles County, and MDNR. This program is funded by a DOE grant. The well field was originally owned and operated by St. Charles County; however, in 2005 the well field was sold to PWSD No. 2. The monitoring program has been continued by PWSD No. 2 and consists of annual, quarterly, and monthly sampling events of operating production wells, the RMW-series wells, and raw and treated water from the water plant. Results of this monitoring program can be obtained through the PWSD No. 2.

QROU activities are documented in the *Quarry Residuals Operable Unit Interim Remedial Action Report* (DOE 2003a).

2.3.4.3 QROU System Operation and Maintenance

The long-term monitoring and maintenance activities discussed in the CPOU section also apply to the QROU. This includes the LTS&M Plan (DOE 2008a), inspections, and ICs. Other maintenance activities include maintenance of the wells, which are inspected during each sampling event and maintained regularly. ICs for the QROU are discussed in Section 5.3.1.5.

2.3.5 Southeast Drainage

2.3.5.1 Southeast Drainage Remedy Selection

Cleanup for the Southeast Drainage was addressed as a removal action under CERCLA but is administratively considered part of the CPOU along with the other vicinity properties. The EE/CA report (DOE 1996) evaluated options for addressing contaminated soils and sediments in the Southeast Drainage; it recommended that sediment in accessible areas of the drainage should be removed. The excavated materials would be stored temporarily at an onsite storage area until final disposal in the disposal cell.

2.3.5.2 Southeast Drainage Remedy Implementation

The Southeast Drainage is a natural drainage area with intermittent flow that traverses both the Army property and the Weldon Spring Conservation Area from the Chemical Plant site to the Missouri River (Figure 2). Both the Army and AEC used the drainage to discharge water from sanitary and process sewers to the Missouri River. Also, contaminated liquids in the Raffinate Pits were decanted to the plant process sewer and subsequently discharged to the Southeast Drainage; overflow from the Raffinate Pits continued to discharge into the drainage after plant operations ceased. As a result, sediments and soils in the Southeast Drainage were contaminated. Radioactive COCs were uranium-238, radium-226, thorium-232, and thorium-230. Spring water in the Southeast Drainage (Springs SP-5303 and SP-5304) was contaminated with uranium and low concentrations of nitroaromatic compounds from the contaminated sediment.

Soil removal was in two phases: 1997–1998 and in 1999. A total of 1931 cubic yards was excavated in the first phase, and about 22.5 cubic yards was excavated in the second phase.

Postremediation soil sampling was conducted at Southeast Drainage locations after the soil was excavated. The purpose of this sampling was to determine the remaining concentrations of radionuclides within the soil and sediment and to calculate the risk reduction achieved from soil removal. Sampling was conducted in accordance with the *Post-Remediation Sampling Plan for the Southeast Drainage* (DOE 1997e). All postremediation data results were used by Argonne National Laboratory to calculate risk reduction achieved by the removal action.

Complete details of the remediation as well as the postcleanup risk assessment of the Southeast Drainage are in the *Southeast Drainage Closeout Report Vicinity Properties DA-4 and MDC-7* (DOE 1999a).

The Southeast Drainage postcleanup risk assessment is detailed in the above document, which states that the remediation met the postcleanup risk assessment for the hypothetical child. The hypothetical child is based on the future land use scenario that a home would be built in the vicinity of the drainage, allowing a child to access the drainage for use as a play area. The postcleanup risk assessment also states that the results indicate the removal action accomplished the goals presented in the EE/CA report (DOE 1996).

2.3.5.3 Southeast Drainage System Operation and Maintenance

The long-term monitoring and maintenance activities discussed in Section 2.3.1.5 (CPOU) also apply to the Southeast Drainage. This includes the LTS&M Plan, inspections, and ICs. ICs for the Southeast Drainage are discussed in Section 5.1.1.5.

3.0 Progress Since Last Review

This section includes the protectiveness determinations and statements from the last FYR (Table 11) as well as the recommendations from the last FYR and the current status of those recommendations.

Table 11. Protectiveness Determinations/Statement from the 2016 FYR

Operable Unit	Protectiveness Determination	Protectiveness Statement
Chemical Plant	Protective	The remedy that has been implemented at the CPOU is protective of human health and the environment. Contaminant sources are contained in an onsite disposal facility at the Chemical Plant. The environmental monitoring data and annual inspections continue to verify that the disposal cell is functioning as intended. The remedy that has been implemented at the Southeast Drainage is protective of human health and the environment. The remedy consisted of removing contaminated soils and sediment to levels that are protective under the current land use. The drainage has recovered from the removal activities and is stable. ICs are used to maintain appropriate land and resource use and ensure that the remedy remains protective over the long term.
Quarry Bulk Waste	Protective	The remedy for the QBWOU is protective of human health and the environment. The action consisted of excavating the bulk wastes from the Quarry and placing them in controlled temporary storage pending final placement in the onsite disposal cell at the Chemical Plant. Excavating the wastes from the Quarry eliminated the potential for direct contact with the waste material and removed the source of ongoing contaminant migration to groundwater.
Quarry Residuals	Protective	The remedy for the QROU is protective of human health and the environment through long-term monitoring with ICs. The remedy consists of long-term groundwater monitoring and ICs to maintain appropriate land and resource use and ensure that the remedy remains protective over the long-term.
Groundwater	Short-Term Protective	The remedy for the GWOU is currently protective of human health and the environment because exposure pathways that could result in unacceptable risks are being controlled, and ICs are in place to prevent the groundwater from being used in the restricted area. However, for the remedy to be protective in the long-term, additional sampling locations and characterization are needed to demonstrate that the objectives of the MNA remedy can be met.
Sitewide	Short-Term Protective	The FYR found the remedy for the entire site to be currently protective of human health and the environment. However, in order for the remedy to be protective in the long-term, issues will need to be addressed at the GWOU.

For the GWOU, EPA concurred that the remedy is currently protective of human health and environment, but the agency identified an issue that in its opinion may potentially affect the long-term protectiveness. The issue (concern that the MNA remedy for the GWOU is not meeting the objectives, as specified in the 2004 Remedial Design/Remedial Action Work Plan for the GWOU and the 2008 LTS&M Plan for the Site), along with the recommendation to address it, is given in Table 12. The letter from EPA identifying this issue, dated November 23, 2016, and subsequent letters regarding this issue are included in Appendix A.

Also included in Appendix A is a memorandum received from the EPA Center for Environmental Solutions and Emergency Response Groundwater Characterization and Remediation Division, Office of Research and Development (ORD), dated July 21, 2020. The EPA requested the ORD provide an independent technical review of the MNA remedy at the Groundwater Operable Unit, focused on the uranium contamination at the Weldon Spring Site.

The remedy is progressing as originally expected across most of the site. However, persistent elevated uranium concentrations in the upper part of the unweathered unit near the former raffinate pits has shown limited progress. Uranium concentrations are stable in unweathered unit wells MW-3040 and MW-4040 but have yet to begin decreasing. Until concentrations begin to decline, a cleanup time cannot be estimated for the wells in this area. Data from existing downgradient wells and springs suggests that uranium has not migrated far from source areas in the unweathered unit though there is considerable uncertainty due to the limited number of source area and downgradient unweathered unit wells. In 2016, EPA recommend additional characterization of the unweathered unit with the installation of additional monitoring wells to better define the extent of uranium to resolve this issue. Resolution of this issue is still under discussion.

Table 12. Status of Issues from 2016 FYR Identified by EPA

OU	Issue	Recommendations	Current Status	Current Implementation Status Description	Completion Date (if applicable)
GWOU	The MNA remedy for the GWOU is not meeting the objectives, as specified in the 2004 Remedial Design/Remedial Action Work Plan for the GWOU, and the 2008 Long-Term Surveillance and Maintenance Plan for the Site.	Additional sampling locations should be added to the sampling and monitoring program to meet the objectives of the MNA remedy. Additional monitoring and characterization of the uranium impact in the unweathered unit are required to meet the objectives of the MNA remedy.	Under Discussion	Under Discussion	

4.0 Five-Year Review Process

4.1 Community Notification, Involvement and Site Interviews

EPA and MDNR were formally notified that the FYR process had begun in a letter dated September 30, 2020. The letter stated that work on the Weldon Spring Site sixth FYR process was initiated on September 15, 2020. The work at that time consisted of preparing a draft schedule, reviewing guidance, and preparing for the lidar aerial survey. A separate letter, dated October 27, 2020, notified EPA and MDNR that the annual LTS&M inspection was to take place December 1 and 2, 2020. A teleconference was held with EPA and MDNR on December 3, 2020, to discuss the FYR. Participants included Gwen Hooten of DOE; LMS contractor personnel Yvonne Deyo, Rebecca Roberts, and Terri Uhlmeyer; Danny O'Connor of EPA Region 7; and Tiffany Drake and Taylor Grabner of MDNR.

Activities to involve the community in the FYR were initiated in October 2020. DOE sent a letter, dated November 3, 2020, to its distribution list, which includes many members of the public. The information in the letter was also emailed to the Site's two email distribution lists. One list includes anyone who has signed up to receive email notifications about the Site and includes 669 email addresses; the other email list includes educators in the region that DOE keeps updated on Interpretive Center program-related updates and content, and that list includes 2571 email addresses. The letter notified recipients that DOE had initiated the sixth FYR, discussed the purpose of it, and stated that community involvement is an integral part of the process; input or suggestions, via a survey that DOE posted online, were requested. The survey included questions that EPA had suggested for community interviews in the FYR guidance. Appendix B includes a copy of the letter and survey. Three individuals, including the MDNR project manager, responded to the online survey, and their responses are included in Appendix B. During the annual inspection, stakeholder and IC contacts are contacted by email, as part of the FYR process the emails included the survey questions. The emails that responded to the survey questions are also included in Appendix B.

4.2 Data Review

Monitoring data are reviewed quarterly and reported annually in the Site Environmental Reports. Historical water quality and water level data for existing wells and water quality data for surface locations are available on the Geospatial Environmental Mapping System (GEMS) at http://gems.lm.doe.gov in the Groundwater Quality by Location report under the Data tab (after selecting the Weldon Spring, MO, Site). Photographs, maps, and physical features can also be viewed on this website.

The monitoring programs at the Weldon Spring Site include the sampling and analysis of water collected from wells at the Chemical Plant, the Quarry, adjacent properties, and selected springs near the Chemical Plant. The groundwater monitoring programs are formally defined in the LTS&M Plan (DOE 2008a).

Testing for temporal trends was performed on the following datasets using the Mann-Kendall test for the most recent 5 years of data (10/1/2015 to 9/30/2020 or simply 2016 to 2020):

- Uranium, nitrate, TCE, and nitroaromatic compounds for the GWOU using data collected between 2016 and 2020, as required in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004d). Results for the trending analysis are reported for the Objective 2 wells and the Objective 5 springs because these locations monitor the area of groundwater impact and the aquifer discharge points.
- Total uranium and 2,4-DNT data from the Quarry collected between 2016 and 2020. Results for the trending analysis for uranium and 2,4-DNT are reported for wells in Lines 1 and 2 of the Quarry monitoring network, as these wells monitor the area of groundwater impact.

The EPA maximum contaminant level (MCL) for uranium in groundwater is 30 µg/L, which is a mass unit. Uranium data for the Weldon Spring Site have consistently been reported as activity in pCi/L. The activity-to-mass conversion factor that was adopted for the Weldon Spring Site is 680 pCi/mg (equivalent to 0.68 pCi/µg). With this conversion factor, the mass MCL equates to an activity MCL of 20.4 pCi/L, which will be rounded to a more conservative 20 pCi/L. Uranium activities in pCi/L are referred to as concentrations throughout this report.

4.2.1 Groundwater Operable Unit

Contaminated groundwater remains beneath the Chemical Plant. Contaminants include uranium, nitrate, TCE, and nitroaromatic compounds. Contamination in groundwater is generally confined to the shallow, weathered portion of the Burlington-Keokuk Limestone. Some contamination exists in the deeper, unweathered portion of the bedrock, primarily beneath the former Raffinate Pits. The groundwater at the Chemical Plant has been contaminated by past operations that resulted in multiple source areas. Remediation activities have eliminated the primary sources for groundwater contamination beneath the site. The distribution of contaminants in the shallow aquifer is controlled by bedrock topography that influences groundwater flow and several processes, such as transformation, adsorption, desorption, dilution, or dispersion; the primary attenuation mechanisms are dilution and dispersion.

4.2.1.1 Hydrogeologic Description

The Chemical Plant site is in a physiographic transitional area between the Dissected Till Plains of the Central Lowlands province to the north and the Salem Plateau of the Ozark Plateaus province to the south. Subsurface flow and transport in the Chemical Plant area occur primarily in the carbonate bedrock. The unconsolidated surficial materials are clay-rich, mostly glacially derived units, which are generally unsaturated beneath the site. These materials become saturated to the north and influence groundwater flow. The thickness of the unconsolidated materials ranges from 20 to 50 ft (DOE 1992a).

The aquifer of concern beneath the Chemical Plant is the shallow bedrock aquifer within the Mississippian Burlington-Keokuk Limestone (the uppermost bedrock unit) and the underlying Fern Glen Formation (Figure 8). The Burlington-Keokuk Limestone is described as having two different lithologic zones: a shallow, weathered zone and an underlying unweathered zone. The weathered portion of this formation is highly fractured and exhibits solution voids and enlarged fractures. These features may also be present on a limited scale in the unweathered zone, particularly near buried preglacial stream channels (paleochannels). Localized aquifer properties are controlled by fracture spacing, solution voids, and preglacial weathering, including structural troughs along the bedrock–overburden interface. The unweathered portion of the Burlington Keokuk-Limestone is thinly to massively bedded. Fracture densities are significantly lower in the unweathered zone than in the weathered zone. References to the "shallow aquifer" without specifying weathered or unweathered zone refer to the combination of both zones.

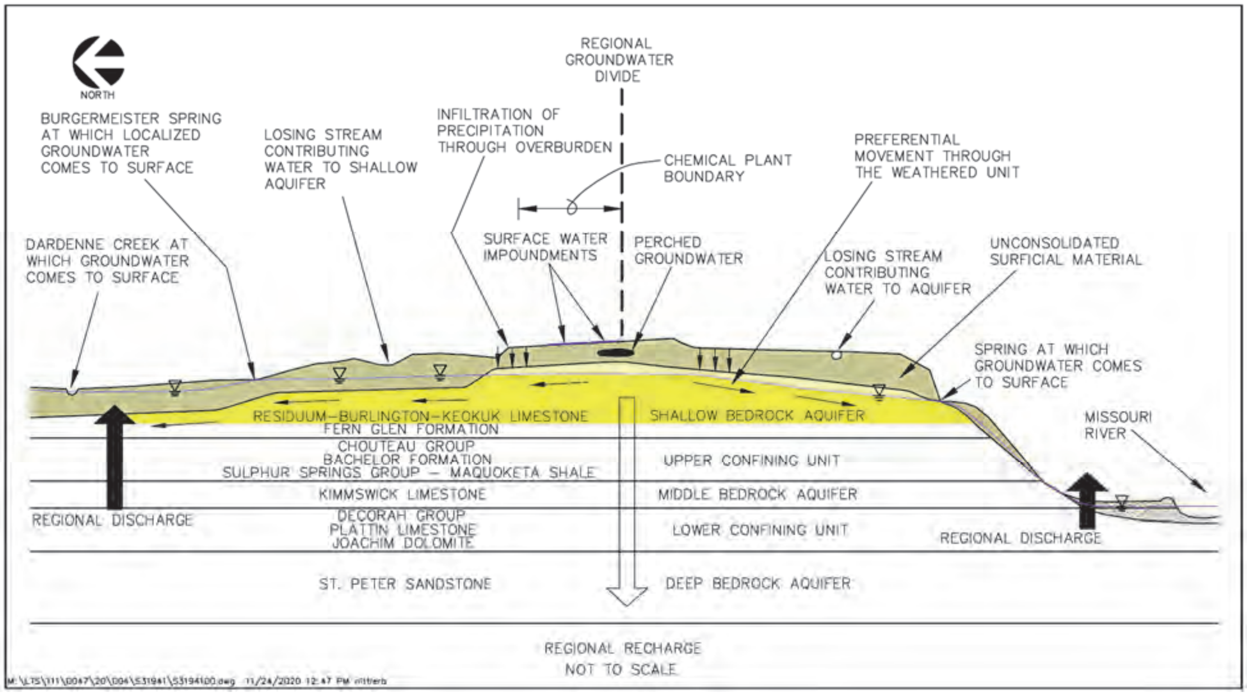


Figure 8. Conceptual Hydrogeologic Cross Section for the Weldon Spring Site

All monitoring wells at the Chemical Plant are completed in the Burlington-Keokuk Limestone. Most of the wells are completed in the weathered zone of the bedrock where groundwater has the greatest potential to be contaminated and to migrate. The highest uranium concentrations at the Chemical Plant occur in monitoring wells screened in the unweathered zone beneath and adjacent to the former raffinate pits (i.e., MW-3024, MW-3026, MW-3040, and MW-4040). MW-3006 and MW-4042 are located north and west, respectively, of former raffinate pit 4 and are screened in deeper portions of the unweathered aquifer to assess vertical migration in those areas. Horizontally downgradient wells in the unweathered unit (MW-4007, MW-2021, MW-2022, and MW-2023) monitor for lateral migration within this zone. Monitoring wells within the boundaries of the Chemical Plant are near historical contaminant sources and preferential flow pathways (paleochannels) to assess the movement of contaminated groundwater in the shallow aquifer. Additional wells are outside the Chemical Plant boundary to monitor for and evaluate the potential for offsite migration of contaminants (Figure 9).

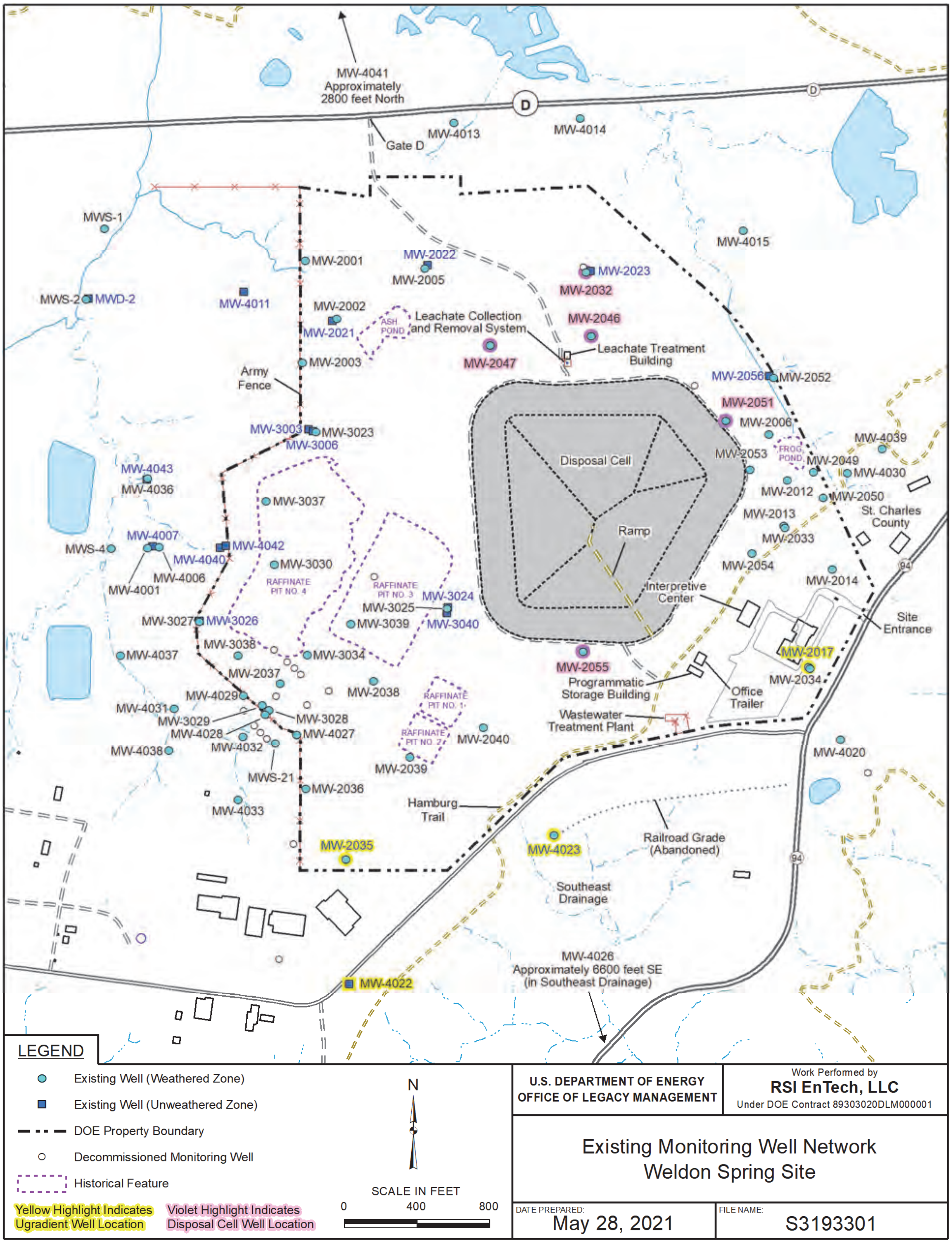


Figure 9. Monitoring Well Network at the Chemical Plant

A groundwater divide along the southern boundary of the site can be seen on potentiometric maps of both the weathered and unweathered units (Figure 10 and Figure 11). Groundwater north of the divide flows north toward Dardenne Creek and ultimately to the Mississippi River, and groundwater south of the divide flows south to the Missouri River. Localized flow is controlled largely by bedrock topography. Groundwater movement is generally by diffuse flow through an equivalent porous media until reaching localized zones of discrete flow through secondary porosity features such as fractures and solution channels. Dashed contours are used on the maps in areas where data are less abundant.

Preferential flow zones (Figure 12) have been inferred from bedrock topography, groundwater surface maps, hydraulic conductivity data, and subsurface tracer results (DOE 2005b). Subsurface data indicate the presence of linear bedrock lows that are likely paleochannels (also referred to as preglacial drainages) in the top of the weathered Burlington-Keokuk Limestone near the northern and western boundaries of the Chemical Plant site. The contact between the weathered and unweathered units is lower, and hydraulic conductivities are typically higher in the paleochannel areas. This provides preferential flow paths that coincide with the northtrending-bedrock lows that are indicated on the groundwater elevation maps of both the weathered (Figure 10) and unweathered (Figure 11) units.

Numerous springs, a common feature in carbonate terrains, are present near the site. Four springs that are monitored routinely (Figure 13) have been historically influenced by Chemical Plant discharge water or groundwater that contained one or more of the COCs. The springs occur where surface water features intercept the water table within the weathered bedrock aquifer.

The presence of elevated total uranium and nitrate at Burgermeister Spring (SP 6301) 1.2 miles north of the site, which is beyond downgradient monitoring wells with background levels, indicates that discrete subsurface flow paths are present near the site. Groundwater tracer tests performed in 1995 (DOE 1997a) confirmed that a discrete and rapid subsurface hydraulic connection exists between the northern portion of the Chemical Plant and Burgermeister Spring. These flow paths are associated with the paleochannels present beneath the site.

4.2.1.2 Chemical Plant Hydrogeologic Data Analysis

Groundwater flow at the site is monitored using water elevations in all MNA network wells (Objectives 1, 2, 3, and 4 wells; see description of objectives in Section 4.2.1.5) and additional wells (Objective 6 wells) that were selected to provide adequate coverage to identify changes in groundwater flow that might affect the protectiveness of the remedy. Groundwater levels in monitoring network wells are measured quarterly to evaluate site groundwater flow directions at different times of the year. This allows the variability in flow directions to be monitored and the adequacy of the network to be assessed for shifts in potential contaminant migration.

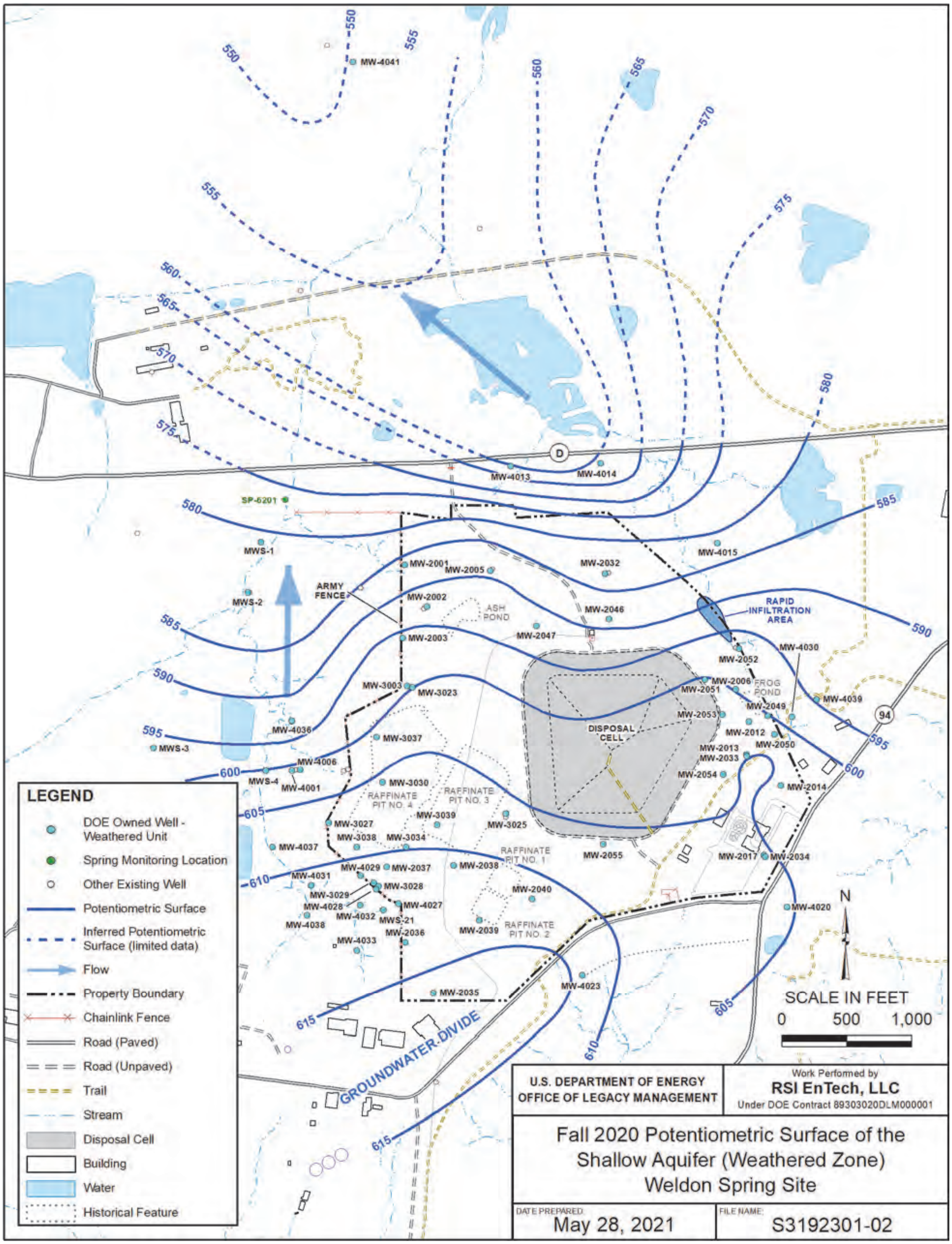


Figure 10. Weathered Unit Groundwater Surface at the Weldon Spring Former Chemical Plant (Fall 2020)

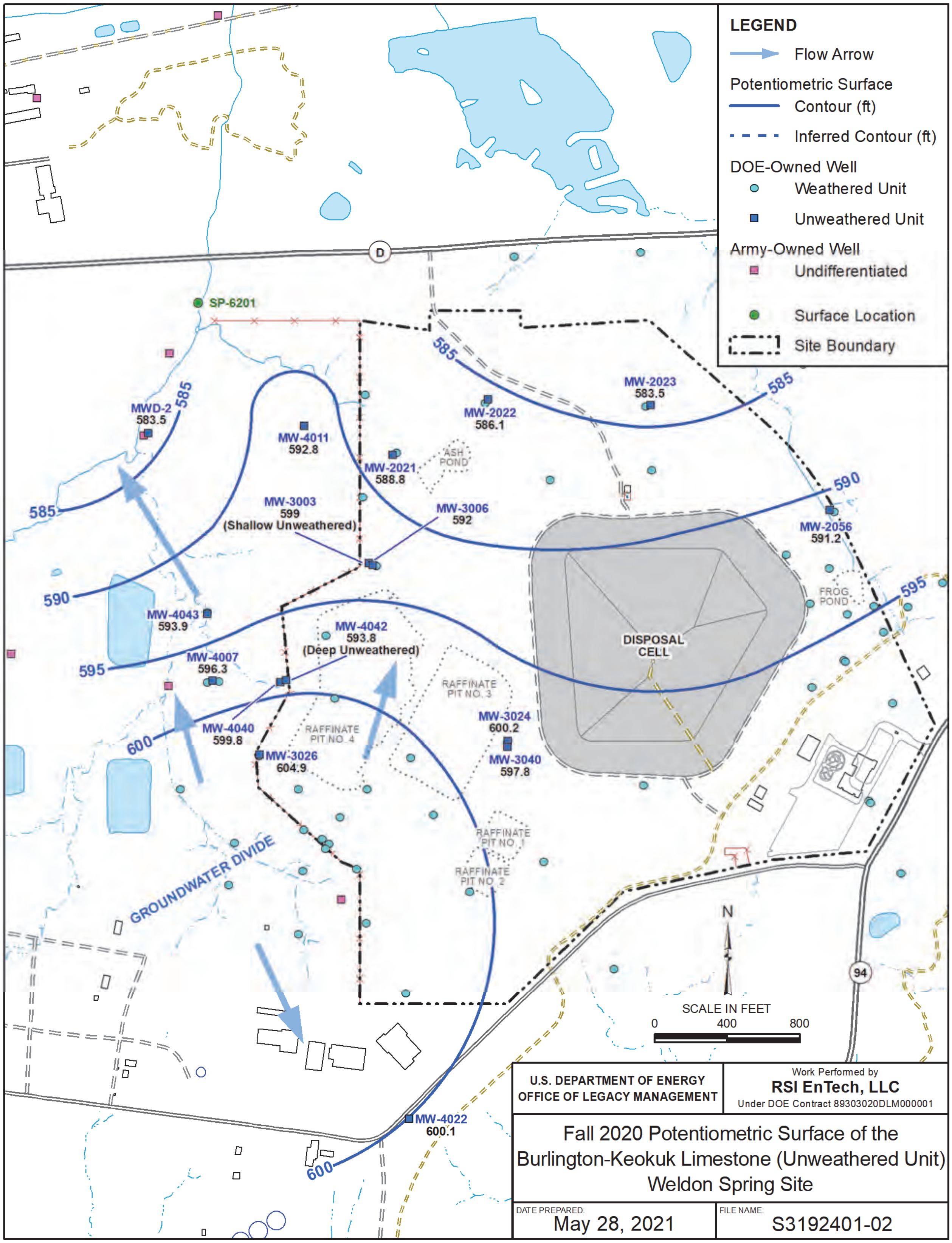


Figure 11. Unweathered Unit Groundwater Surface at the Weldon Spring Former Chemical Plant (Fall 2020)

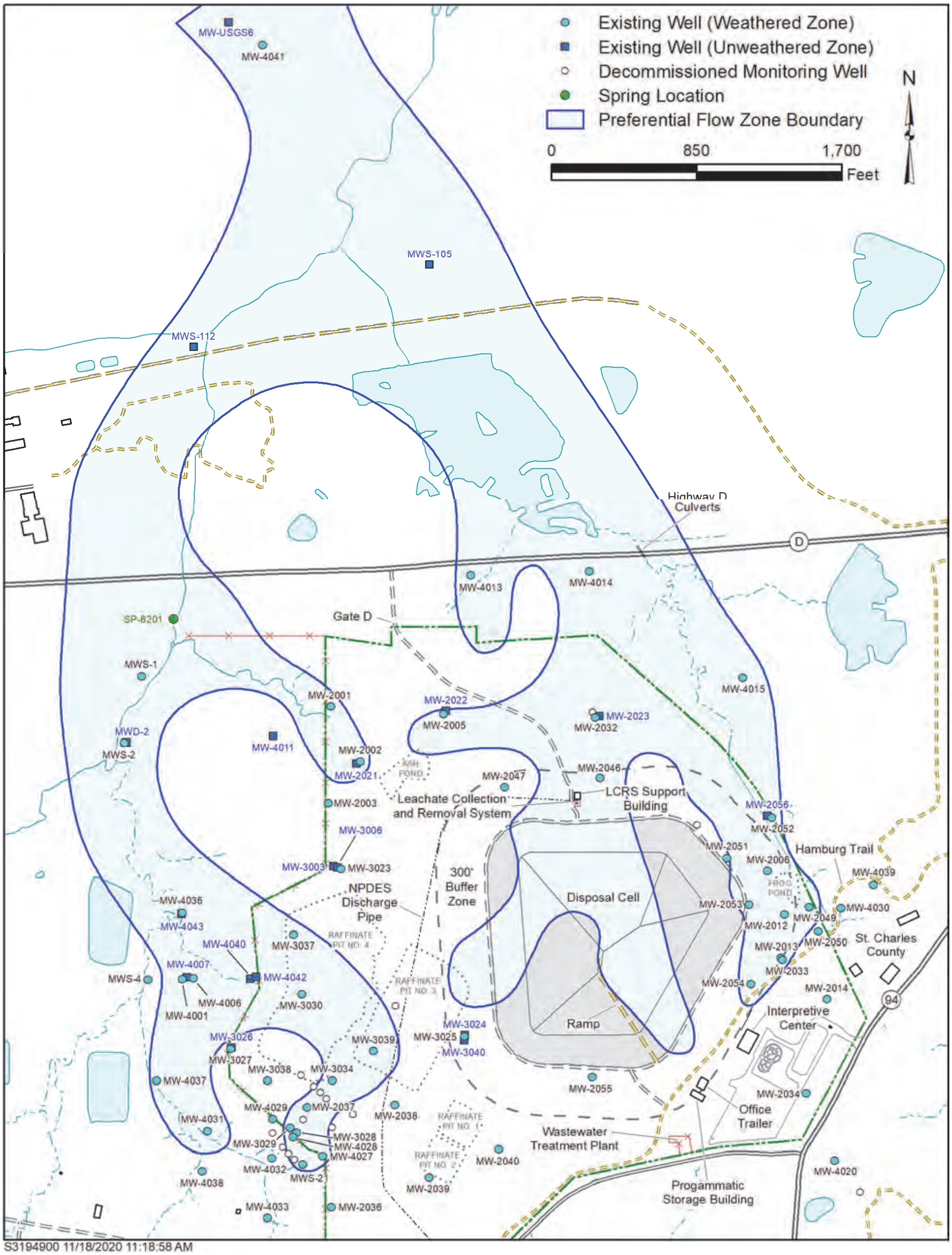


Figure 12. Preferential Flow Paths in the Burlington-Keokuk Limestone at the Chemical Plant Area

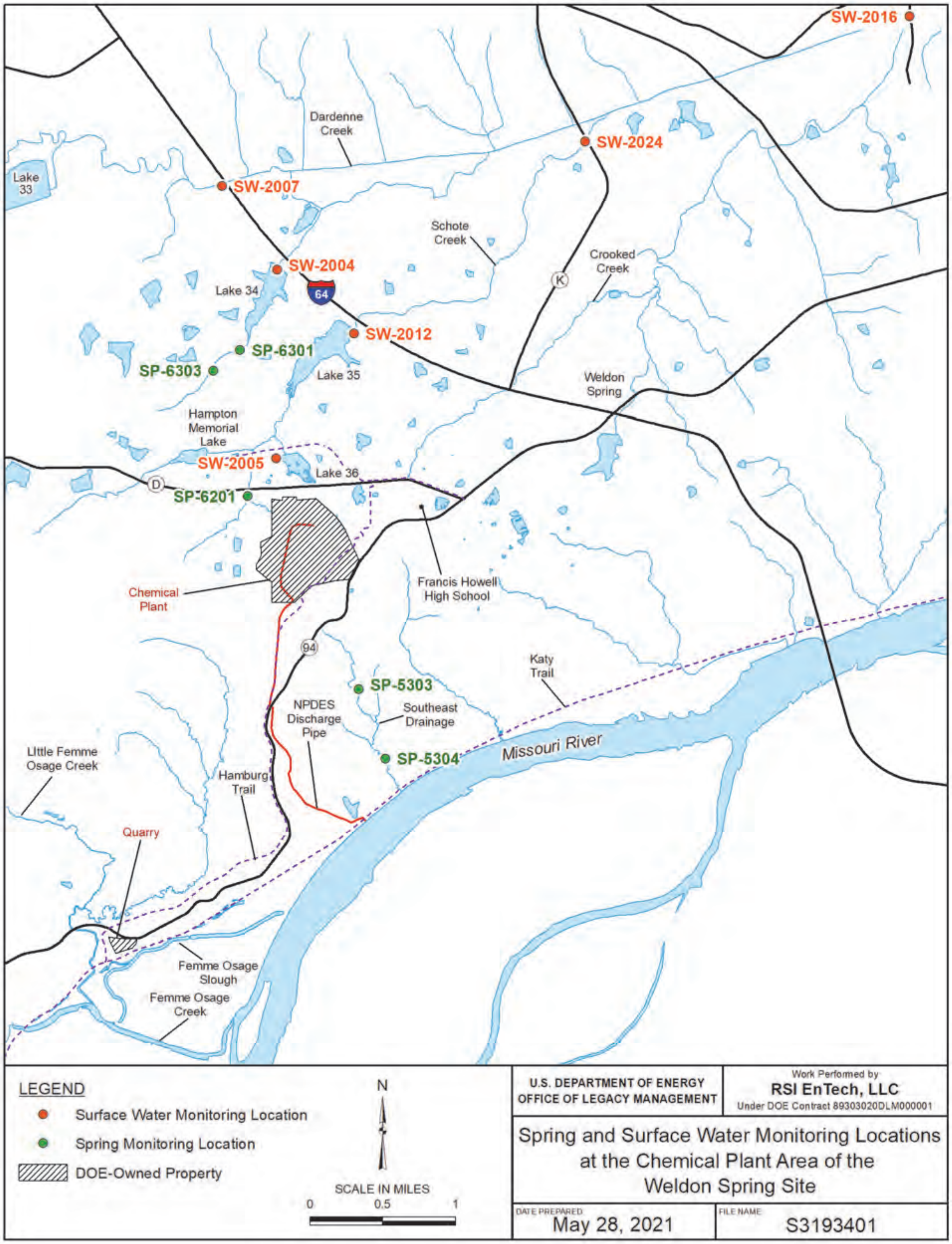


Figure 13. Spring and Surface Water Monitoring Locations at the Chemical Plant Area

The groundwater elevations in mean sea level (msl) measured at Chemical Plant area wells in the fall of 2020 (on September 29) were used to construct potentiometric surface maps of the weathered and unweathered units of the shallow aquifer (Figure 10 and Figure 11). The configuration of the potentiometric surfaces is similar throughout the year and has remained relatively unchanged from previous years. Even though groundwater elevations vary somewhat during the year in response to wet and dry periods, the groundwater flow direction has been consistently to the north. Troughs in the groundwater surfaces coincide with the location of paleochannels. The potentiometric head levels also vary somewhat from the upper, middle, to lower portions of each unit. This can cause water elevations of wells in the same unit to vary depending on the portion of the unit the wells are screened in, even if they are on the same well pad. Well MW-4042 is screened in the deep portion of the unweathered unit and has a lower head than the upper part of the unweathered unit indicated by the water elevation in MW-4040 (Figure 11).

Groundwater elevations generally decreased in the weathered unit of the Burlington-Keokuk Limestone in response to site remediation activities in the late 1990s and early 2000s, but they have since stabilized and even increased slightly in response to recent wet years (Figure 14). Spring SP-6303 (northwest of the site) was sampled once during 2019 (February 26, 2019). It had been dry since April 4, 2013. This was the second longest period of no sampling at this spring since the 1995–2001 period. The drawdown in 2001 indicated on Figure 14 for well MW-3028 was in response to pumping related to the field studies on the GWOU (DOE 2002c).

After remediation activities, some wells in the former Frog Pond area have had groundwater elevations vary 5 ft or more during the year (MW-2012 and MW-2052 in Figure 14). Cracks were observed on the surface near MW-2012 soon after remediation was completed. Some of the large water level increases in well MW-2052 occur within hours after significant rain events. A low area where water can back up and rapid infiltration is believed to occur is shown in Figure 10, just north of MW-2052.

Groundwater elevations in both the weathered and unweathered units decreased from the late 1990s to 2007 in the Raffinate Pits area (MW-2040 and MW-3025 in Figure 14, and MW-3024 on Figure 15) in response to the removal of large surface water impoundments, such as the Raffinate Pits, during site remediation. Water elevations have been steady for the last 10 years.

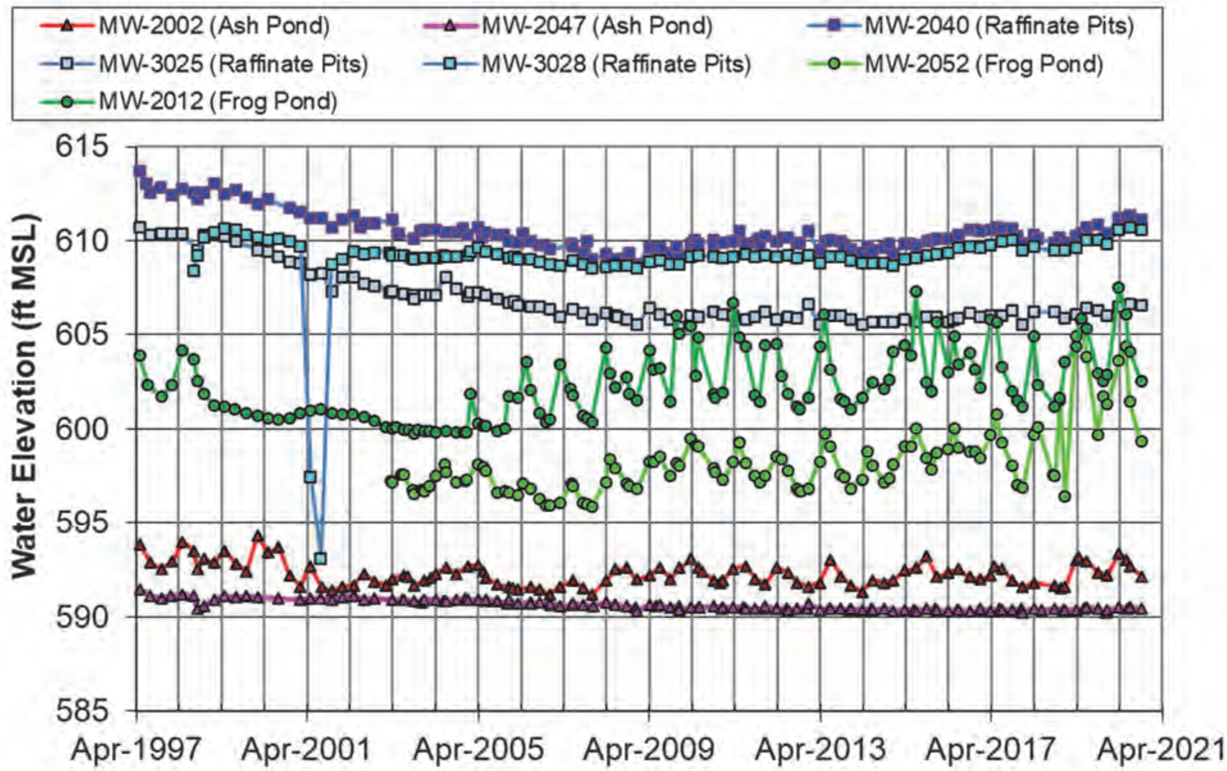


Figure 14. Groundwater Elevations in the Weathered Unit

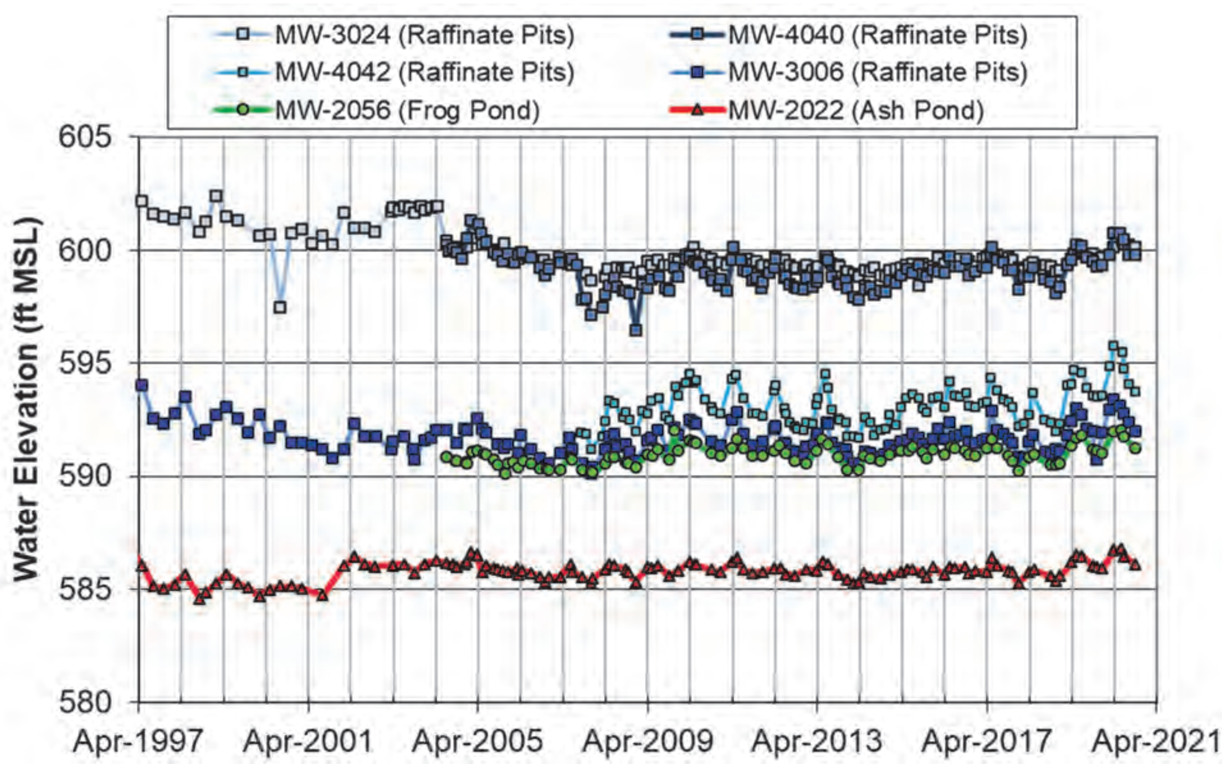


Figure 15. Groundwater Elevations in the Unweathered Unit

4.2.1.3 Frequently Collected Water Level Data

Pressure transducers have been placed in 12 wells (Figure 16) in the Chemical Plant area to record groundwater elevations every hour. Locations that have both a weathered unit and unweathered unit well have been prioritized to allow short-term and long-term hydrologic interactions between the units to be evaluated across the site. Select individual wells have been equipped to monitor water levels that may affect other processes: Well MW-4041 monitors water elevation changes in the downgradient discharge area north of the site, and MW-2012 has nitroaromatic concentrations that can vary more than an order of magnitude from one sampling event to the next.

There is a downward vertical gradient near the former Raffinate Pits (Figure 16). This area is on a topographic high where groundwater recharge is expected. West of the raffinate pits, water elevations (Figure 17) in upper unweathered unit well MW-4040 (red) are higher than those in deeper unweathered unit well MW-4042 (dark red). Immediately north of the raffinate pits, water elevations in MW-3003 (green, screened across the transition from weathered to unweathered unit) are higher than those in MW-3006 (dark green, screened in the deeper unweathered unit). This area is on a topographic high where groundwater recharge, and a downward gradient, is expected.

The groundwater system transitions from recharging to discharging (the deeper well of the paired wells has a higher head) as the surface topography slopes to the north from a relative high near the former raffinate pits to a relative low in the August Busch Preserve, a groundwater discharge area with many lakes. The transition from downward to upward gradient is seen in water elevations at the MW-4036/MW-4043 and MWS-2/MWD-2 well clusters. The water elevations in the shallow well (MW-4036, blue line) are below those in the deeper well (MW-4043, dark blue line). The persistent upward gradient at this location is maximized during wet periods, typically in the spring. As described in Section 5.2.1.7, higher uranium concentrations in the unweathered unit (MW-4043) appear to be pushed upward, causing a seasonal increase in uranium in the overlying weathered unit (MW-4036). The water elevations in the shallow well (MWS-2, gray line) are below those in the deeper well (MWD-2, black line), indicating an upward vertical gradient, except during the spring wet season when the water elevations are about the same (Figure 17).

Groundwater discharges in the low area north of the site, replenishing surface water bodies in dry periods and contributing additional water during wet periods. Groundwater levels in this area are more variable, with water levels in MW-4041 (about 1 mile north of the site) varying by as much as 10 ft during the year. The steady discharge of groundwater is what keeps Burgermeister Spring (about a third of a mile north of MW-4041) flowing year-round.

The variable nitroaromatic concentrations in MW-2012 have been associated with seasonal water level changes, with higher concentrations occurring in the fall when water levels are lower. A subsidence feature related to Frog Pond investigation trenching developed near MW-2012 in the early 2000s; this feature could promote rapid infiltration and dilution. Data from transducers installed in MW-2012, MW-2052, and MW-2056 in June 2018 show variable water elevations in the weathered unit wells (MW-2012 and MW-2052) in comparison to that of unweathered unit well MW-2056 that is on the same well pad as MW-2052 (Figure 18).

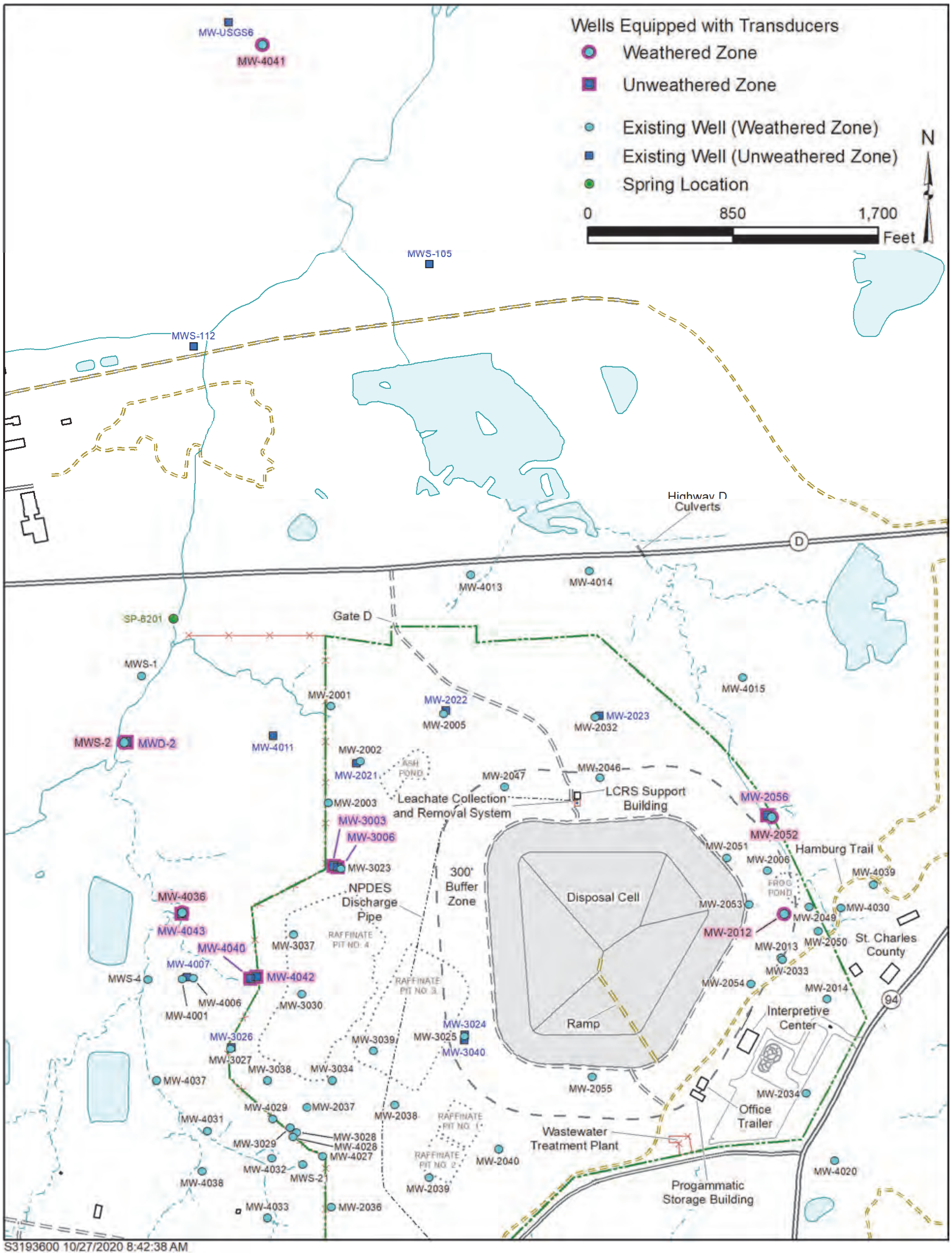


Figure 16. Wells Equipped with a Pressure Transducer

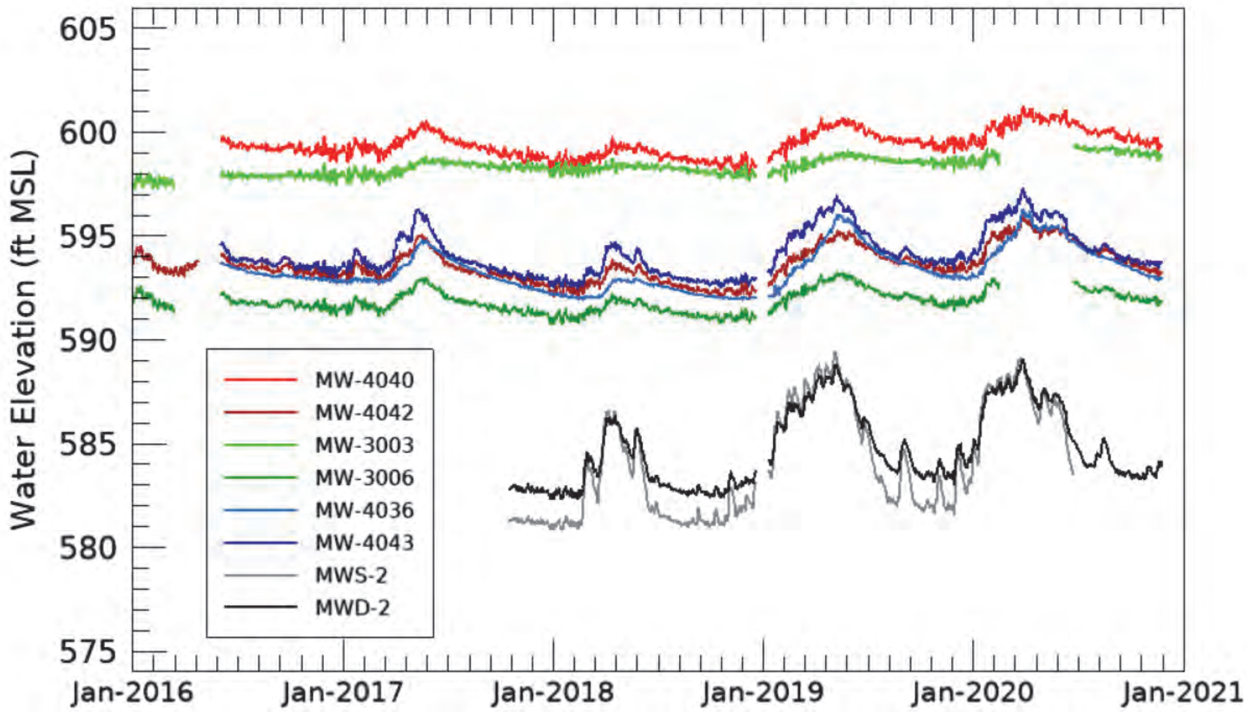


Figure 17. Transducer Water Elevations in Wells West of the Disposal Cell

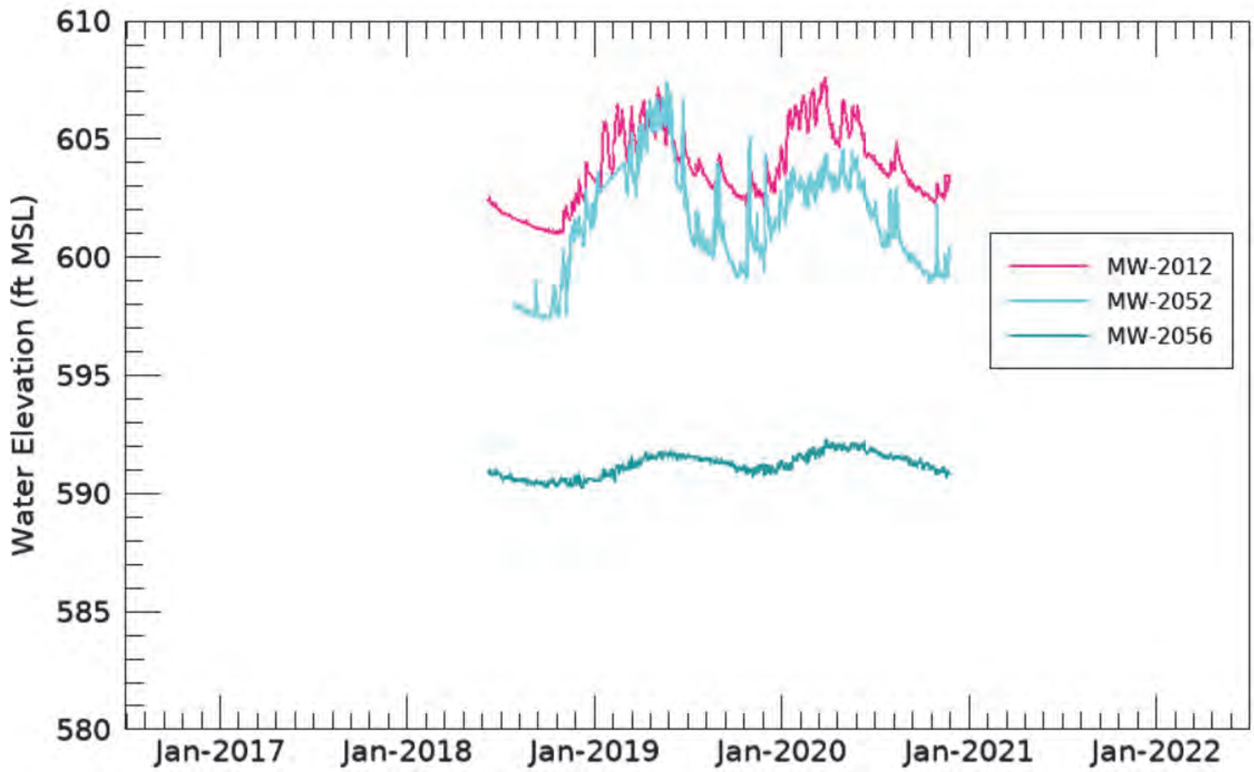


Figure 18. Transducer Water Elevations in Wells East of the Disposal Cell

4.2.1.4 Contaminants of Interest

Contaminated groundwater remains beneath the Chemical Plant. Contaminants include uranium, nitrate, TCE, and nitroaromatic compounds. Contamination in groundwater is primarily limited to the weathered portion of the Burlington-Keokuk Limestone. However, persistent elevated uranium concentrations in the upper portion of the unweathered bedrock in the former Raffinate Pits area has increased concern about the effectiveness of the MNA remedy in that area. This section has limited groundwater flow and less flushing relative to the more permeable overlying weathered section. The groundwater at the Chemical Plant has been contaminated by past operations that resulted in multiple source areas. Remediation activities at the site have removed the primary source zones for groundwater contamination. The distribution of contaminants in the shallow aquifer at the site is controlled by several processes, such as adsorption, desorption, dilution, or dispersion; the primary attenuation mechanisms at the time the remedy was accepted and approved in the Chemical Plant ROD were dilution and dispersion.

The Raffinate Pits were the primary historical source for uranium contamination in groundwater. Uranium entered the shallow aquifer via infiltration through the thin overburden beneath the pits. The extent of uranium in groundwater is limited, because uranium is partially sorbed to the clays in the overburden materials. Where uranium-contaminated water migrated beneath the overburden, it entered the limestone conduit system and subsequently discharged to springs north of the site. The oxidizing conditions of the shallow aquifer are not favorable for the precipitation of uranium from solution. Uranium-contaminated sediments were also discharged offsite during past operations. These sediments accumulated in subsurface cracks and fissures in the losing stream segments and act as residual sources to groundwater and springs. Total uranium mass concentrations are reported in milligrams per liter (mg/L) from the laboratory. This value is converted to pCi/L by dividing the uranium mass concentration by the Weldon Spring mass-to-activity conversion factor of 0.0015 mg/pCi (DOE 1997b). For example, a uranium concentration of 0.03 mg/L (30 µg/L) is equivalent to an activity of 20 pCi/L. Uranium activities in pCi/L will be referred to as concentrations throughout this report.

Nitrate is present in the groundwater near the former Raffinate Pits area and the Ash Pond area, which are the historical sources of this contaminant. Nitrate is more mobile than uranium in the shallow groundwater system, as it does not readily sorb to subsurface materials. Conditions for natural denitrification have not been identified in the shallow aquifer, so nitrate persists in groundwater, enters the limestone conduit system, and subsequently discharges to springs north of the site. Nitrate was reported from the laboratory as “nitrate as N” before 2006 and as “nitrate + nitrite as N,” with “N” being nitrogen, since 2006. Nitrite quickly oxidizes to nitrate in environmental systems and is typically not detectable when measured separately. Throughout the document, “nitrate as N” will be referred to as “nitrate” for simplicity.

Groundwater contaminated with TCE is localized in the weathered portion of the bedrock aquifer near former Raffinate Pit 4. Drums that were disposed of in Raffinate Pit 4 were the source of TCE contamination. The oxidizing conditions in the shallow bedrock aquifer do not promote the biodegradation of TCE.

Nitroaromatic compounds (1,3-dinitrobenzene [DNB]; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; and nitrobenzene [NB]) in the groundwater system coincide with former Army production line locations. The presence of nitroaromatic compounds in groundwater is a result of leakage from former TNT process lines, discharges from water lines, and leaching from contaminated soils and waste lagoons (Figure 19). The mobility of nitroaromatic compounds in the bedrock aquifer is high due to little sorption to the bedrock materials.

4.2.1.5 Chemical Plant (GWOU) Monitoring Program

Monitoring at the Chemical Plant was changed in July 2004 to focus on MNA, the selected remedy. Under the monitoring program, total uranium, nitroaromatic compounds, TCE, and nitrate are monitored at selected locations throughout the Chemical Plant area. The sampling locations target areas of highest impact in the shallow aquifer and migration pathways associated with paleochannels in the Burlington-Keokuk Limestone. Deeper wells MW-4042 and MW-3006 are sampled to assess potential vertical migration in the raffinate pits area. Deeper horizontally downgradient wells are sampled to assess potential vertical migration in areas horizontally downgradient of the impacted area.

There were 48 wells, five springs, and one surface water location sampled at the Chemical Plant during 2020 to assess the progress of the MNA remedy. The locations are depicted in Figure 9 (wells) and Figure 13 (springs and surface water). Each well was selected to fulfill objectives specified in the GWOU ROD (DOE 2004a) for the MNA monitoring network.

The monitoring network is designed to provide data either to show that natural attenuation processes are acting as predicted or to trigger the implementation of contingencies when these processes are not acting as predicted (e.g., unexpected expansion of the plume or sustained increases in concentrations within the area of impact). The data analysis and interpretation will satisfy the following:

- Objective 1: Upgradient locations to monitor background levels
- Objective 2: Locations that monitor concentrations within the area of impact (source zone)
- Objectives 3, 4, and 5 (lateral, vertical, and springs): Downgradient locations to monitor for contaminant migration
- Objective 6: Water levels are measured at all monitoring network wells, even those that are not routinely sampled, to evaluate groundwater flow directions at the site

Data are evaluated as outlined in the Baseline Concentrations Report (DOE 2008b). The evaluation of data was established to satisfy the monitoring objectives for the MNA remedy.

Trigger Levels

Trigger level indicators were set for each contaminant at the performance and detection monitoring locations in the event of unexpected increases. There are two trigger level types for each contaminant, the first of which is independent of the specific contaminant. The primary trigger level is set at what would be considered a statistically significant increase of a contaminant concentration at a location and is defined as the mean of the previous eight data points plus 3 standard deviations. Contingency actions are defined in Appendix M of the LTS&M Plan. This trigger is most useful for downgradient wells with relatively low and stable concentrations. It is less useful for higher-concentration wells adjacent to an impacted area where results are typically more variable. Higher-concentration zones where contamination was previously stable could be subject to a period of unstable, increasing concentrations after remediation. Removal of the source eventually leads to decreasing trends.

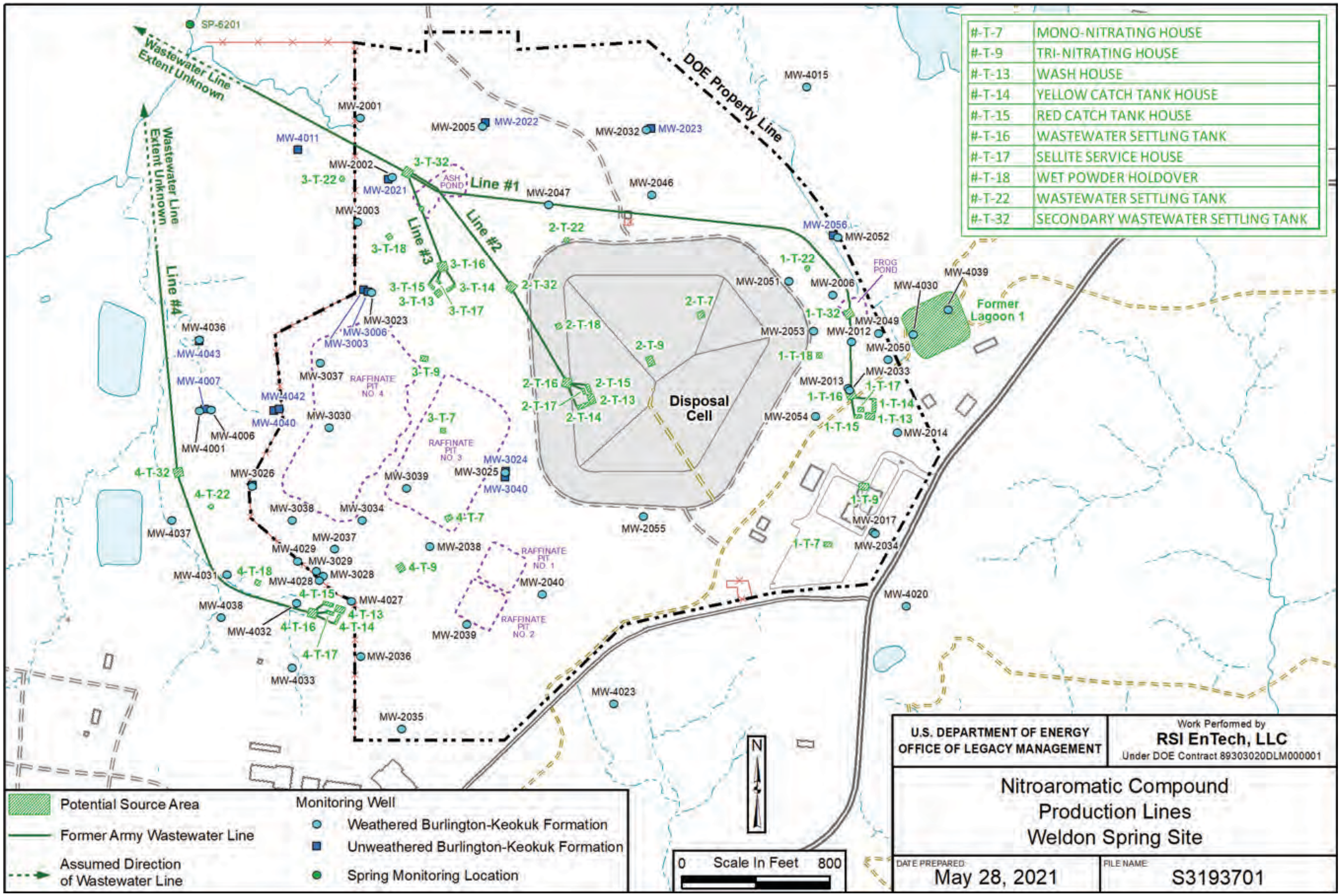


Figure 19. Nitroaromatic Compound Production Lines of the Weldon Spring Site

The secondary trigger levels are fixed concentrations, for each objective area and analyte, that were established as a level above which concentration increases would be considered unacceptable from an MNA perspective (Table 13). The fixed trigger levels were based on a review of data collected before 2004 and were set at roughly 2 times the typical results with consideration for variability. They are typically set at higher levels near impacted areas and at lower levels, such as the MCL, in downgradient, nonimpacted areas. The fixed trigger levels were formalized in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004c). The trigger levels, both primary and secondary, are used to evaluate MNA performance.

Table 13. Fixed Trigger Levels for Performance and Detection Monitoring for the GWOU

<table>
<tr><th>Analyte</th><th>Cleanup Standard</th><th>Objective 2</th><th>Objective 3 (Near)</th><th>Objective 3 (Far)</th><th>Objective 4</th><th>Objective 5</th></tr>
<tr><td>Nitrate (mg/L)</td><td>10</td><td>1350</td><td>30</td><td>10</td><td>20</td><td>20</td></tr>
<tr><td>Uranium (pCi/L)</td><td>20</td><td>100</td><td>50</td><td>20</td><td>40</td><td>150</td></tr>
<tr><td>TCE (μg/L)</td><td>5</td><td>1000</td><td>15</td><td>5</td><td>10</td><td>5</td></tr>
<tr><td>2,4-DNT (μg/L), FP</td><td rowspan="2">0.11</td><td>2300</td><td>1.1</td><td rowspan="2">0.11</td><td rowspan="2">0.22</td><td rowspan="2">0.22</td></tr>
<tr><td>2,4-DNT (μg/L), RP</td><td>5</td><td>0.55</td></tr>
<tr><td>2,6-DNT (μg/L)</td><td>1.3</td><td>2000</td><td>13</td><td>1.3</td><td>2.6</td><td>1.3</td></tr>
<tr><td>2,4,6-TNT (μg/L)</td><td>2.8</td><td>500</td><td>11.2</td><td>2.8</td><td>5.6</td><td>2.8</td></tr>
<tr><td>1,3-DNB (μg/L)</td><td>1.0</td><td>20</td><td>4</td><td>1</td><td>2</td><td>1</td></tr>
<tr><td>NB (μg/L)</td><td>17</td><td>50</td><td>34</td><td>17</td><td>17</td><td>17</td></tr>
</table>

Notes:
Cleanup standards from the "National Primary Drinking Water Regulations" (40 CFR 141) and Missouri "Water Quality Standards" (10 CSR 20-7.031).
By site convention, uranium concentrations are expressed as an activity. A uranium activity of 20 pCi/L is equivalent to the 30 μg/L uranium cleanup standard concentration.

Abbreviations:
FP = Frog Pond; RP = Raffinate Pits

The fixed triggers were set for each contaminant and are different for the area of impact (Objective 2), outside the area of impact (Objectives 3 and 4), or at discharge points (Objective 5). Objective 3 wells are subclassified into "near" and "far." Near wells include both close wells that delineate the plume and wells that are farther away and are used to confirm migration has not extended to those points. Far wells are those at a distance beyond where concentrations that might pose a risk would reasonably be expected to migrate—essentially a downgradient background well. If a fixed trigger is exceeded, consideration is given as to whether site conditions have changed unexpectedly. Exceeding a fixed trigger at a downgradient location could indicate that a contaminant plume is expanding, though not fast enough to trip the trigger of the average plus 3 standard deviations.

In impacted areas, where concentrations are expected to vary, a concentration that exceeds the fixed trigger may not be significant when considered in the context of all other data. For example, uranium levels in three wells adjacent to the former Raffinate Pits (contained within ICs) currently exceed the uranium fixed trigger level for impacted areas (100 pCi/L). This trigger level was set a few years after contaminated material was removed from the Raffinate Pits and before receiving the initial sampling results from newly installed wells (MW-4040 and

MW-3040); two of the three “high” concentration wells. The concentration in the third high-concentration well (MW-3024) increased and exceeded the trigger level soon after nearby remediation operations (which tend to mobilize remnant contamination) were completed. The 100 pCi/L trigger was selected to provide a goal to judge MNA performance in the impacted area, not as an indicator that implies risk. For instance, the average uranium concentration in two of the three wells is below the 150 pCi/L limit for downgradient discharge areas where receptors have potential access.

Data collected since 2004 indicate that the fixed trigger for uranium in the impacted area was set prematurely and is actually lower than the point of exposure springs. The 2004 to 2006 baseline study (DOE 2008b) did not include the new wells in the reevaluation of initial concentrations and suggested that additional data were needed to better establish baseline concentrations. Uranium levels in the three wells that exceed the fixed trigger value have stabilized; the 2020 average uranium concentrations are almost the same as the 2015 through 2020 average. Concentrations of more mobile constituents in the Raffinate Pits, such as nitrate, initially increased in impacted area well MW-4040 but have since stabilized. The nitrate concentrations in MW-3024 and MW-3040 have been declining consistently. Given sufficient time, uranium concentrations should also begin to decline. Appropriate responses to concentrations in excess of the fixed triggers would be to increase sampling frequency to ensure that the trend is not seasonally affected, add downgradient sampling locations, or revise the trigger as warranted. A detailed discussion of the recommendations is in the *Optimization for the Groundwater Operable Unit Monitored Natural Attenuation Network for Uranium Impact in the Unweathered Unit of the Burlington-Keokuk Limestone at the Weldon Spring, Missouri, Site* (DOE 2014). The fixed trigger levels are provided in the RD/RA Workplan (DOE 2004d).

Nonparametric Trend Analysis

Testing for temporal trends was performed using uranium, nitrate, TCE, and nitroaromatic compound data from the previous 5 years (2015–2020), in general accordance with the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004c). Results for the trending analysis are reported for the Objective 2 (impacted area) wells and Objective 5 springs. The trend analysis is conducted using the Mann-Kendall test described in Helsel and Hirsch (2002). The Mann-Kendall trend calculation is implemented in Microsoft Excel using the Visual Basic for Applications macro language. The Mann-Kendall test is also implemented in the Visual Sample Plan software (Gilbert 1987; Hirsch et al. 1982), which was used to confirm the Microsoft Excel macro calculations.

The Mann-Kendall test is used for temporal trend identification because it can easily accommodate for missing data and does not require the data to conform to a particular distribution (such as a normal or lognormal distribution). The nonparametric method is valid for scenarios that include a high number of nondetect data points. Data reported as trace (estimated) concentrations or as nondetects can be used by assigning them a common value that is smaller than the smallest measured value in the dataset. This approach is valid because only the relative magnitudes of the data, rather than their measured values, are used in the method.

A possible consequence of this approach is that the test can produce biased results if a large fraction of data within a given time series are nondetects and if detection limits change significantly between sampling events. The specified detection limit was used for nondetect sample results (those reported at or below the detection limit). Results classified as nondetect are shown on the data charts as empty or white-filled symbols (identified in the legend as a location name preceded by an “n,” e.g., “nMW-1001”) and are the same shape as the corresponding color-filled symbol for results classified as “detect.” A trend is considered statistically significant if the *p* value is less than 0.05 (equivalent to a 95% confidence level). The *p* value is a statistical parameter that evaluates the possibility of a trend that could simply be the result of random chance. A calculated trend also requires at least 10 values to be considered statistically significant.

Trends are calculated from sample results collected at a location during the previous 5 years, less duplicates and rejected values. Trend results are shown on the data charts with their *p* value and slope. If the *p* value is less than 0.05 (the selected level of significance), then the trend is considered statistically significant and either “up” or “down,” depending on the slope. If the *p* value is greater than 0.05, then the trend is not considered to be statistically significant (“none”). It has been shown that the false discovery rate for a *p* value of 0.05 is close to 30% (Colquhoun 2014), meaning there is a 30% chance of concluding that a trend exists that could simply be the result of random chance. The more rigorous two-tailed test (essentially a *p* value of 0.025 for a one-tailed test) for determining if a trend exists was used to reduce the number of false trends.

The data are plotted on a log-scale, since the rate of concentration increase or decrease typically slows with time, and it allows changes in lower-concentration wells to be compared with changes in higher-concentration wells. A linear regression line (Isaaks and Srivastava 1989) is plotted with the data on the charts to visually represent the slope and the period of data used for trending if it does not significantly interfere with the data. Otherwise, a line indicating the “trended data range” is shown on the bottom of the plot. If concentrations increase or decrease significantly over the period of trending, the linear fit line will curve, since it is plotted on a log scale.

Baseline Monitoring Results for the GWOU

Baseline conditions are monitored in four upgradient wells—MW-2017, MW-2035, MW-4023, and MW-4022 (highlighted in Figure 9)—to determine if possible changes in downgradient areas of impact are the result of changes in upgradient conditions. The objective of this monitoring is to verify that baseline conditions have remained stable. Each of these wells was sampled once during 2020. Table 14 lists corresponding results for each parameter, and the historical uranium results are presented in Figure 20. The concentrations measured in 2020 are similar to those from previous years and indicate no significant change in upgradient groundwater quality.

Table 14. Baseline Monitoring for the GWOU MNA Remedy (2016–2020)—Averages

Location	MW-2017	MW-2035	MW-4022	MW-4023
	Weathered	Weathered	Unweathered	Weathered
Parameters				
Uranium (pCi/L)	NR	0.46	2.4	3.4
Nitrate (mg/L)	NR	0.8371	0.35	0.59
TCE (µg/L)	NR	ND (<0.16)	NR	NR
2,4-DNT (µg/L)	ND (<0.019)	ND (<0.019)	NR	NR
2,6-DNT (µg/L)	ND (<0.022)	ND (<0.022)	NR	NR
2,4,6-TNT (µg/L)	ND (<0.022)	ND (<0.022)	NR	NR
1,3-DNB (µg/L)	ND (<0.014)	ND (<0.014)	NR	NR
Nitrobenzene (µg/L)	ND (<0.033)	ND (<0.033)	NR	NR

Abbreviations:
ND = analyte not detected above reporting limit indicated in parentheses
NR = analyte not required

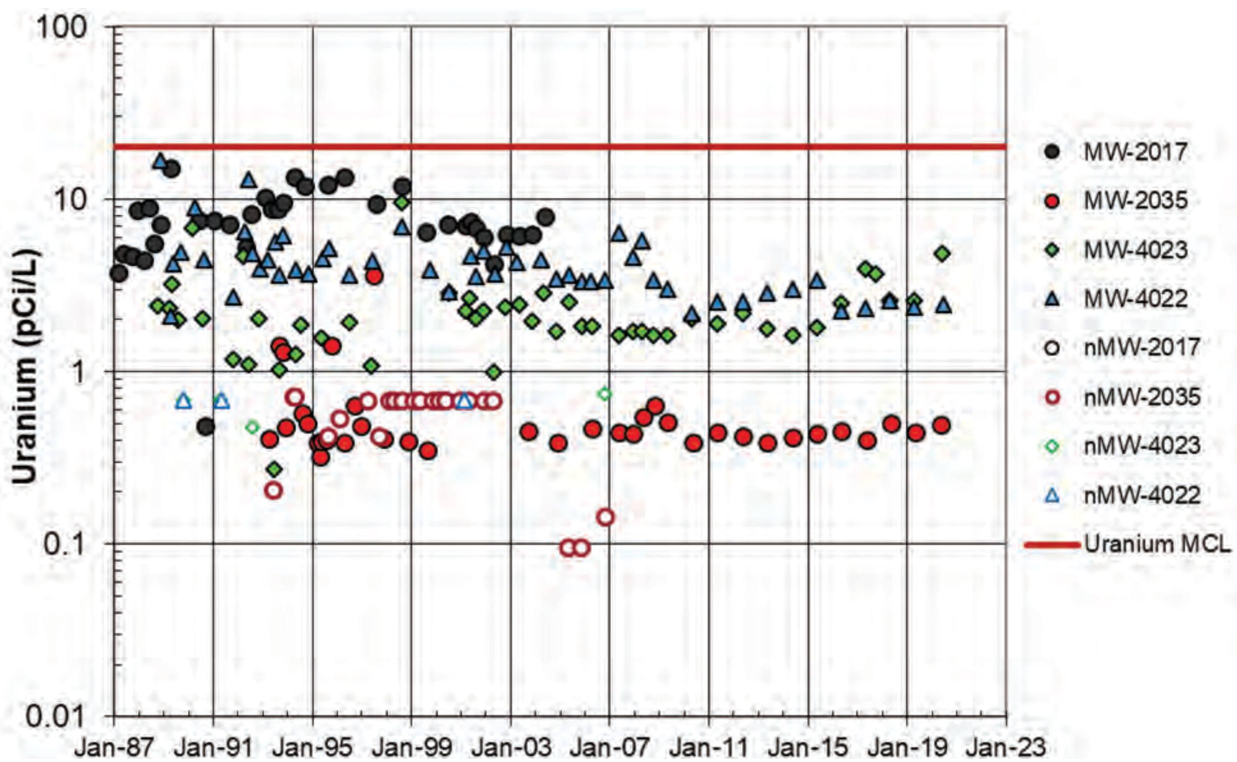


Figure 20. Uranium Concentrations in Upgradient Wells

4.2.1.6 Performance Monitoring for the GWOU

The performance of the MNA remedy is assessed through the sampling of the Objective 2 monitoring wells. Objective 2 wells are within the areas of impact and monitor both the weathered and unweathered units of the Burlington-Keokuk Limestone. Objective 2 of the MNA strategy is to verify that contaminant concentrations are declining or remaining stable as expected and that cleanup standards will be met in a reasonable time frame.

Performance of the remedy is gauged against long-term trend analysis as outlined in the MNA Baseline Concentrations Report (DOE 2008b) and the LTS&M Plan. Some locations are expected to show temporary upward trends due to ongoing dispersion, analytical variability, or other factors. Concentration-versus-time graphs serve as visual indicators of MNA progress.

Detection monitoring consists of sampling to fulfill Objectives 3, 4, and 5 of the MNA strategy. Wells along the fringes and downgradient (both laterally and vertically) of the areas of impact are monitored to ensure that lateral and vertical migration remains within the current area of impact and that expected lateral downgradient migration within the paleochannels is minimal. Springs and surface water locations are also monitored because they are the closest groundwater discharge points for the shallow aquifer near the Chemical Plant. These locations are monitored to ensure that concentrations remain protective of human health and the environment and that water quality continues to improve in the springs.

Uranium GWOU Performance Monitoring Results

The area of uranium impact is in the former Raffinate Pits area in the western portion of the site. Uranium levels exceed the 20 pCi/L MCL in both the weathered and unweathered units of the Burlington-Keokuk Limestone. Table 15 presents a summary of the uranium values for the 2016–2020 period. Figure 21 shows performance (red) and detection (blue) monitoring locations with 2020 uranium averages.

Table 15. Uranium Averages from GWOU Performance Monitoring Wells

Location	Uranium (pCi/L)				
	2016	**2017**	**2018**	**2019**	**2020**
Weathered Unit					
MW-3003	2.6	2.5	2.4	2.5	2.3
MW-3030	24	23	24	22	22
Unweathered Unit					
MW-4040	334	326	324	320	318
MW-3040	122	126	126	128	128
MW-3024	128	127	122	128	122
MW-3026	23	48	51	20	6.7

Notes:
MW-3003 is screened across the transition from the weathered to the unweathered zone.
2020 averages are from 10/1/2019 through 9/30/2020.

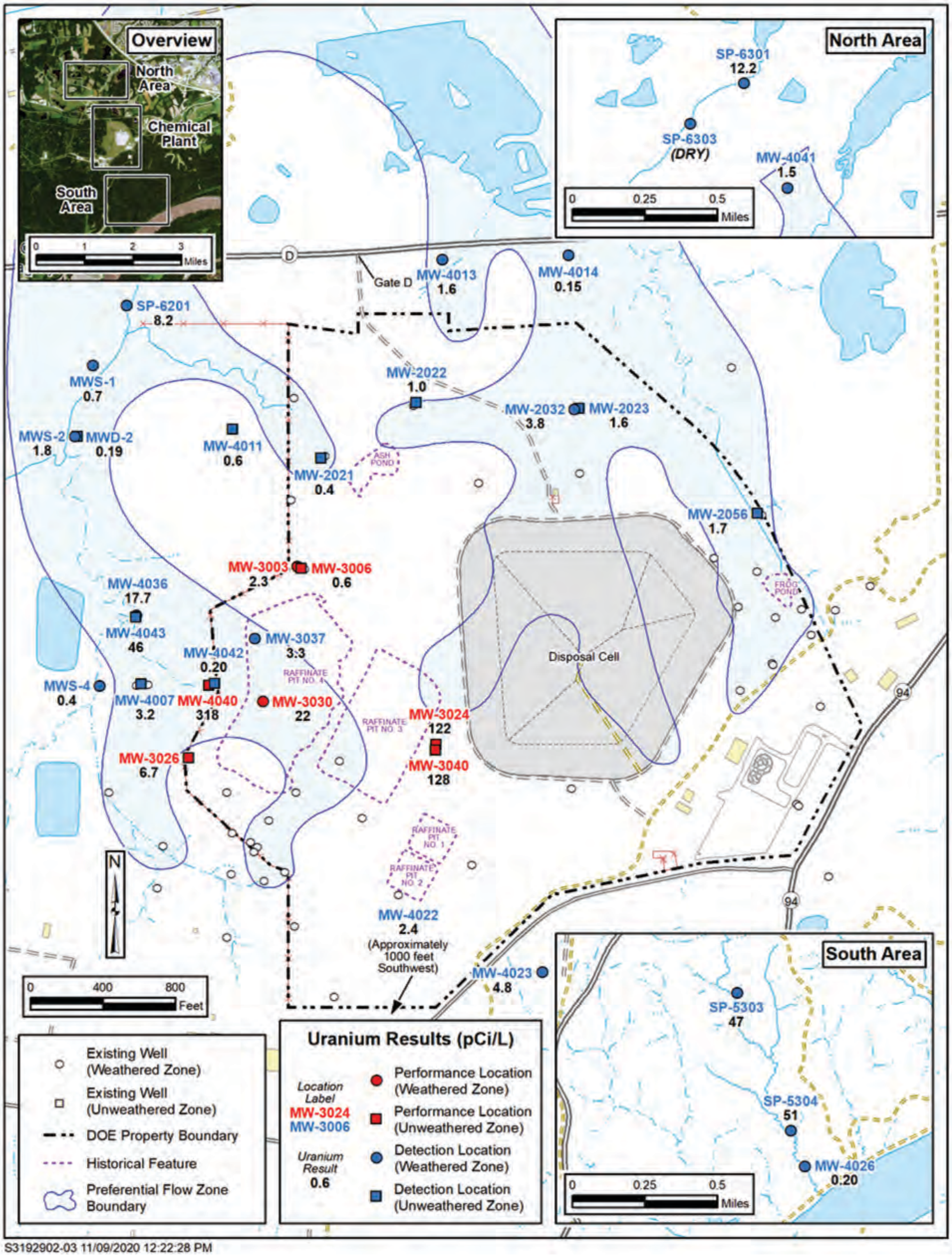


Figure 21. Uranium Monitoring Locations with 2020 Average Concentrations

Uranium impact in the weathered unit is monitored in two wells. The highest uranium levels in this unit are measured in MW-3030 (Figure 22), which is installed beneath the former Raffinate Pits. The Objective 2 wells screened in the weathered unit have shown gradually decreasing uranium levels since removal of the pits. The levels in MW-3003 have consistently been less than the MCL since 2000. Well MW-3003 is screened where the weathered unit transitions to the unweathered unit. Uranium levels in MW-3003 have declined to low levels and are beginning to stabilize near background levels (approximately 1–3 pCi/L for the weathered unit based on 10-year averages from unimpacted weathered unit wells).

Uranium levels in wells screened in the weathered unit have continued to decrease over the past 5 years. A statistically significant downward trend is indicated for both MW-3003 and MW-3030 based on the last 5 years of results. The rate of decline is slowing (Figure 22), but uranium levels in MW-3030 should be below the 20 pCi/L uranium MCL by 2025 to 2030.

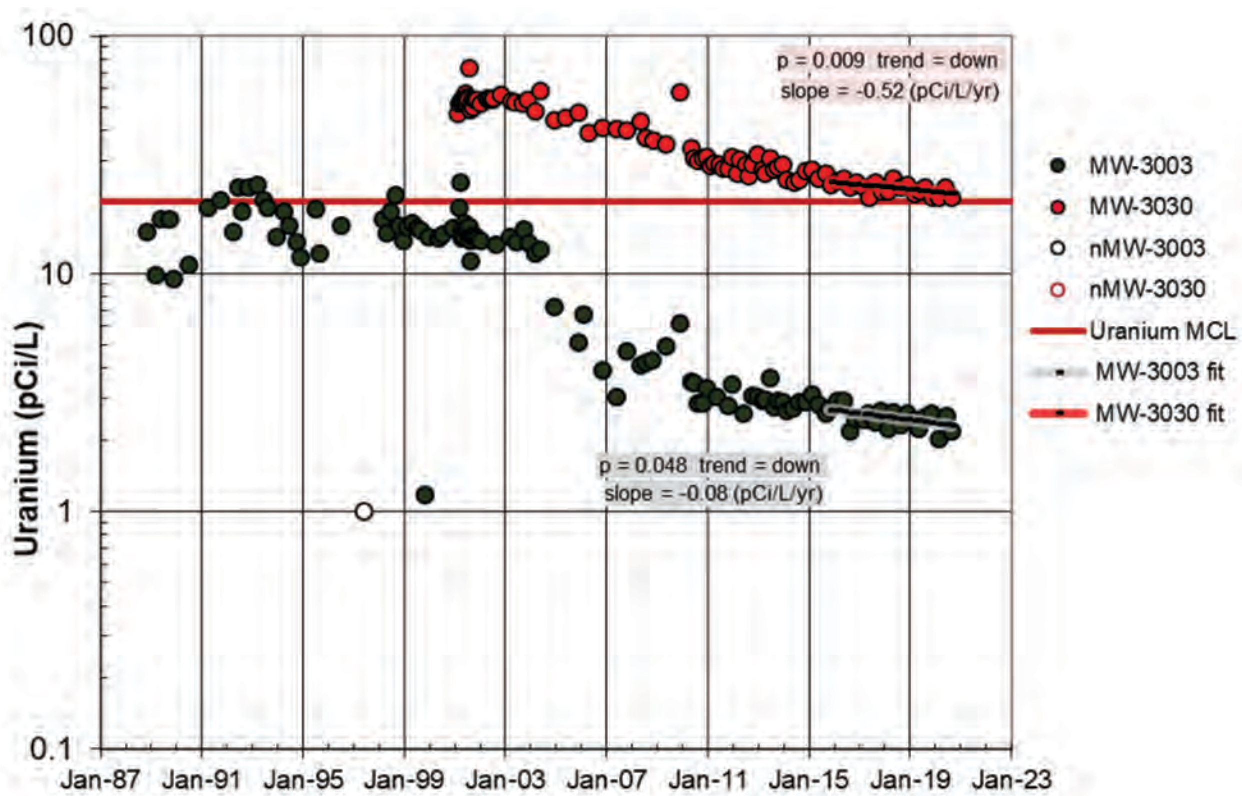


Figure 22. Uranium in Performance Monitoring Wells—Weathered Unit

Uranium impact is greatest in the wells that are screened in the upper part of the unweathered unit beneath and immediately downgradient of the former Raffinate Pits (Figure 21). Remediation and removal of the Raffinate Pits were completed in 2000. Wells MW-3040 and MW-4040 were installed in 2004 to provide uranium data for the unweathered unit in this area. Uranium results in wells MW-4040, MW-3040, and MW-3024 were consistently above the 100 pCi/L Objective 2 trigger level during the previous 5 years. However, the uranium concentrations in these wells have stabilized in that results since 2013 have been within a relatively narrow range that is neither increasing nor decreasing.

Well MW-3026, which had not been sampled since 2004 due to low concentrations and a downward trend, was added to the uranium monitoring network in 2014 because of its proximity to former Raffinate Pit 4. The results since 2014 have been typically higher and more variable than samples collected 10 years earlier (Figure 23). The results from MW-3026 initially appeared to be increasing after sampling resumed, but results have been within a predictable but somewhat variable range below the Objective 2 trigger value. Based on the last 5 years of data, which varies over several orders of magnitude, uranium in monitoring well MW-3026 is in a statistically significant downtrend. Uranium results (0.2–0.3 pCi/L since 2011) from well MW-4042 (on the same well pad as high concentration well MW-4040 but screened deeper in the unweathered unit) indicate that uranium has not migrated into the deeper part of the unweathered unit at that location.

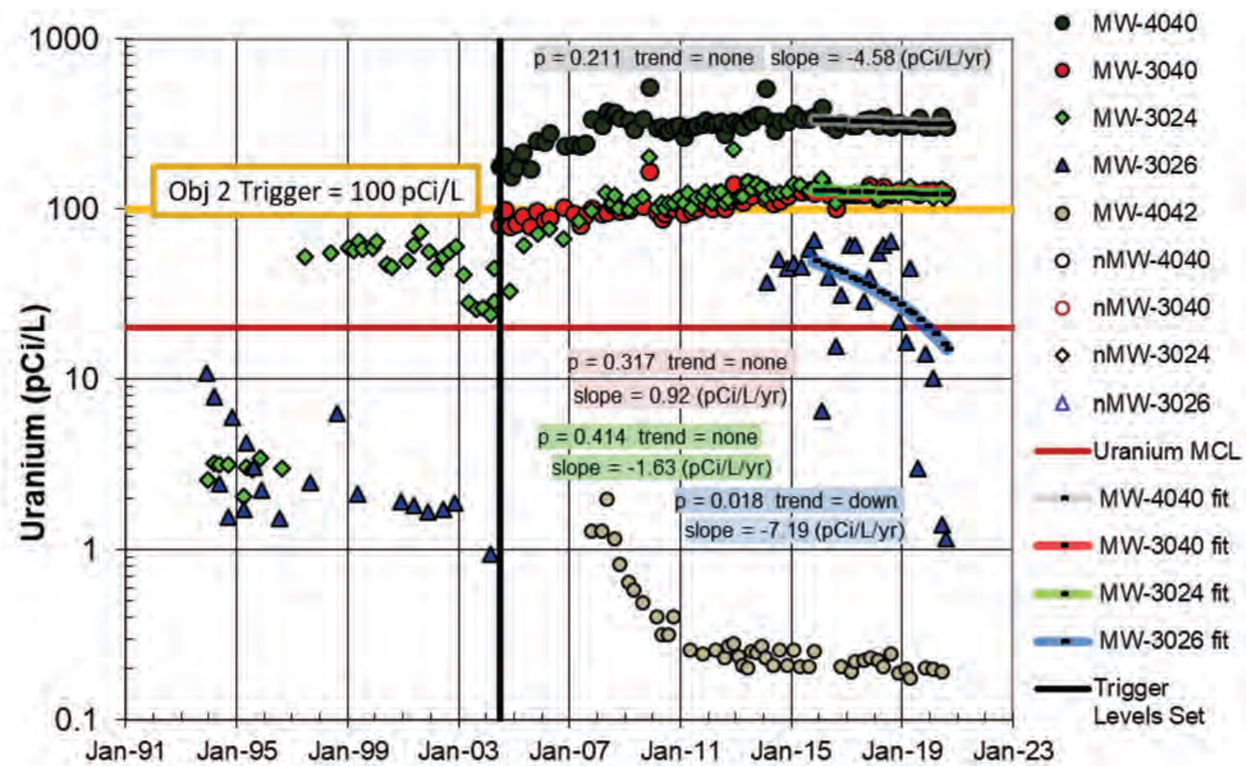


Figure 23. Uranium in Performance Monitoring Wells—Unweathered Unit

Uranium GWOU Detection Monitoring Results

Uranium detection monitoring locations are listed in Table 16. In the weathered unit, uranium levels have been at or below typical background levels for all detection monitoring wells except MW-4036 (Figure 24). None of the weathered unit detection monitoring wells have a discernable trend. Uranium levels in MW-4036 vary seasonally, ranging from 3.5 to 65 pCi/L from 2015 through 2020.

Table 16. Uranium GWOU Detection Monitoring Locations

Locations	Detection Monitoring Areas
Weathered Unit	
MW-3031[a]	Fringe
MW-3037	Fringe
MW-4026	Southeast Drainage (alluvium)
MW-4036	Downgradient
MW-4041	Downgradient
MWS-1	Downgradient
MWS-4	Downgradient
Unweathered Unit	
MW-3006	Fringe
MW-4042	Downgradient
MWD-2	Downgradient
Springs and Surface Water	
SP-5303	Southeast Drainage
SP-5304	Southeast Drainage
SP-6301	Burgermeister Spring branch
SP-6303	Burgermeister Spring branch
SW-2007	Dardenne Creek

Note:
[a] MW-3031 was decommissioned in July 2013.

In the unweathered unit, uranium levels have been at or below typical background levels (less than 1 pCi/L) for all detection monitoring wells except MW-4043 (Figure 25). Well MW-4043 averaged 55 pCi/L over the previous 5 years and has been trending downward, with the most recent result at 51 pCi/L. If the current downward trend continues, uranium concentrations in well MW-4043 should reach the 20 pCi/L MCL by 2035 to 2040. Well MW-4043 is on the same well pad as weathered unit well MW-4036. The indicated uptrends for the last 5 years of data in wells MW-4007 and MWD-2 are of little concern at their current very low levels.

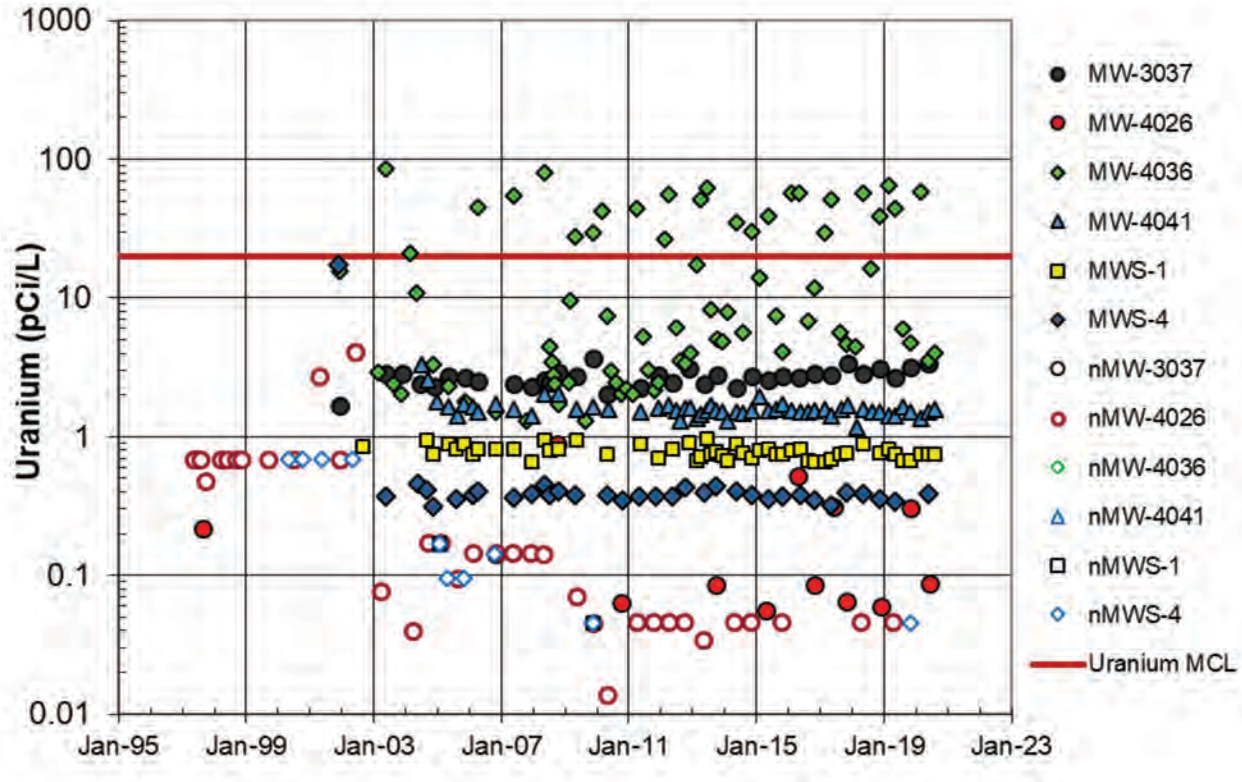


Figure 24. Uranium in Detection Monitoring Wells—Weathered Unit

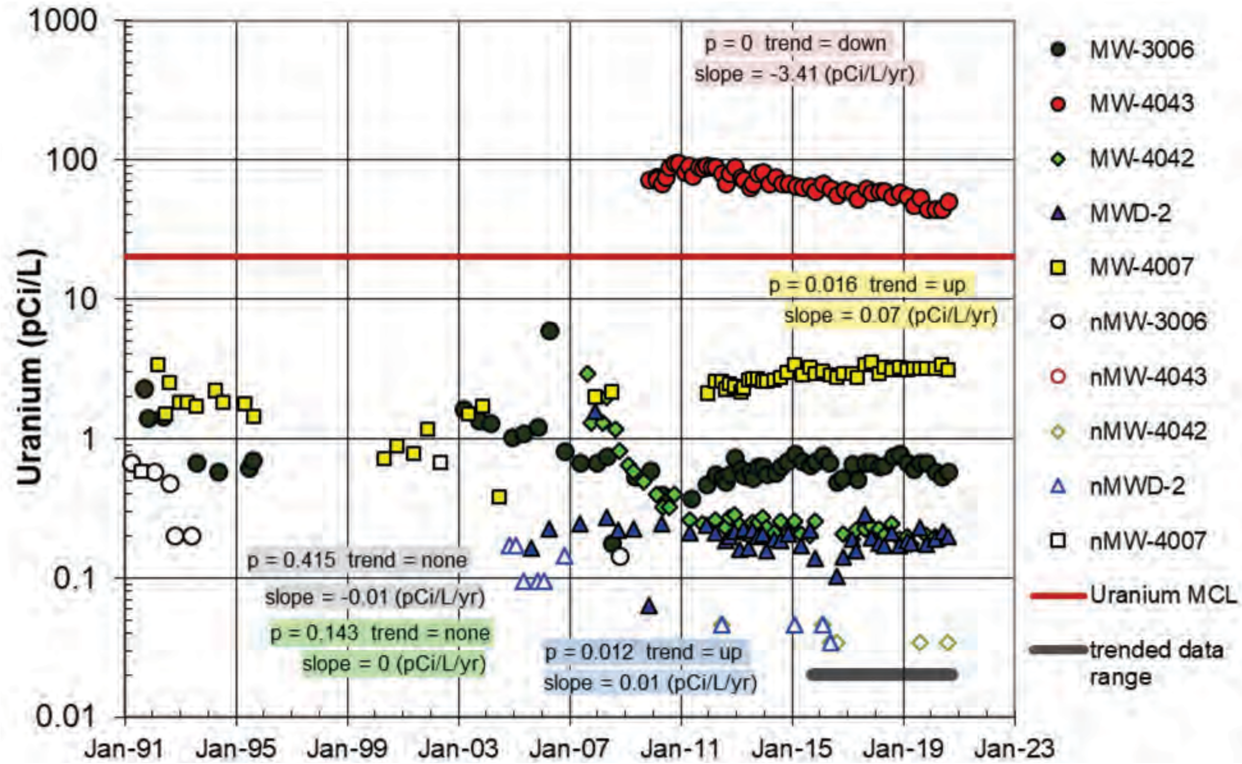


Figure 25. Uranium in Detection Monitoring Wells—Unweathered Unit

Uranium concentrations in MW-4036 vary nearly 2 orders of magnitude, ranging from higher than those in upgradient impacted area well MW-3030 to near weathered unit background levels (about 2 pCi/L) during the year (Figure 26). The variation in this well is a response to seasonal effects that cause water levels in the unweathered unit to rise more than those in the overlying weathered unit, creating a seasonal upward vertical hydraulic gradient, typically most pronounced in the winter and spring. Uranium concentrations in weathered unit well MW-4036 are similar to those in unweathered unit well MW-4043 when the upward hydraulic gradient is at its highest. When there is little to no upward gradient, concentrations in MW-4036 decline to near background levels. These data suggest that uranium has migrated horizontally from the impacted area in the unweathered unit within the paleochannel. The higher uranium concentrations in weathered unit well MW-4036 are not decreasing, suggesting there may be contribution from a shallow secondary source that is mobilized when water levels are relatively high.

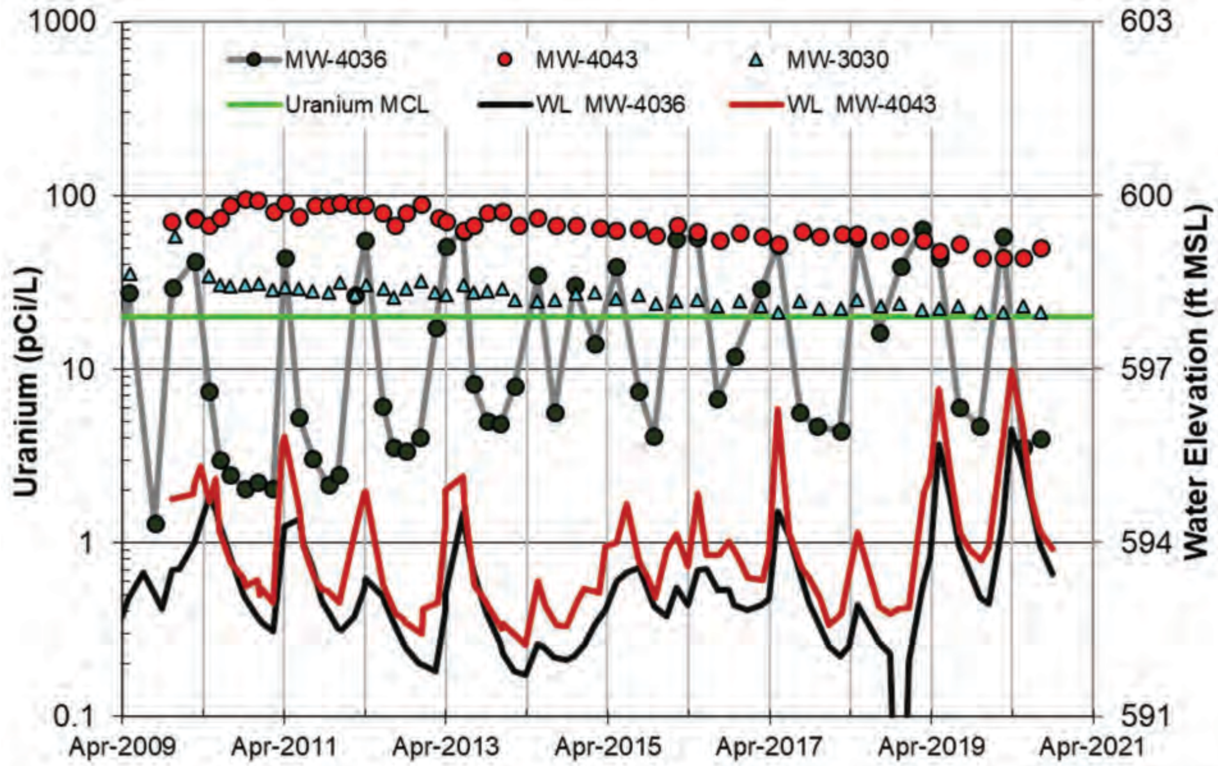


Figure 26. Seasonally Variable Uranium Concentrations in MW-4036

The installation of unweathered unit well MW-4043 in 2009 was the result of a special study initiated in 2008 to investigate the variable uranium levels in MW-4036. This location is in the western preferential flow zone (paleochannel) that extends north-northwest from Raffinate Pit 4.

Well MW-4042 is a deep unweathered unit well adjacent to MW-4040, the high uranium concentration well in the upper part of the unweathered unit just west of Raffinate Pit 4. MW-4042 was installed in August 2007 to bound the lower vertical extent of uranium in the impacted area. The top of the screen in MW-4042 is about 65 ft below the bottom of the screen in MW-4040. The low concentrations in MW-4042 confirm that uranium has not migrated downward to the deeper part of the unweathered unit. The initial slightly elevated concentrations in MW-4042 that dissipated over the next few years (Figure 25) were likely introduced during well installation; the well was drilled through the upper part of the unweathered unit, which has higher concentrations of uranium.

In general, the distribution of uranium has expanded along the western side of the Raffinate Pits area, as indicated by the variable uranium values reported in MW-4036 and the elevated uranium levels measured in MW-4043. The presence of uranium in downgradient spring SP-6201, with a 5-year average value of 6.2 pCi/L, also supports the conclusion of downgradient migration of uranium. Downgradient migration at relatively low and decreasing levels is expected. Fixed trigger values for Objective 3 (near) wells were set to take into account the migration of contaminants in the paleochannels. Uranium impact is contained within the paleochannel located within the upper portion of the shallow aquifer (weathered and unweathered units of the Burlington-Keokuk Limestone).

Uranium concentrations at surface water locations north of the Chemical Plant have not significantly changed from those of the previous 5-year period (Figure 27). Concentrations in Dardenne Creek have been low, typically below 1 pCi/L since monitoring resumed at location SW-2007 in 2001. Concentrations at spring SP-6303 had been declining on a long-term trend and were at background levels from 2010 until it was sampled on April 4, 2013, the last sample before an extended dry period. It was briefly flowing and sampled once in 2019 (February 26), with a result of 0.75 pCi/L. Uranium concentrations at Burgermeister Spring (SP-6301) continue to vary (by about an order of magnitude) but remain within historical ranges and well below the trigger level of 150 pCi/L (Figure 27). The most recent uranium result (August 2020) was 6.7 pCi/L. Results at SP-6301 are highest during low-flow times. The previous sample, taken in June, was 23 pCi/L.

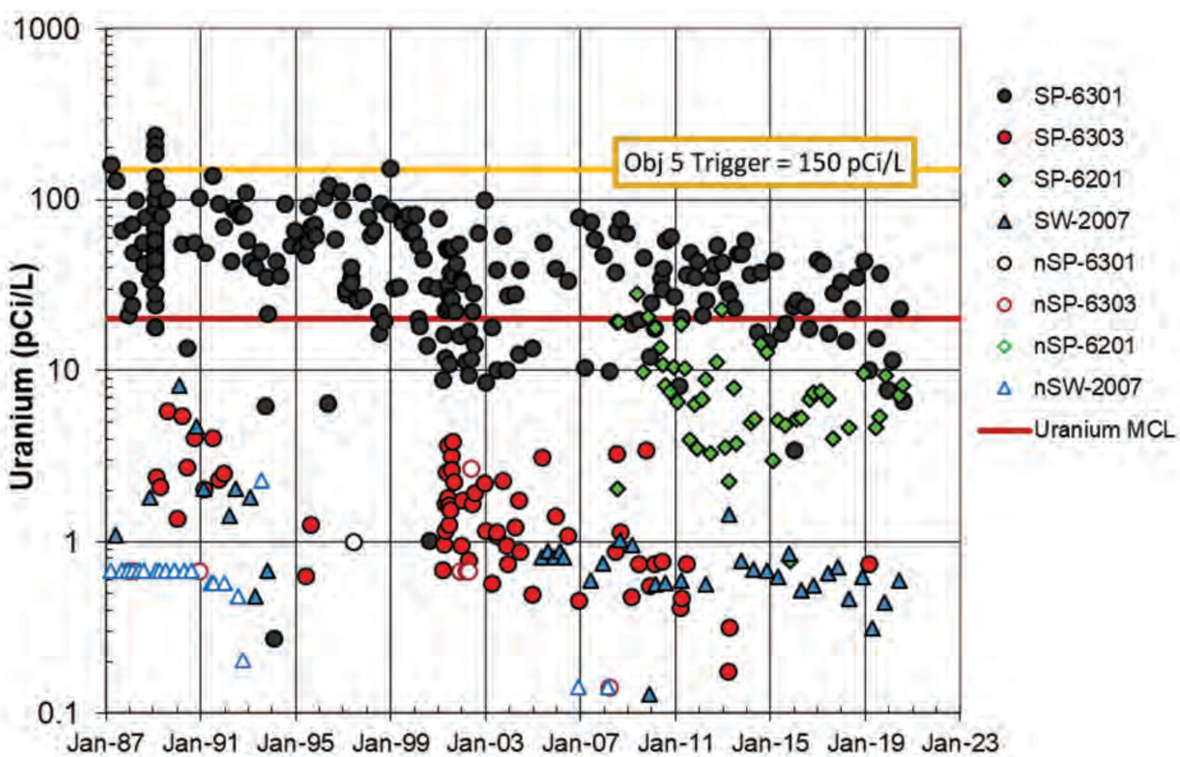


Figure 27. Uranium in Surface Locations North of the former Chemical Plant

The uranium levels in Burgermeister Spring (SP-6301) and SP-6303 are not correlated, other than both have exhibited long-term decreasing concentrations. The intermittent periods of SP-6303 being dry, concentrations near background levels, and local land surface topography support the interpretation that most of the water supplied to this spring is from a limited recharge area. The variability of uranium concentrations at Burgermeister Spring is inversely related to the variability that occurs at MW-4036 (Figure 28). As water elevations increase in response to increased rainfall, uranium concentrations at Burgermeister Spring decrease, due to increased dilution. The unusually low uranium result (3.5 pCi/L) at SP-6301 on December 30, 2015 (Figure 27), was from a sample taken after 11 inches of rain fell over the previous few days, to confirm this effect. Groundwater travel times from the site to Burgermeister Spring are on the order of 2–9 days, as determined from dye tracing (DOE 1997a).

Identifying trends in the Burgermeister Spring uranium results over 5-year intervals has been problematic because of the variable results. The period from 2009 through 2014 suggested an upward trend. The period from 2015 through 2020 indicates no statistically significant trend, but with an obvious downward slope. The trending of data constrained to a 5-year period can be influenced by just a few data points. A longer time frame provides a more reliable trend that can be projected forward (Figure 29). The chart provides linear regression fits, Mann-Kendall trends, and slopes for three periods. Extrapolating the line that decreases by an “order of magnitude every 60 years” (labeled “OM 60 yrs” in Figure 29 and Figure 30) suggests that the highest uranium concentrations seen at Burgermeister Spring could be below the 20 pCi/L MCL by 2045 (Figure 30).

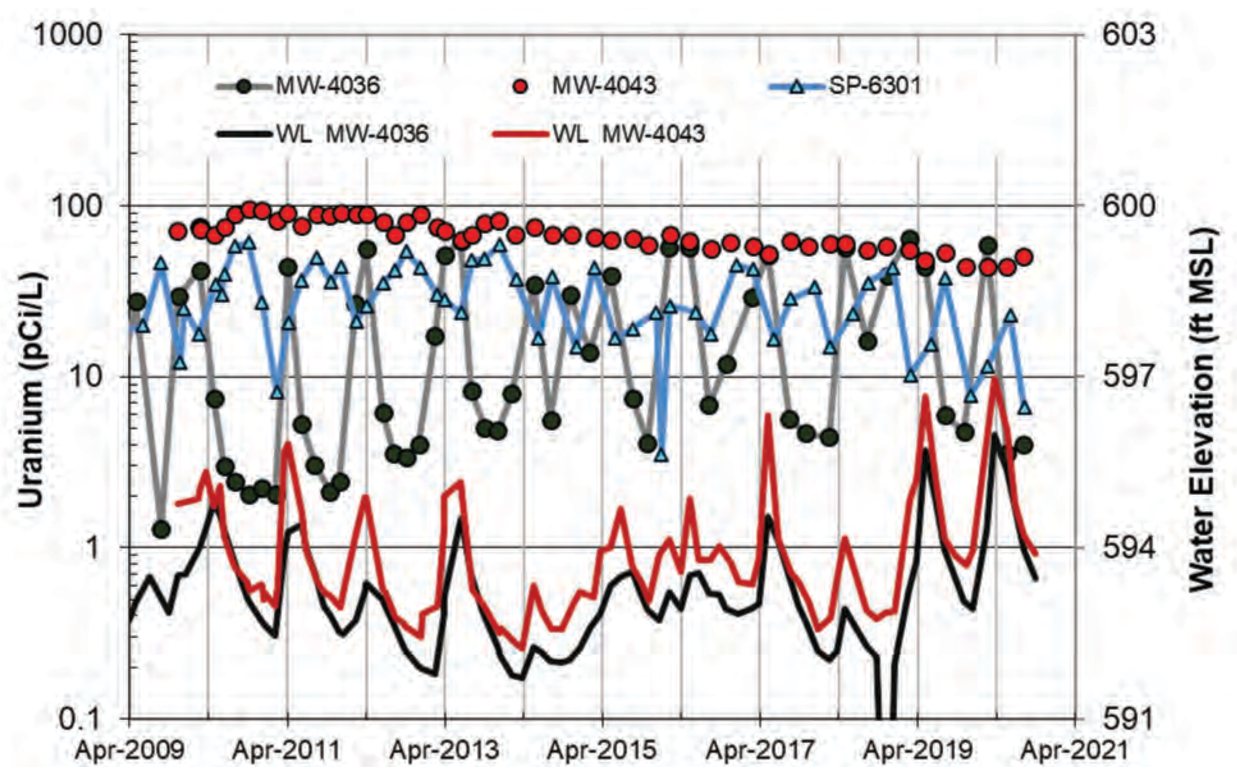


Figure 28. Variable Uranium at Burgermeister Spring (SP-6301)

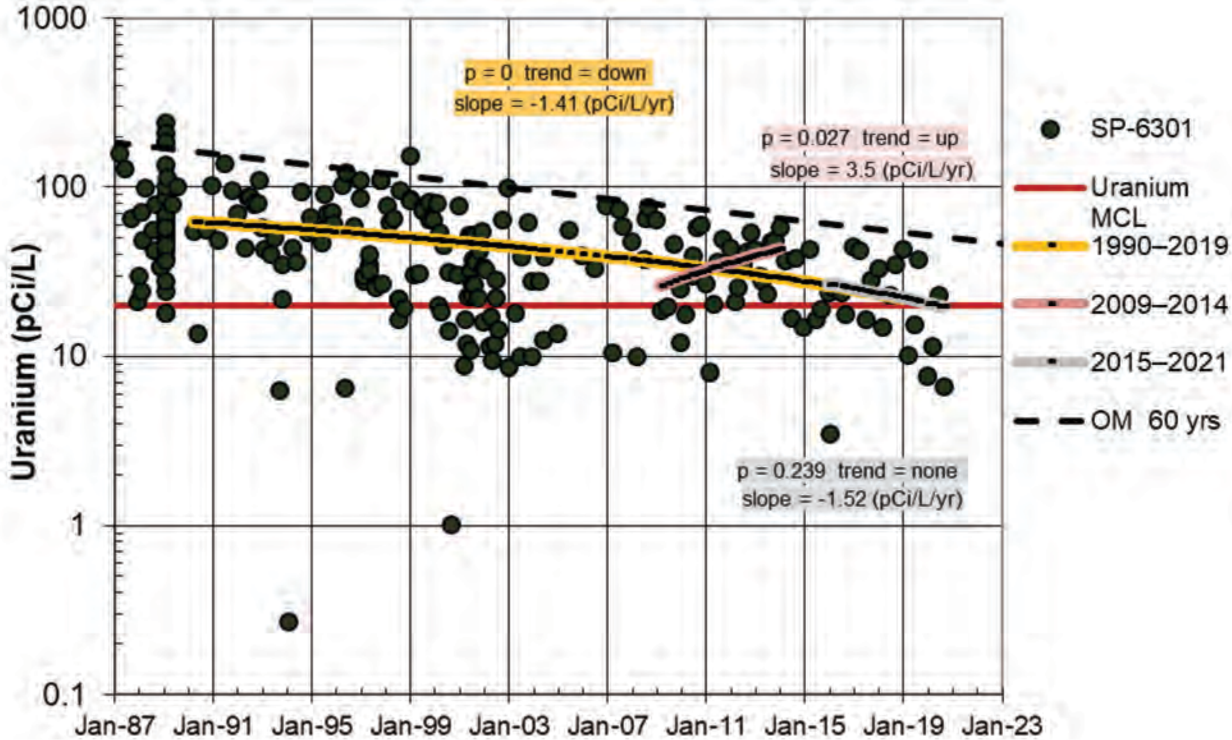


Figure 29. Trending of Uranium at Burgermeister Spring (SP-6301)

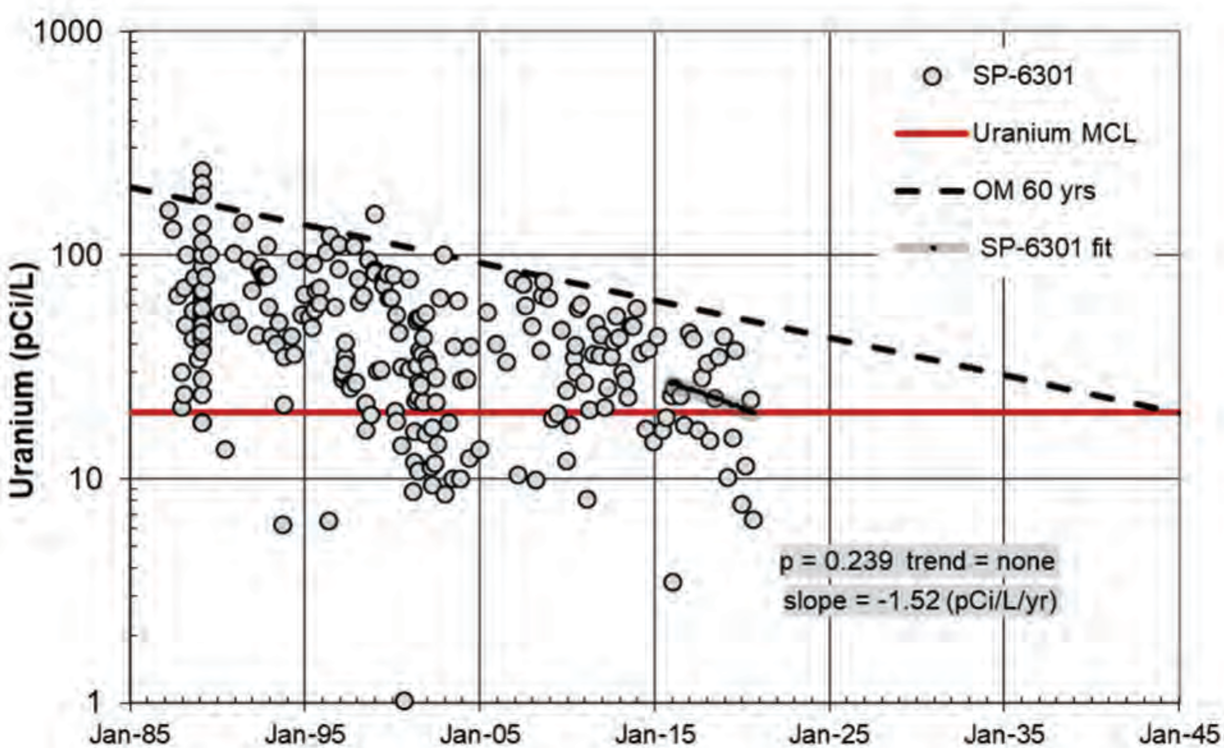


Figure 30. Long-Term Projection of Uranium in Burgermeister Spring SP-6301

Uranium impact in the Southeast Drainage is the result of historical discharges to this drainage during plant operation that resulted in contaminated soil and sediment within the drainage. Residually contaminated sediments within the bedrock fracture system are the source of uranium impact in the two springs (SP-5303 and SP-5304). Uranium levels behave similarly in both springs (Figure 31). Uranium levels in the springs exceed the 20 pCi/L MCL but are below the 150 pCi/L trigger level. Concentrations in the shallow monitoring well MW-4026 (downgradient of the two springs) are typically at background levels or below detection limits (Figure 31).

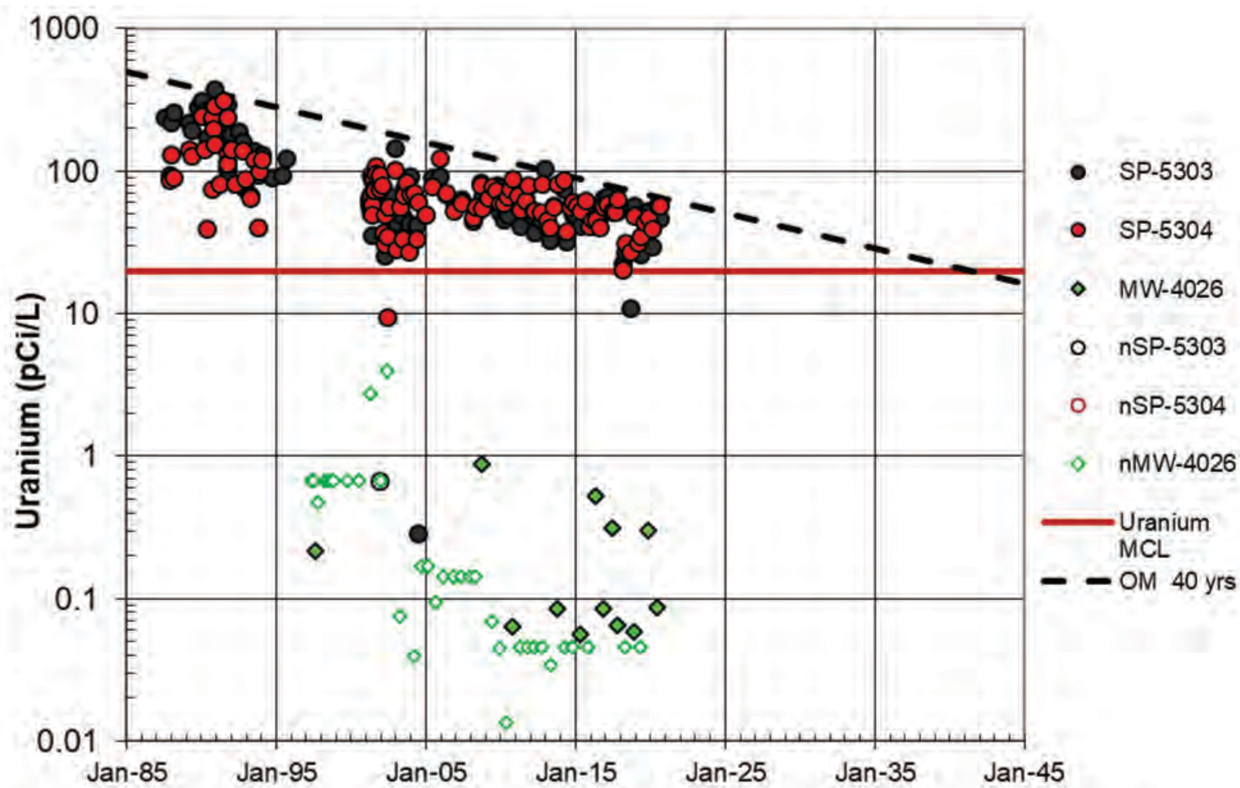


Figure 31. Uranium in Southeast Drainage Springs and MW-4026

Analysis of the data from 2016 through 2020 indicated no statistically significant trends for these two springs. However, the historical dataset indicates that uranium levels at SP-5303 and SP-5304 have been decreasing over the long term (Figure 32).

While uranium levels in the Raffinate Pits area increased in some wells after the 2004 implementation of the MNA remedy for uranium, average uranium levels in the impacted area unweathered unit wells are no longer increasing and have been stable since the 2009 to 2013 period (Figure 23). Groundwater flow directions have remained unchanged in the Raffinate Pits area since stabilizing after their removal (Figure 10 and Figure 11).

Uranium levels have consistently been decreasing in the weathered unit due to dilution and dispersion (Figure 22). Removal of the Raffinate Pits decreased infiltration and recharge, thereby reducing the dilution and flushing of unweathered unit groundwater. Increased uranium levels from 2004 are the result of residual uranium from contaminated materials that were forced deeper into the bedrock by the high hydraulic head present when the Raffinate Pits were full. The reduced infiltration and the relatively low permeability of the unweathered unit will take longer to flush uranium from the impacted area.

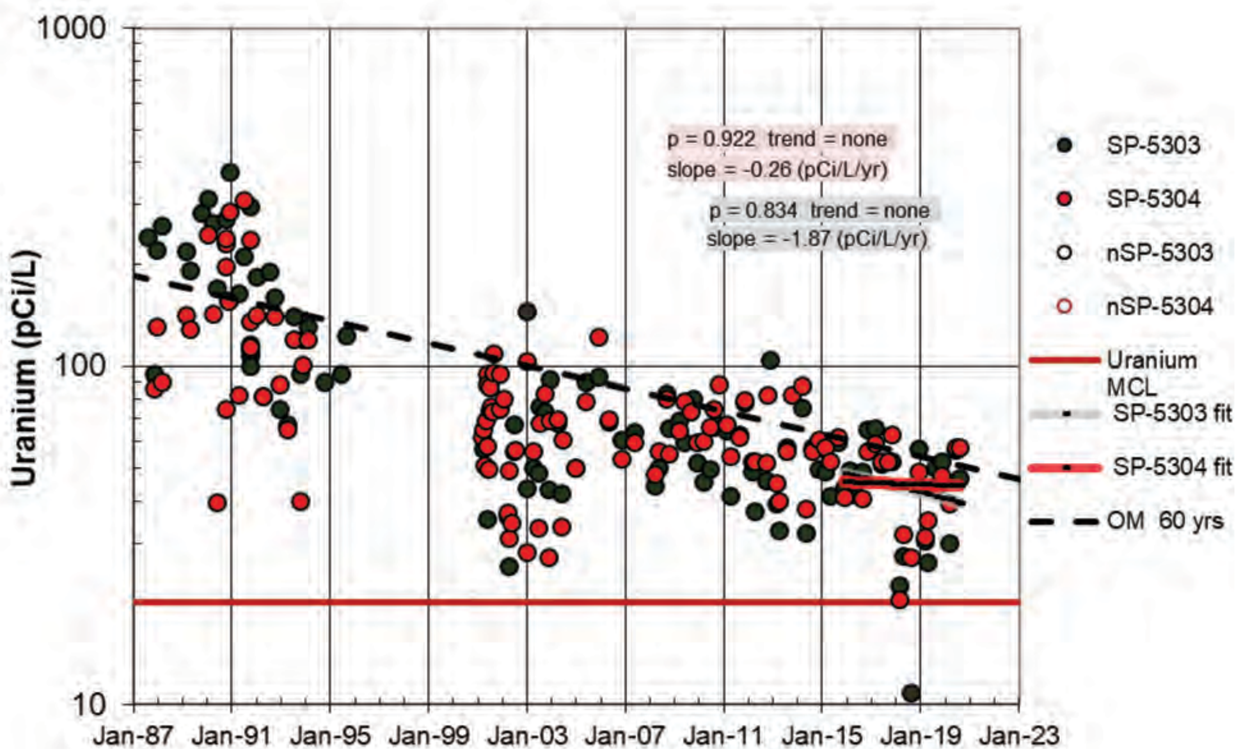


Figure 32. Trending of Uranium in Southeast Drainage Springs

Overall, uranium impact is contained within the upper portion of the shallow aquifer (weathered and upper unweathered units of the Burlington-Keokuk Limestone). Uranium levels in the weathered unit are decreasing as a result of source removal and natural attenuation (dilution and dispersion) and will reach the MCL before 2030 if decreases continue at the current rate.

Uranium Distribution Overview

The 2020 review of the uranium distribution indicated two areas of uranium impact—one associated with former Raffinate Pit 4 and to the west and another east of former Raffinate Pit 3. The uranium associated with former Raffinate Pit 3 is restricted to wells MW-3040 and MW-3024, both screened in the unweathered unit at essentially the same location, immediately east of the former pit. The top of the 20 ft long screened interval in MW-3024 is in the upper part of the unweathered unit near the weathered–unweathered unit interface. Well MW-3040 was installed in 2004 to isolate the lower 10 ft portion of this interval to limit contribution from the overlying weathered unit. This source location is not within a preferential flow zone (paleochannel), thereby limiting downgradient uranium migration.

The area of uranium impact associated with former Raffinate Pit 4 and the uranium to the west of Pit 4 is present in both the weathered and unweathered units. This source is above a preferential flow zone (the western paleochannel) that permits uranium migration downgradient to the north.

Unweathered unit well MW-4040 has the highest uranium concentration at the former Chemical Plant with a 2017–2020 average of 344 pCi/L. Downgradient, 550 ft to the northwest at well MW-4043, unweathered unit uranium concentration decreases to 52 pCi/L. Another 1000 ft downgradient to the north, concentrations decrease to background levels at well MWS-2 (~2 pCi/L) and MWD-2 (<1 pCi/L). The 2020 uranium distribution extends beyond wells MW-4036 and MW-4043 (Figure 34). The decreasing uranium concentrations at MW-4043 (Figure 25) suggest that the uranium distribution in the unweathered unit in the western paleochannel is contracting downgradient. Well MW-4043 is screened in the upper part of the unweathered unit (Figure 33), where elevated uranium concentrations have been identified in the impacted area.

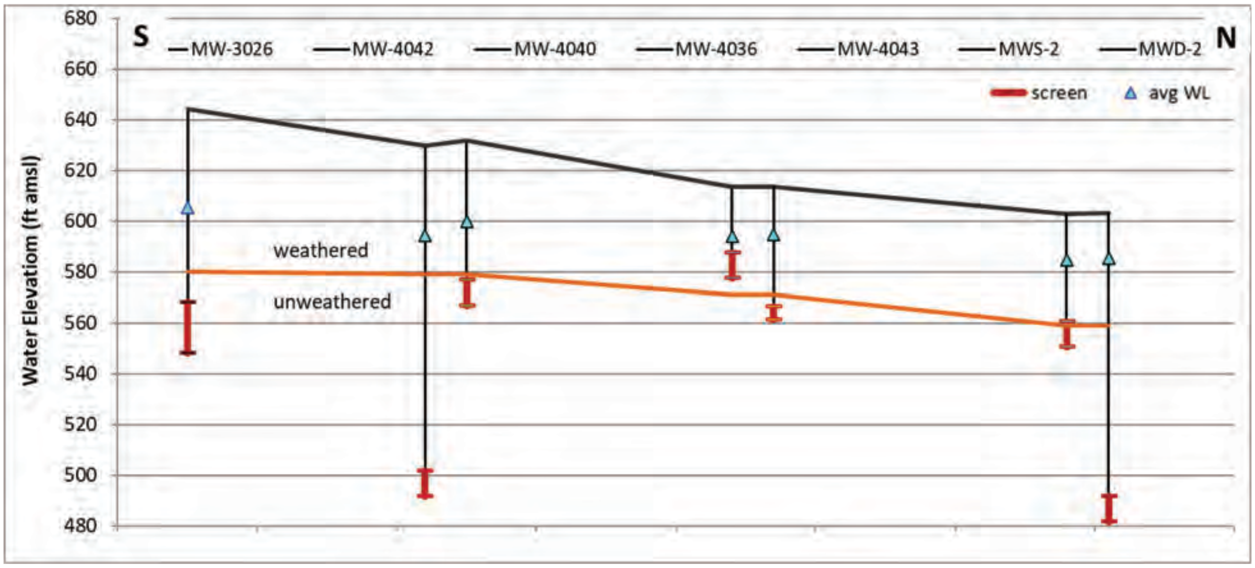


Figure 33. Schematic Cross Section (relative horizontal positions) Showing Screened Intervals of Paleochannel Wells

Results from unweathered unit well MW-3026 (2017–2020 average of 28 pCi/L) show decreased concentrations over the past 5 years. Sampling of MW-3026 was resumed in 2014 because it is about the same distance west of Raffinate Pit 4 as high-concentration well MW-4040, which is 400 ft to the north. Even though MW-3026 is currently upgradient, mounding beneath the former Raffinate Pits would have pushed contamination both down and then outward away from the mounding, locally overwhelming the natural hydraulic gradient. The uranium concentration in MW-3026 is decreasing with a statistically significant downtrend over the last 5 years (Figure 23), but due to the variability of the results, at least 5 more years of data is needed to arrive at a meaningful conclusion.

Monitoring well MW-3030 is within the footprint of former Raffinate Pit 4 and screened in the weathered unit. Uranium concentrations have been steadily decreasing in this well (3-year average of 23 pCi/L) and may reach the uranium MCL in the next 5 years (Figure 22). About 800 ft downgradient, 2017–2020 average uranium concentrations in weathered unit well MW-4036 are 26 pCi/L, an increase from the 2012–2015 average of 20 pCi/L. The weathered unit uranium distribution was extended beyond the MW-4036 location. The variability in uranium concentrations at well MW-4036 is influenced by a few values in the averaging that are the result of the variability in uranium concentrations at this well.

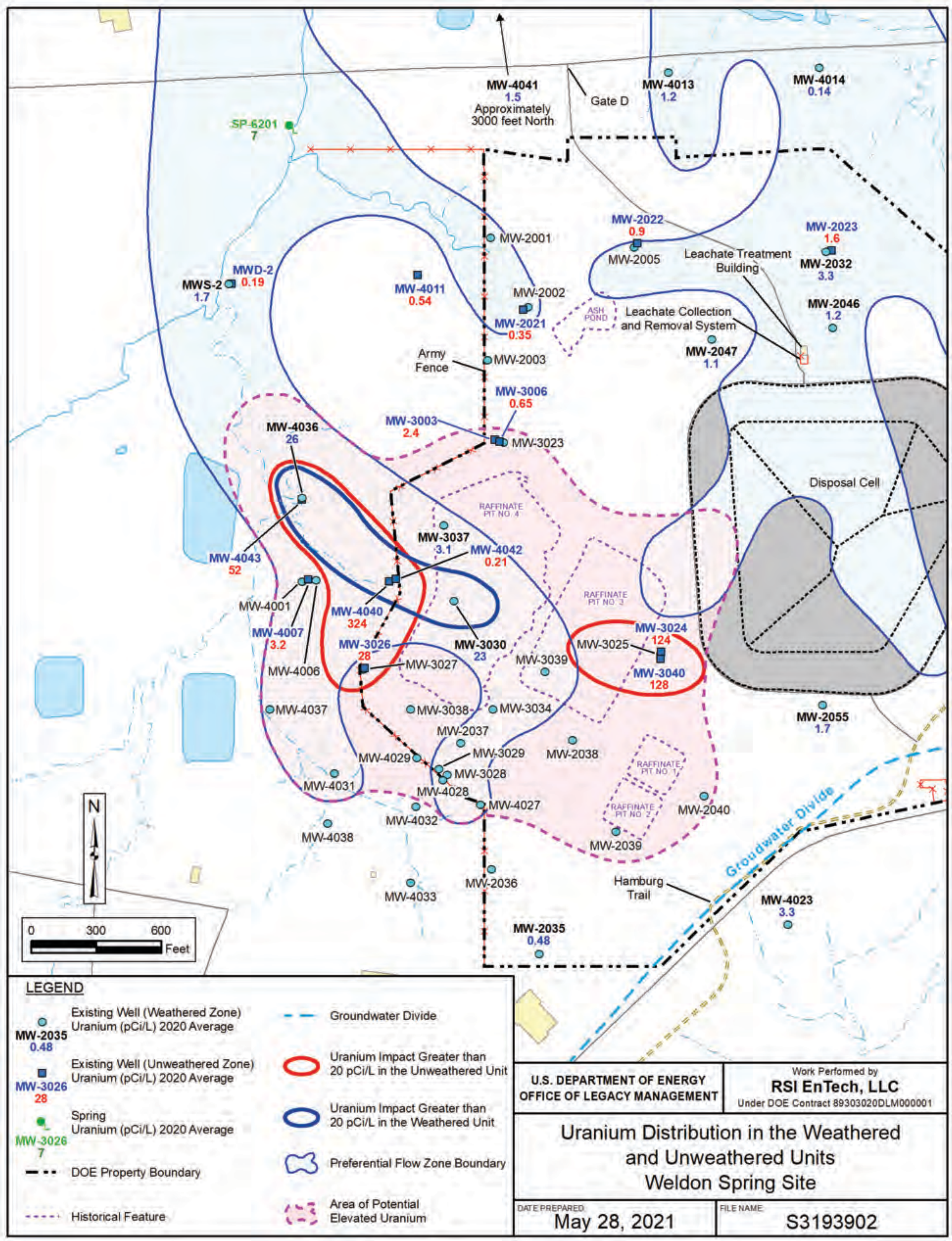


Figure 34. Uranium Distribution in the Weathered and Unweathered Units Average Uranium from 10/1/2017 to 10/1/2020

Unweathered Unit Uranium Monitoring Network

A subset of wells and springs was identified in a special study conducted from February 2012 to February 2014 to monitor the elevated uranium levels in the unweathered unit. This study was in response to the three impacted area wells that continue to exceed the 100 pCi/L trigger value for uranium in impacted areas (MW-4040, MW-3024, and MW-3040). The network has been expanded to include all 15 wells screened in the unweathered unit, advantageously located weathered unit wells, and three downgradient springs (Table 17). The study determined that sampling frequencies of the monitoring wells were adequate to detect any significant changes. The inclusion of historically low-concentration downgradient wells increases the likelihood of detecting potential future migration. The steadily declining uranium concentrations in downgradient well MW-4043 suggests that the uranium extent is shrinking in that area. Continued monitoring of uranium concentrations in unweathered unit wells, in weathered unit wells, and at surface locations will document the progression and protectiveness of the MNA remedy.

Nitrate GWOU Performance Monitoring Results

Elevated nitrate concentrations are present in the former Raffinate Pits area and former Ash Pond areas. Both are historical sources of this contaminant. Five weathered unit wells (MW-2047, MW-2001, MW-2002, MW-2003, MW-2005) and one unweathered unit well (MW-4011) in the former Ash Pond area were added to the nitrate monitoring network in 2018 in response to the increasing nitrate concentrations in downgradient well MWS-1 (Figure 35). Most of these wells had not been sampled for nitrate since 2006. The higher mobility of nitrate compared to that of other contaminants at the site has resulted in a larger distribution of this contaminant in the shallow aquifer. Nitrate levels exceed the MCL of 10 mg/L (for nitrate as N) in all the Objective 2 (source area) wells in both the weathered and unweathered units of the Burlington-Keokuk Limestone. Table 18 presents a summary of the nitrate data for the period from 2016 through 2020.

Nitrate concentrations are highest in the weathered unit of the Burlington-Keokuk Limestone in the former Raffinate Pits area. Concentrations in wells MW-2038, MW-3003, MW-4029, MW-3034, and MW-4013 are all currently above 100 mg/L but below the 1350 mg/L fixed trigger value (Figure 36). Well MW-4031 recently dropped below 100 mg/L due to a long-term decreasing trend (Figure 37). Average nitrate concentrations in well MW-4013 have been just above or below 100 mg/L over the past 15 years (Figure 38). Concentrations in wells MW-2040 and MW-4036 are below 100 mg/L but above the 10 mg/L MCL. The past 5 years of data indicate no statistically significant trend in MW-4013, MW-2040, or MW-4036 for the 2016–2020 period (Figure 38).

Recent data indicate that concentrations are decreasing (5-year negative slopes) in the higher-concentration weathered unit wells, with only MW-3003 and MW-4031 meeting the criteria for statistical significance. Concentrations are relatively stable in the lower-concentration weathered unit wells, though MW-4036 varies about an order of magnitude. Well MW-4036 is within the preferential flow path that extends north from Raffinate Pit 4. Its variability (Figure 39) appears to be related to dilution during wet periods when there is a strong upward gradient from the underlying unweathered unit, which has low nitrate concentrations. This is the opposite of what is seen for uranium, which has higher concentrations in the unweathered unit that increase weathered unit uranium concentrations during wet periods.

Table 17. Unweathered Unit Uranium Monitoring Network Locations

Location	Objective	Unit	Average Uranium[a] 2012–2014 Study (pCi/L)	Average Uranium 2020 (pCi/L)	Recommended Frequency (samples per year)
MW-4040	2	Unweathered	338 (14)	318	4
MW-3026[b]	2	Unweathered	36.8 (1)	6.7	4
MW-3040	2	Unweathered	119 (13)	128	4
MW-3024	2	Unweathered	132 (13)	122	4
MW-3003	2	Weathered[c]	2.9 (10)	2.3	4
MW-3006	2	Unweathered	0.57 (12)	0.59	4
MW-4042	4	Unweathered	0.24 (12)	0.20	4
MW-4043	3	Unweathered	76.7 (13)	46	4
MW-4036[b]	3	Weathered	19.6 (13)	18	4
MWS-2	3	Weathered	1.6 (12)	1.8	4
MWD-2	3	Unweathered	0.19 (12)	0.19	4
MW-4007	3	Unweathered	2.5 (12)	3.2	4
MW-4011[b]	3	Unweathered	0.53 (1)	0.55	2
MW-4041	3	Weathered	1.5 (12)	1.5	4
MW-2021[b]	3	Unweathered	0.53 (1)	0.38	2
MW-2022[b]	3	Unweathered	1.0 (1)	1.0	2
MW-2023[b]	3	Unweathered	NS	1.6	2
MW-2032[b]	3	Weathered	2.0 (4)	3.8	2
MW-2056[b]	3	Unweathered	NS	1.7	1
MW-4013[b]	3	Weathered	NS	1.6	1
MW-4014[b]	3	Weathered	NS	0.15	1
SP-6201	5	Spring	7.5 (10)	8.2	4
SP-6301	5	Spring	37.8 (13)	12.2	4
SP-6303[b]	5	Spring	0.25 (2)	Dry	4
MW-4022	1	Unweathered	2.8 (3)	2.4	1

Notes:
[a] Value in parentheses is number of samples used to calculate the average.
[b] Wells and springs added to the unweathered unit monitoring network in 2014.
[c] MW-3003 is screened across the weathered–unweathered unit interface.
Well locations are in Figure 9, and the spring locations are in Figure 13.
Objective 1 = upgradient locations.
Objective 2 = area of groundwater impact.
Objective 3 = downgradient and lateral locations.
Objective 4 = locations beneath the area of groundwater impact.
Objective 5 = springs or surface water locations.
2020 averages are from 10/1/2019 through 10/1/2020.
MW-3040 and MW-4040, originally planned as Objective 4, were reclassified to Objective 2.

Abbreviation:
NS = not sampled

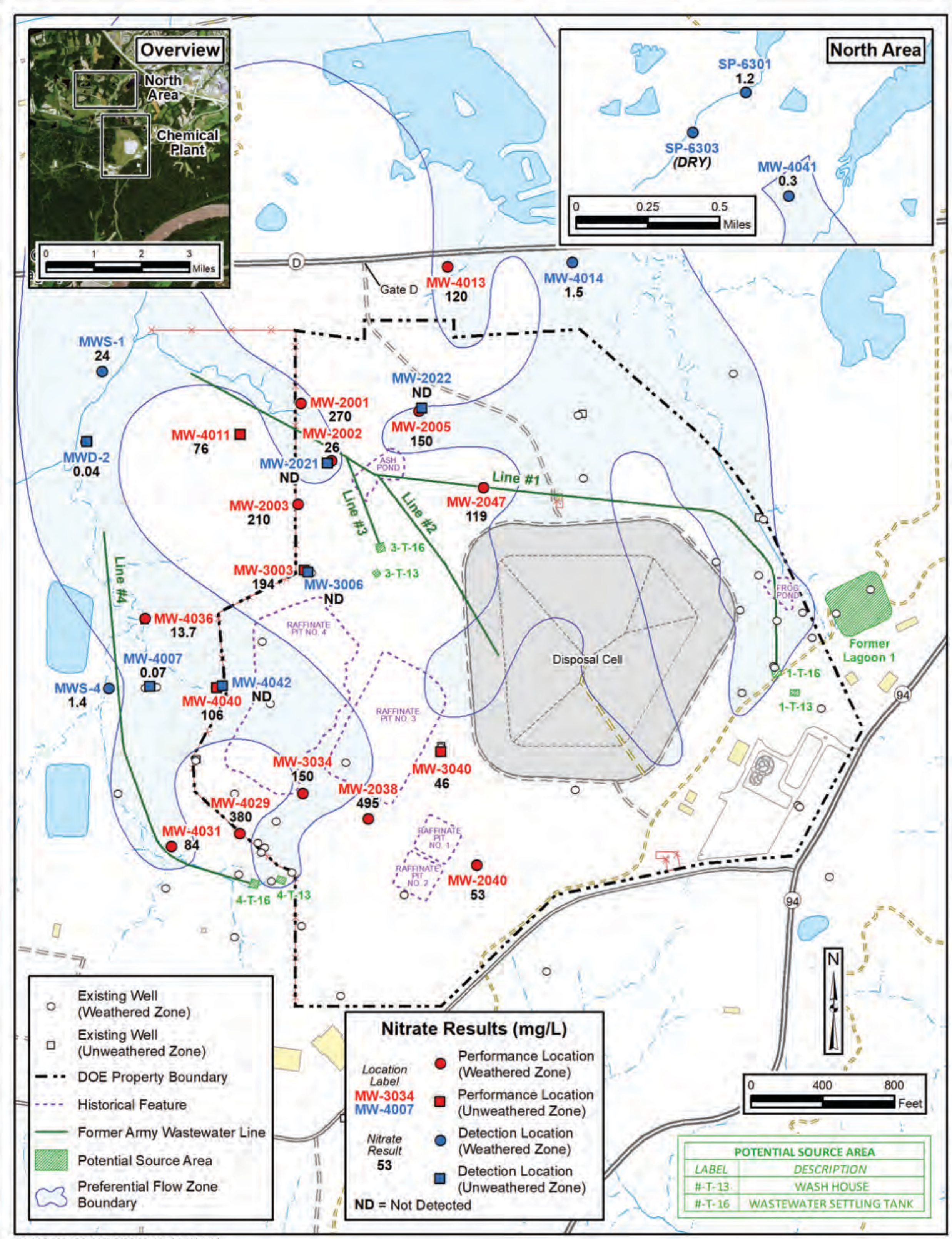


Figure 35. Nitrate Monitoring Locations with 2020 Average Concentrations

Table 18. Average Nitrate Concentration from GWOU Performance Monitoring Wells

Location	Nitrate Concentration (mg/L)				
	2016	2017	2018	2019	2020
Weathered Unit					
MW-2038	405	440	440	385	495
MW-3003	412	336	273	260	194
MW-4029	405	480	450	385	380
MW-3034	170	180	175	160	150
MW-4031	141	101	95	102	84
MW-4013	103	127	122	125	120
MW-2040	60	64	74	53	53
MW-4036	10	16	16	13	14
MW-2047[a]	--	109	118	119	119
MW-2001[a]	--	--	284	298	270
MW-2002[a]	--	--	56	6.3	26
MW-2003[a]	--	--	238	258	210
MW-2005[a]	--	--	172	171	150
Unweathered Unit					
MW-3040	65	59	54	50	46
MW-4040	118	118	117	110	106
MW-4011[a]	--	93	81	73	76

Note:
[a] Wells near the former Ash Pond added to the nitrate monitoring network in 2018.

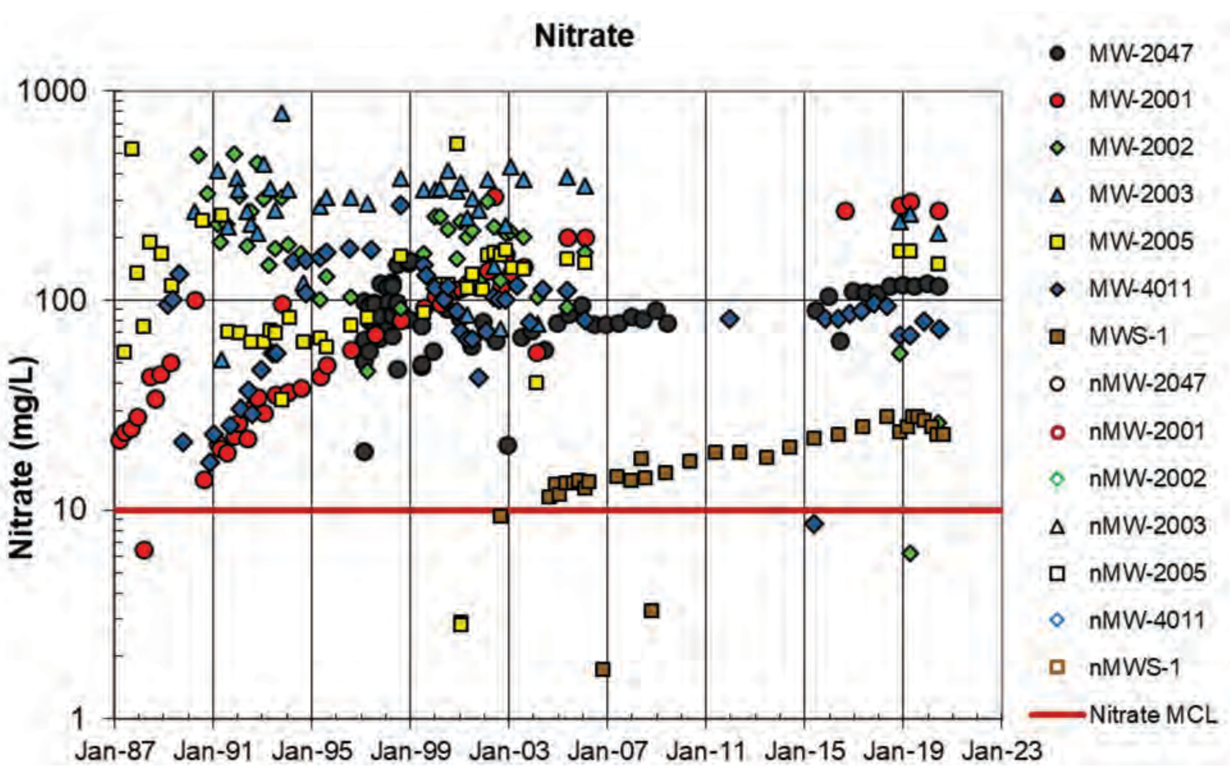


Figure 36. Nitrate at Performance Monitoring Locations Added in 2018 (MWS-1 for comparison)

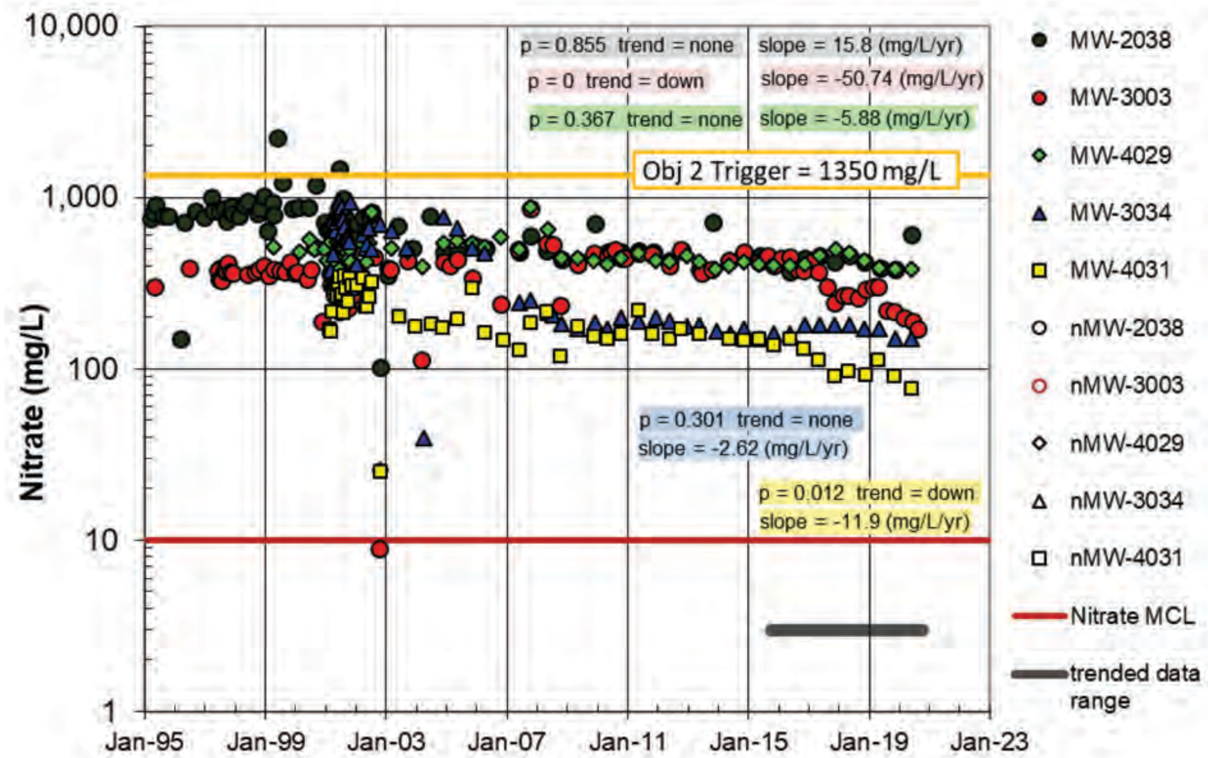


Figure 37. Nitrate at Performance Monitoring Wells—Weathered Unit (Higher Concentration Wells)

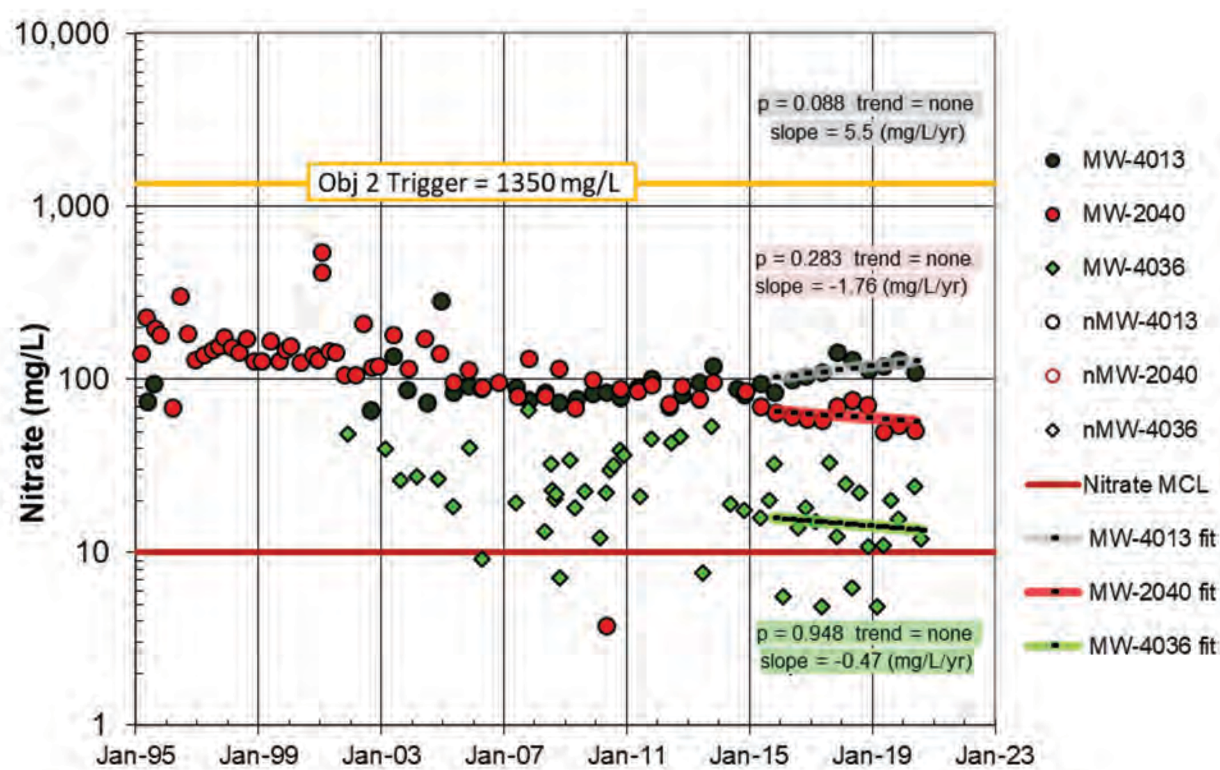


Figure 38. Nitrate in Performance Monitoring Wells—Weathered Unit (Lower Concentration Wells)

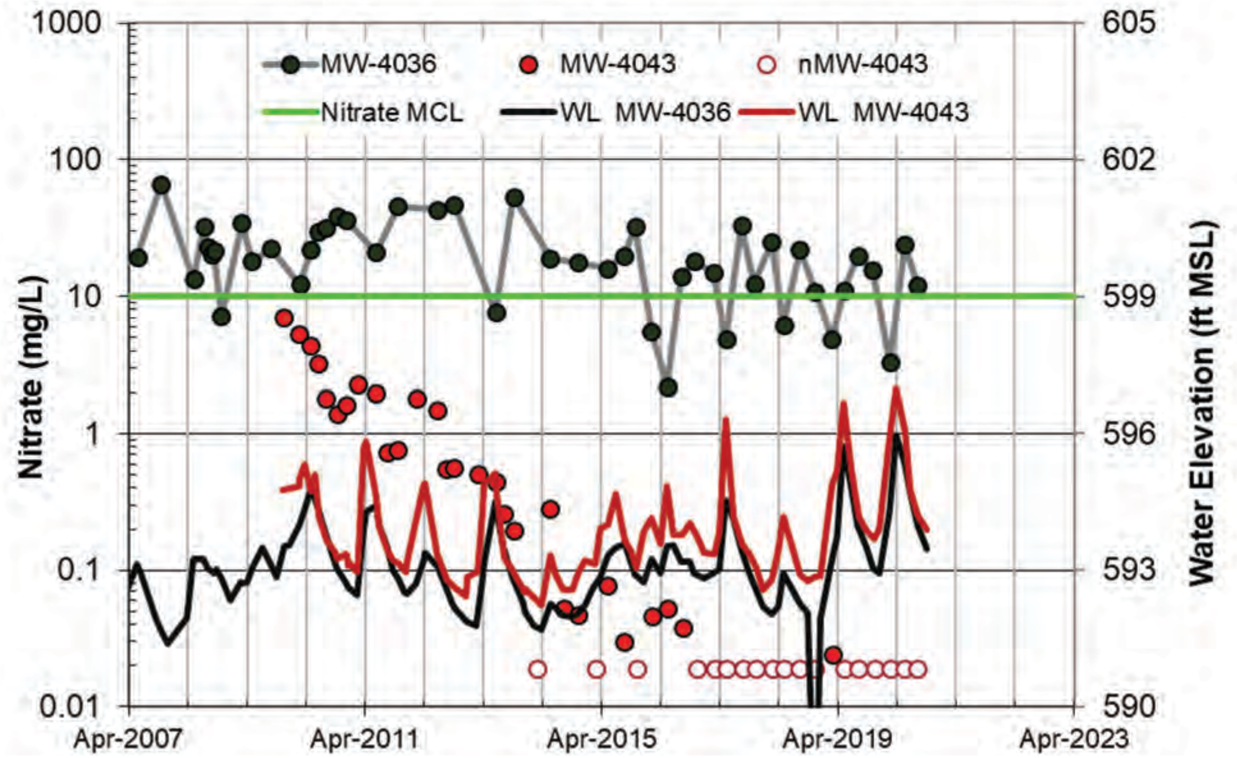


Figure 39. Nitrate Concentrations in Wells MW-4036 and MW-4043

Nitrate concentrations in the unweathered unit (Figure 40) exceed the 10 mg/L MCL in the Raffinate Pits area and at MW-4011 (Figure 36), west of the former Ash Pond. Nitrate concentrations in well MW-4040 (near Raffinate Pit 4) have been relatively stable, with no observable trend since it was installed. Nitrate in well MW-3040 has had a consistent decreasing trend over the long term and the past 5 years, and concentrations at this well could reach the 10 mg/L MCL by 2040. Well MW-3024, which is adjacent to MW-3040, is screened over the same 10 ft interval as MW-3040 plus an additional 10 ft above (20 ft screened interval, with the upper 10 ft nearer the weathered-unweathered unit transition). Nitrate in MW-3024 has a persistent decreasing trend, but at a slower rate that will take longer to reach the 10 mg/L MCL. Nitrate in unweathered unit well MW-4036 rapidly decreased until it reached the detection limit in 2016 (Figure 39). MW-4043 is the well in the west paleochannel downgradient of the source area that has had a steady but slower decrease in uranium concentration (Figure 25).

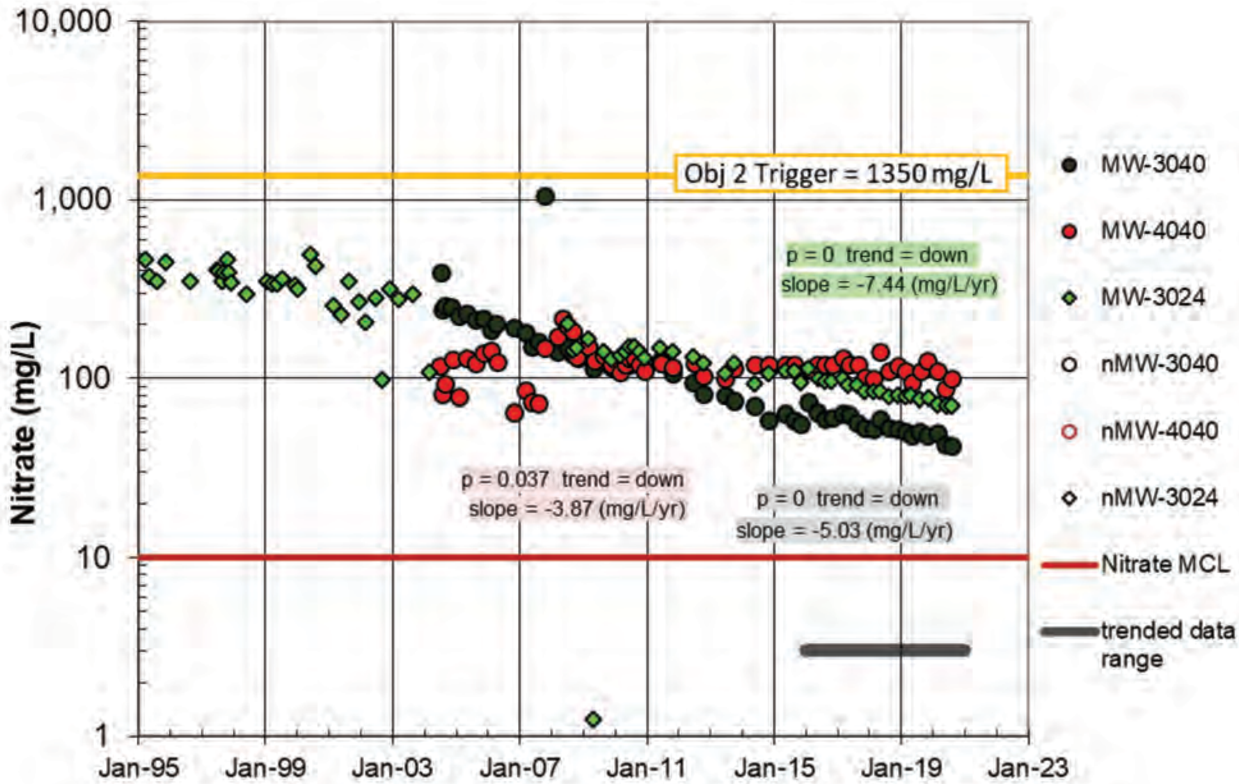


Figure 40. Nitrate in Performance Monitoring Wells—Unweathered Unit

Overall, nitrate impact is contained within the upper portion of the shallow aquifer (weathered and upper unweathered units of the Burlington-Keokuk Limestone). Nitrate concentrations in the weathered and unweathered units are decreasing except along the leading edge of the area of impact in the weathered unit. Some locations were expected to show temporary upward trends due to ongoing dispersion; however, concentrations are not expected to exceed historical maximums seen within the areas of highest impact. The higher mobility of nitrate compared to that of other contaminants at the site has resulted in quicker flushing of this contaminant from the aquifer system.

Nitrate GWOU Detection Monitoring Results

Results at nitrate detection monitoring locations (Table 19) indicate that nitrate migration from the area of impact is behaving as expected. Migration has been restricted to the weathered unit, with only well MWS-1 exceeding the 10 mg/L MCL (Figure 41). Average concentrations of nitrate in well MWS-1 have exceeded the MCL since 2005 and have been slowly increasing. Army well MWS-1 is near the intersection of several former Army nitroaromatic wastewater lines. Trend analysis of data over the last 10 years indicates a long-term upward trend. The nitrate sampling frequency at MWS-1 was increased to semiannual in 2018. The fall 2019 (dry period) result (26.9 mg/L) broke the trend of increasing results, and the sampling frequency was increased to quarterly for 2019 to determine if results are seasonally variable. Results appear to have a seasonal response (through 2020 results) that may become more clear with another year of quarterly samples in 2021 (Figure 41). MWS-1 had been sampled annually in the spring for the previous 10 years.

Table 19. Nitrate Detection Monitoring Locations for the GWOU

Location	Detection Monitoring Areas
Weathered Unit	
MW-4014	Fringe
MW-4041	Downgradient
MWS-1	Downgradient
MWS-4	Downgradient
Unweathered Unit	
MW-2021	Vertical extent
MW-2022	Vertical extent
MW-3006	Fringe
MW-4007	Downgradient
MW-4042	Downgradient
MWD-2	Downgradient
Springs and Surface Water	
SP-6301	Burgermeister Spring
SP-6303	Burgermeister Spring branch

The nitrate concentrations in unweathered unit detection monitoring wells have been consistently more than an order of magnitude below the 10 mg/L MCL (Figure 42). Well MW-4007 has had small temporary increases that subside with concentrations remaining in a limited range.

The nitrate concentrations in Burgermeister Spring ranged from 0.4 to 5.4 mg/L from 2016 through 2020—below the MCL of 10 mg/L. All nitrate concentrations in Burgermeister Spring have been below the MCL since 2003 (Figure 43). Nitrate concentrations in SP-6303, dry since 2013, typically track those of Burgermeister Spring when flowing.

Trend analysis of Burgermeister Spring (SP-6301) results indicates that nitrate concentrations are continuing to decrease (Figure 43). Analysis of the data collected from 2016 through 2020 indicated no statistically significant trend, though concentrations vary by about an order of magnitude. Inspection of the maximum nitrate concentrations since 2008 show values have been flat with maximum values consistently at 4 to 5 mg/L, indicating the range of nitrate values at Burgermeister Spring has stabilized.

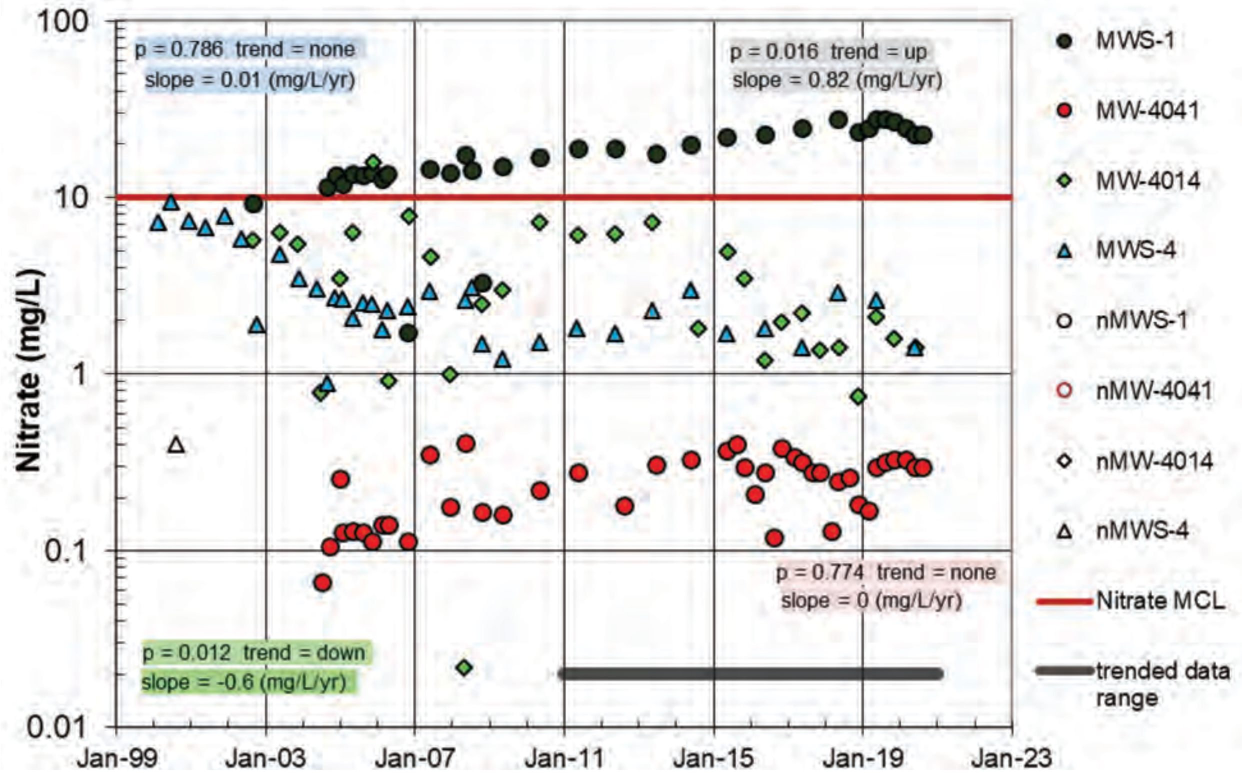


Figure 41. Nitrate in Detection Monitoring Wells—Weathered Unit

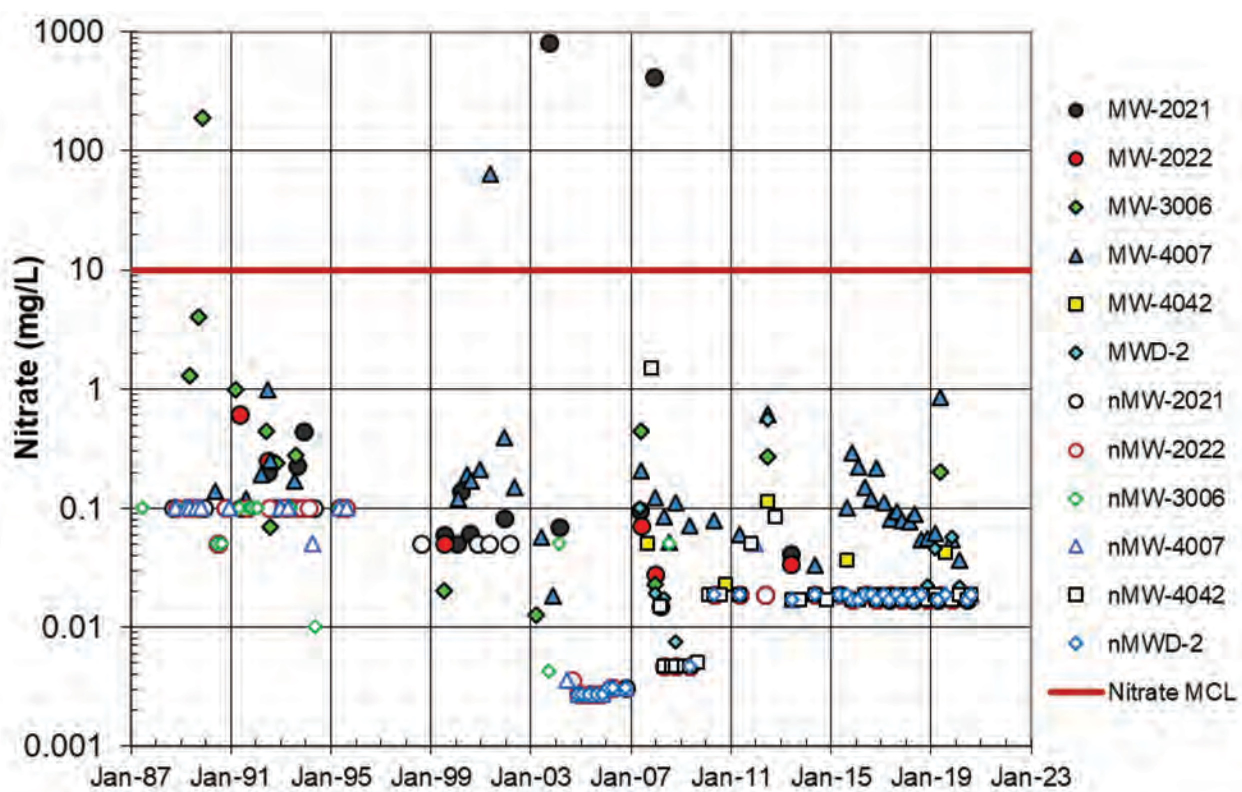
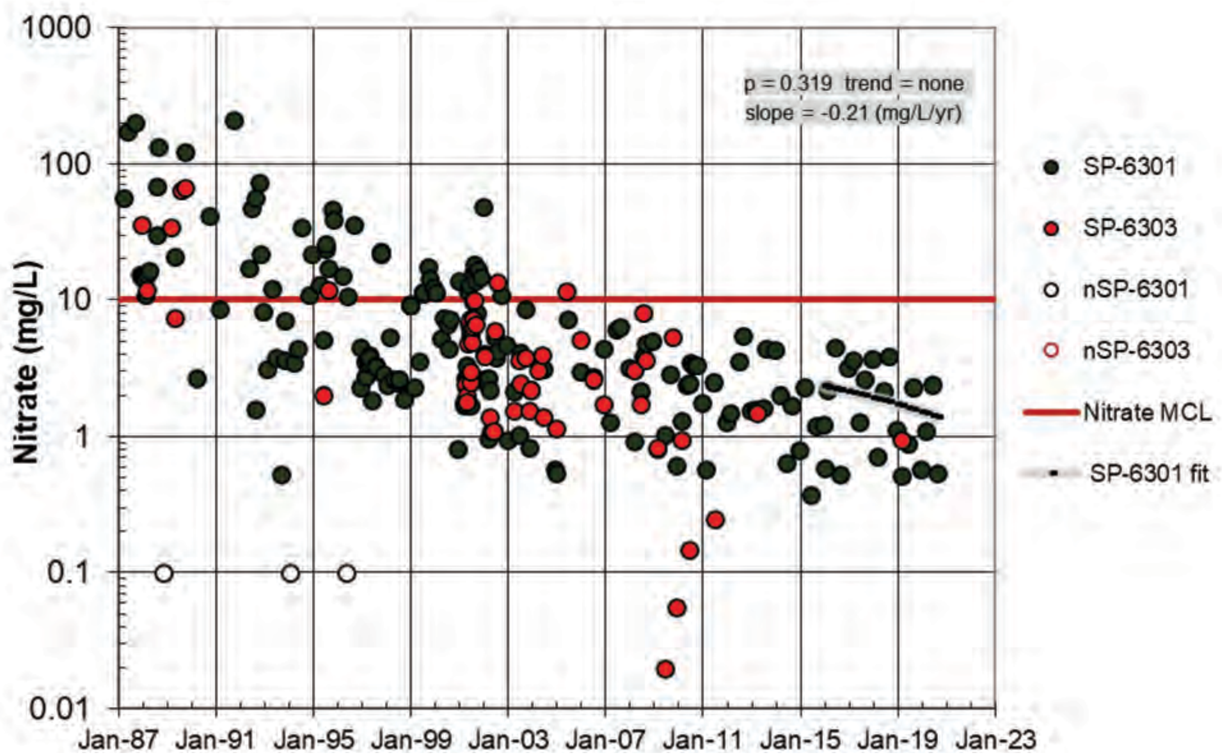


Figure 42. Nitrate in Detection Monitoring Wells—Unweathered Unit



Note: SP-6303 has been dry since April 2013 except for a sample collected in February 2019.

Figure 43. Nitrate in Burgermeister Spring (SP-6301) and SP-6303

Trichloroethene GWOU Performance Monitoring Results

TCE contamination in the shallow groundwater is near former Raffinate Pit 4, where it is suspected that drums containing TCE were discarded. TCE impact is detected only in the weathered unit of the Burlington-Keokuk Limestone. Table 20 presents a summary of the TCE data for the period from 2016 through 2020, and Figure 44 shows well locations and 2020 average TCE concentrations.

Table 20. Average TCE Concentrations from GWOU Performance Monitoring Wells

Location	TCE Concentration (µg/L)				
	2016	2017	2018	2019	2020
MW-3030	165	155	160	146	150
MW-3034	103	100	86	85	80
MW-4029	305	315	345	325	260

TCE impact is highest in well MW-4029, along a preferential flow pathway in the area. The TCE concentrations in MW-3030 and MW-3034 (Figure 45) have varied over time; however, some changes are a result of rebound from field studies performed in 2001 and 2002. Data from recent years indicate decreases in TCE concentrations in these three wells.

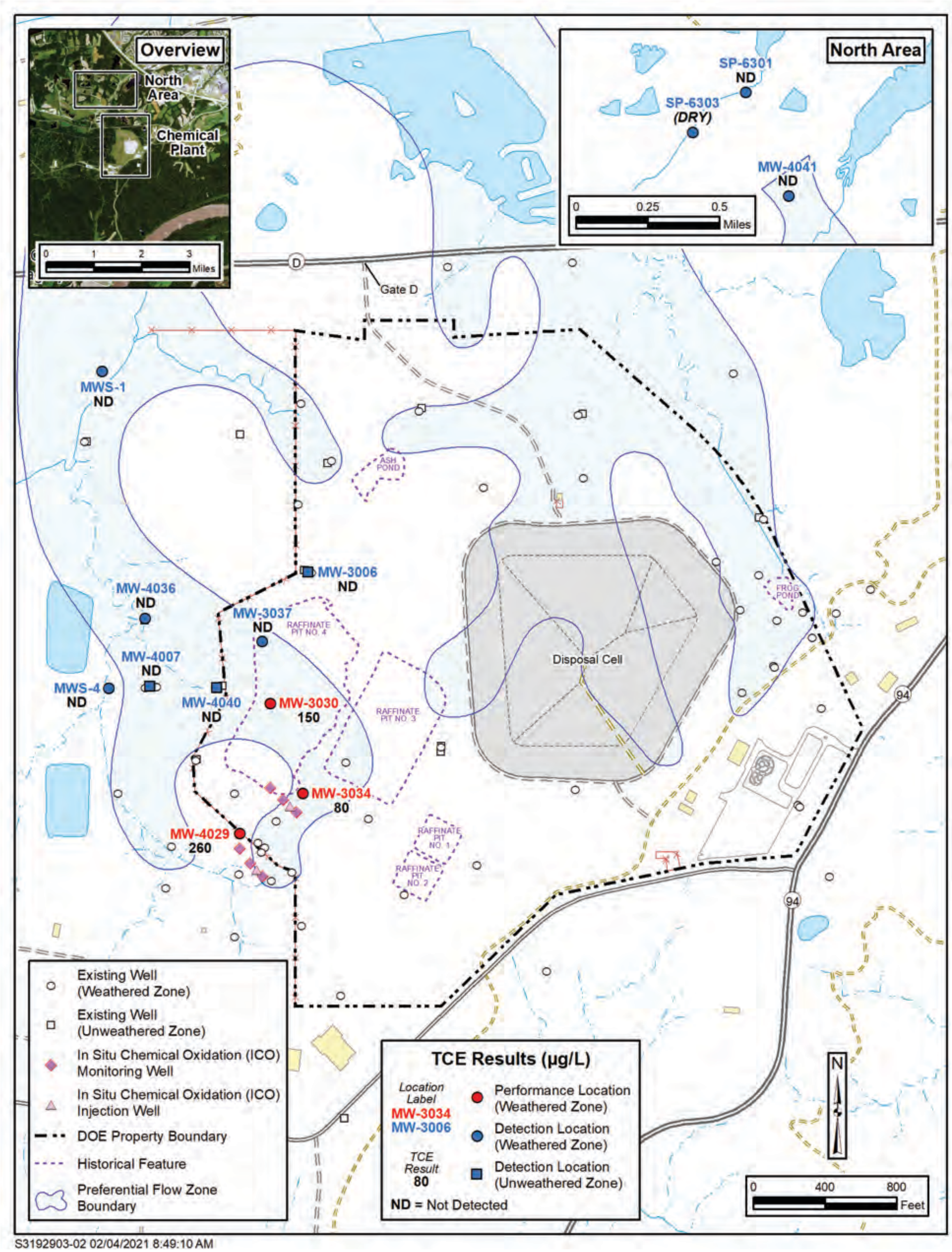


Figure 44. TCE Monitoring Locations with 2020 Average Concentrations

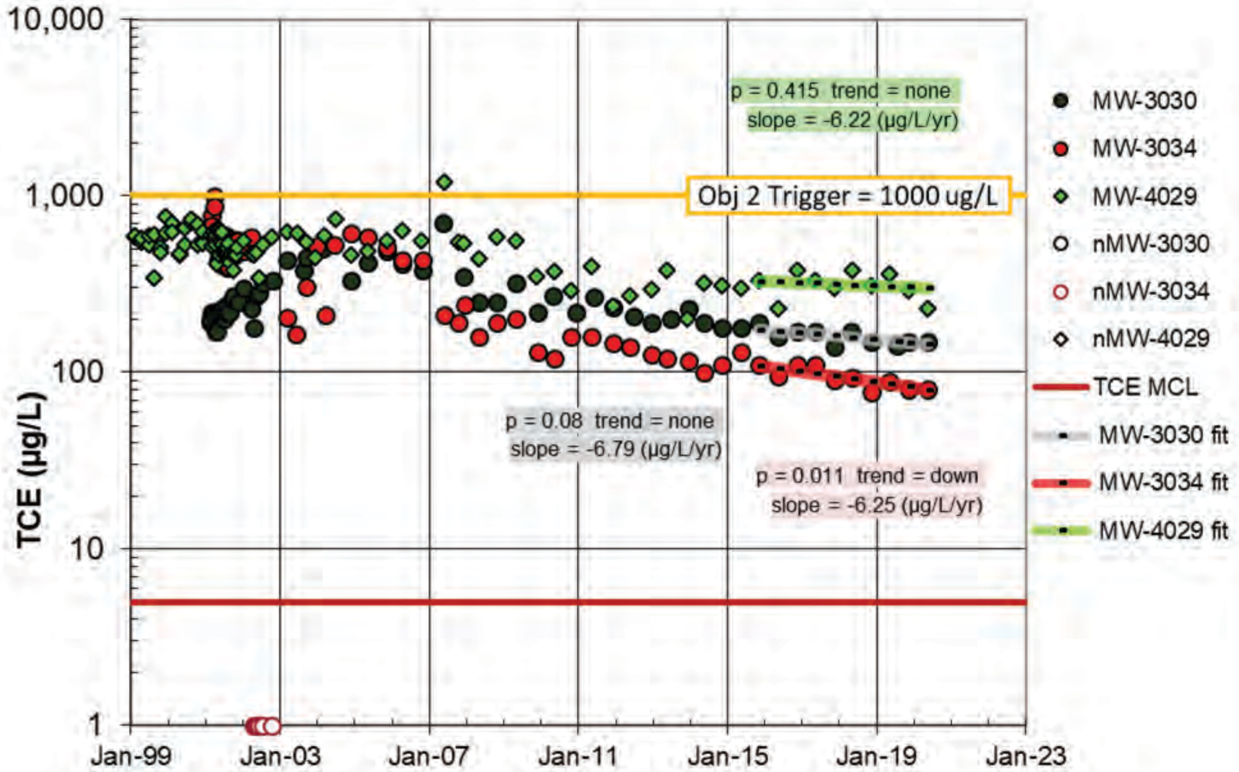


Figure 45. TCE in Performance Monitoring Wells

Concentrations of TCE in all of the Objective 2 (impacted area) wells continue to exceed the 5 µg/L cleanup standard.

Results of the trend analysis indicate that TCE concentrations in groundwater are decreasing. A statistically significant downward trend was calculated for MW-3030 using data from 2016 through 2020. TCE concentrations are trending down for all three wells using datasets for a longer period.

Low levels of the TCE degradation product *cis*-1,2-dichloroethene were measured in the three Objective 2 wells with concentrations significantly below the 70 µg/L MCL (Figure 46). Results of *trans*-1,2-DCE were all less than 1 µg/L and either reported as estimated or nondetect values in the three Objective 2 wells. No reportable concentrations of vinyl chloride were detected in any of the Objective 2 wells. Analysis of *cis*-1,2-DCE in monitoring well MW-3030 indicated a downtrend over the past 5 years. The geochemistry of the groundwater at the Chemical Plant is oxidizing; therefore, reductive dechlorination of TCE is limited.

Overall, TCE impact is confined to a discrete area of the Chemical Plant site and is limited to the weathered unit of the Burlington-Keokuk Limestone. TCE concentrations in the weathered unit are slowly decreasing in the area of impact.

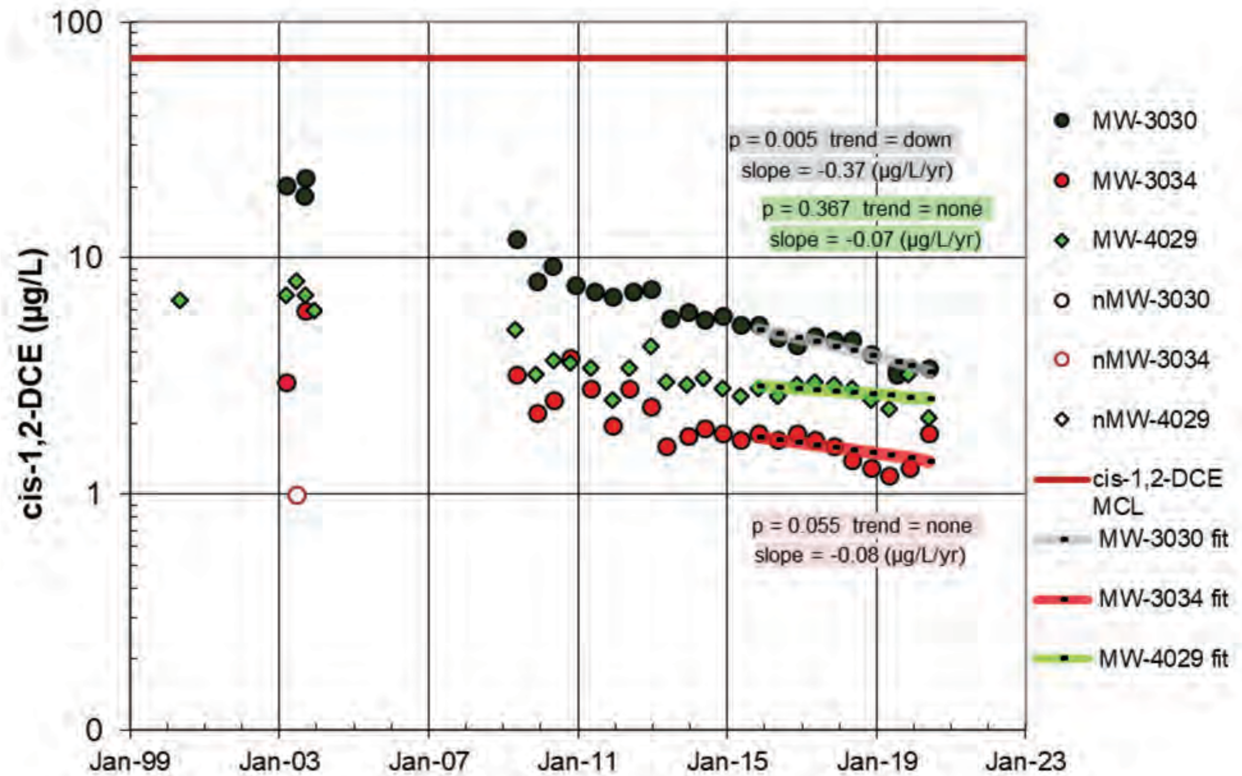


Figure 46. cis-1,2-DCE in Performance Monitoring Wells

Trichloroethene GWOU Detection Monitoring Results

No detections or estimated values of TCE were reported in the detection monitoring wells (weathered unit, Figure 47; unweathered unit, Figure 48) or at Burgermeister Spring from 2016 through 2020. The February 2019 sample from SP-6303 was reported as nondetect. The data from the past 5 years indicate that the area of TCE impact has not expanded, either laterally or vertically. No reportable concentrations of the degradation products *cis*-1,2-DCE, *trans*-1,2-DCE, or vinyl chloride were detected at any of the detection monitoring locations.

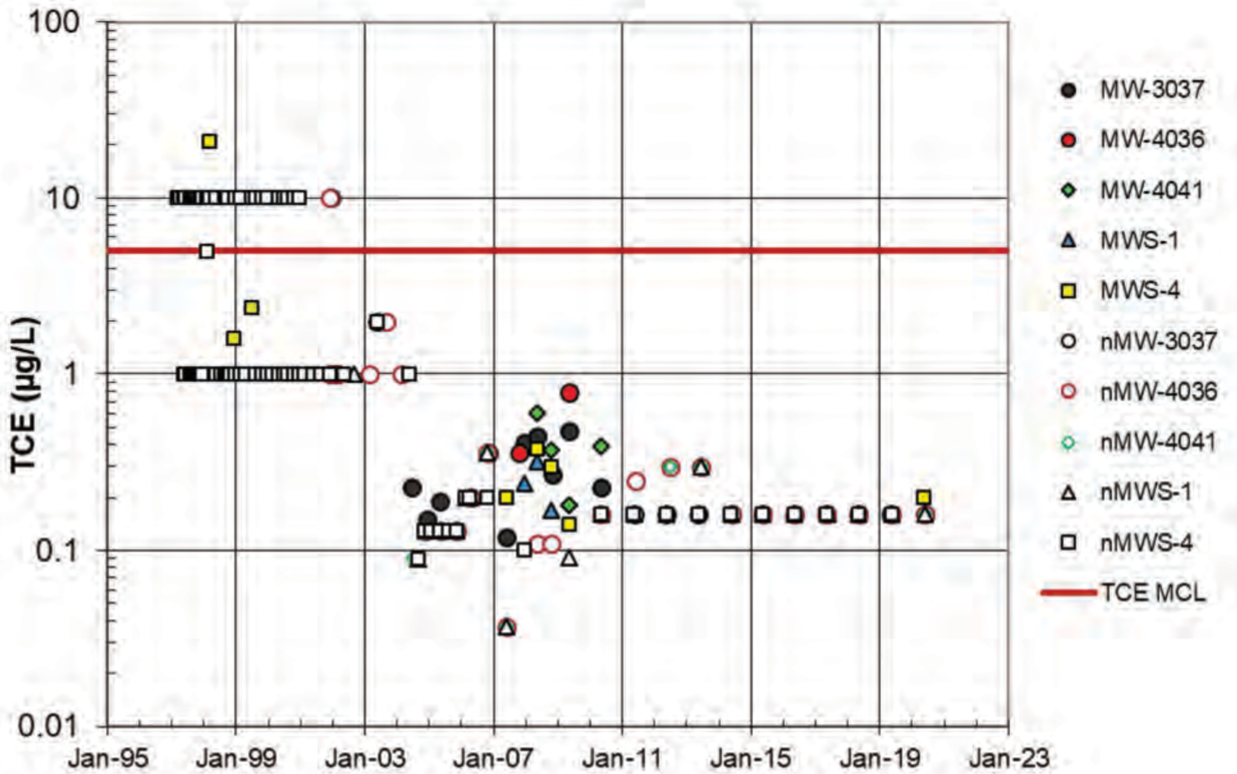


Figure 47. TCE in Detection Monitoring Wells—Weathered Unit

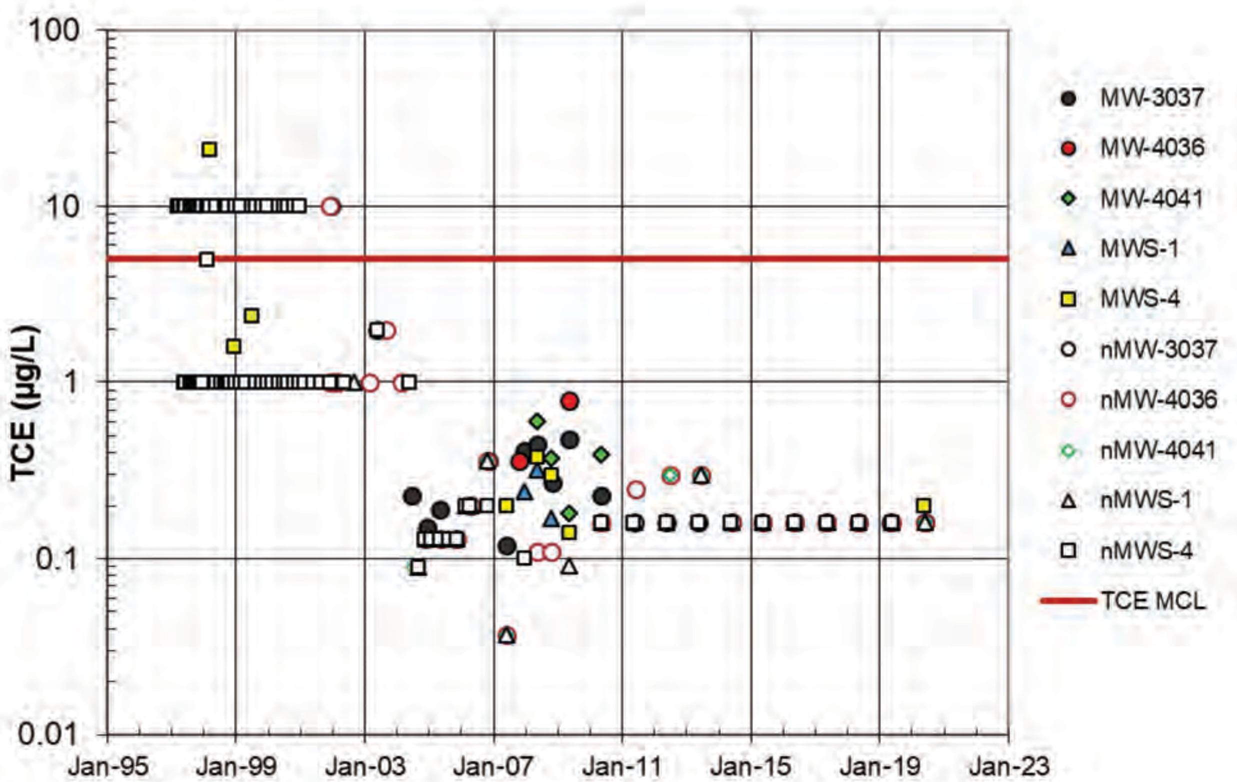


Figure 48. TCE in Detection Monitoring Wells—Unweathered Unit

Nitroaromatic Compounds GWOU Performance Monitoring Results

Former Frog Pond Area

The former Frog Pond area, northeast of the disposal cell, is the most significant area of nitroaromatic compound impact for groundwater at the site and is limited to the weathered unit of the Burlington-Keokuk Limestone. Groundwater in this area has historically had concentrations above the cleanup standards for 1,3-DNB; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; and NB. Concentrations of nitroaromatic compounds increased in this area starting in 1997. More recent data from several performance monitoring wells indicate that concentrations of some compounds have decreased to below cleanup standards and others are trending down.

The distribution of nitroaromatic compounds suggests that the primary source area is Production Line 1, most notably the wash house (T-13) and the wastewater settling tank (T-16) (Figure 19). Some contribution to the nitroaromatic contamination originates from Army Lagoon 1. The preferential flow path near the former Frog Pond has been identified from the bedrock topography, and the contaminant distribution is somewhat controlled by that topography. The impact of nitroaromatic compounds in the former Frog Pond area is isolated to the Burlington-Keokuk Limestone weathered unit.

Nitroaromatic compound concentrations, primarily for the DNTs, have continued to be variable in the former Frog Pond area. Starting in 1997, increases in concentrations were reported, and concentrations increased dramatically during and after the completion of soil excavation in this area and remedial activities performed by USACE in nearby Army Lagoon 1. Also, during this time, groundwater elevations steadily decreased, likely in response to removal of the Frog Pond and redirection of surface water runoff, both of which reduced the amount of infiltration into the groundwater system. Concentrations of nitroaromatic compounds in several wells in this area decreased substantially in 2004.

Since 2007, DNT concentrations in well MW-2012 have varied by 2 to 3 orders of magnitude. The suspected cause is the increased infiltration of surface water runoff during the wet season through a subsidence feature that formed near MW-2012. The surface cracked and subsided in an area where trenching was performed and backfilled during remediation. The continued influence of surface water infiltration is indicated by the fluctuation of groundwater elevations in several Objective 2 wells near the preferential flow pathway in the area (Figure 49). Large fluctuations in groundwater elevations occurred historically when Frog Pond and surface water drainage features were present before remediation. In recent years, groundwater elevations and seasonal variability have generally increased in wells along the preferential pathway, most notably in MW-2012 and MW-2052. This increase is likely attributed to surface water contribution in a natural drainage channel that is beginning to establish in this area.

The “MCL” lines on the data charts for 1,3-DNB and 2,4-DNT are ROD cleanup standards based on Missouri water quality standards. The “MCL” lines on the data charts for 2,6-DNT and 2,4,6-TNT are risk-based ROD cleanup standards. Table 8.1 of the *Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2004b) provides the basis for the cleanup standards.

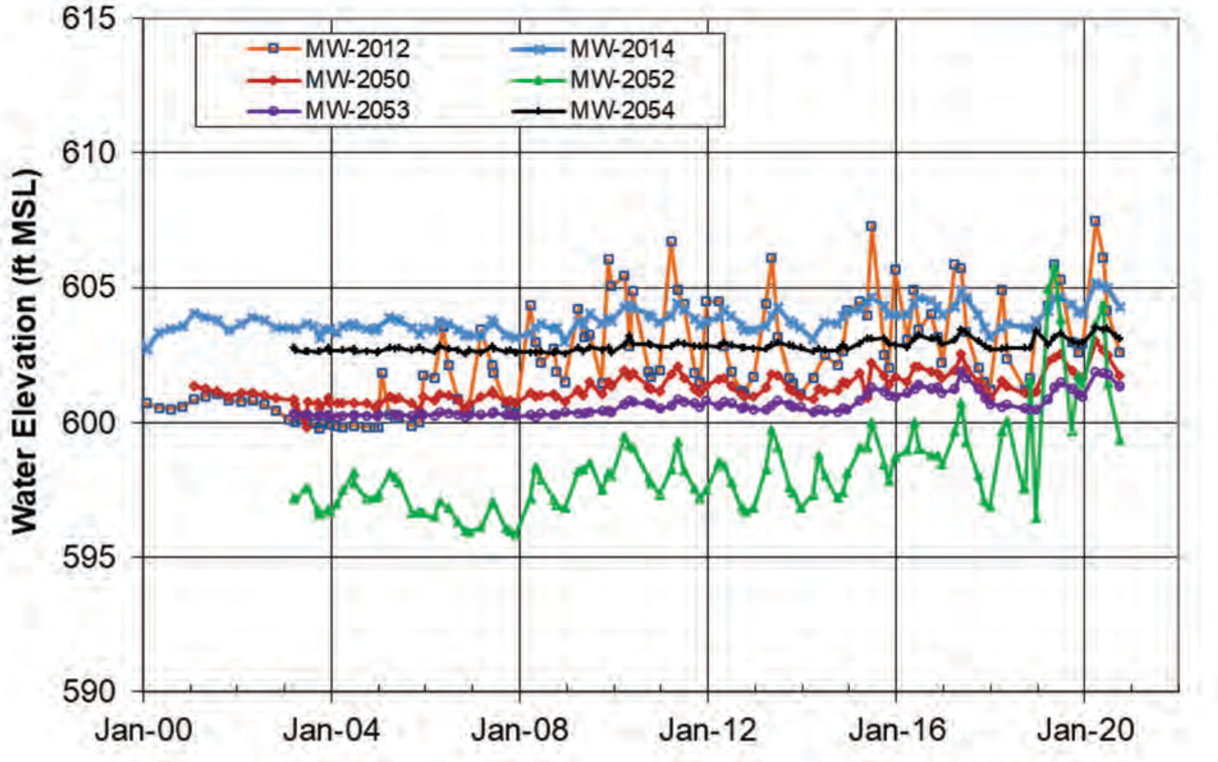


Figure 49. Groundwater Elevations in Frog Pond Area Monitoring Wells

1,3-DNB

Performance monitoring concentrations of 1,3-DNB in well MW-2012 were above the 1 micrograms per liter (µg/L) cleanup standard from late 2001 to early 2006 but have remained below that level since then (Figure 50). Decreases in 1,3-DNB are expected, as this nitroaromatic compound is a photodegradation product of 2,4-DNT, which has also been decreasing. Increases in the concentrations of this compound began during the period that 2,4-DNT–impacted soils were being excavated in this area. Exposure of impacted soil likely resulted in some photodegradation and subsequent infiltration into the aquifer system. Concentrations of 1,3-DNB in wells MW-2050, MW-2052, and MW-2053 have not been above the 1,3-DNB MCL but are impacted by 2,4-DNT. They are included in Figure 50 to illustrate the decline in 1,3-DNB concentrations in MW-2012 since 2003.

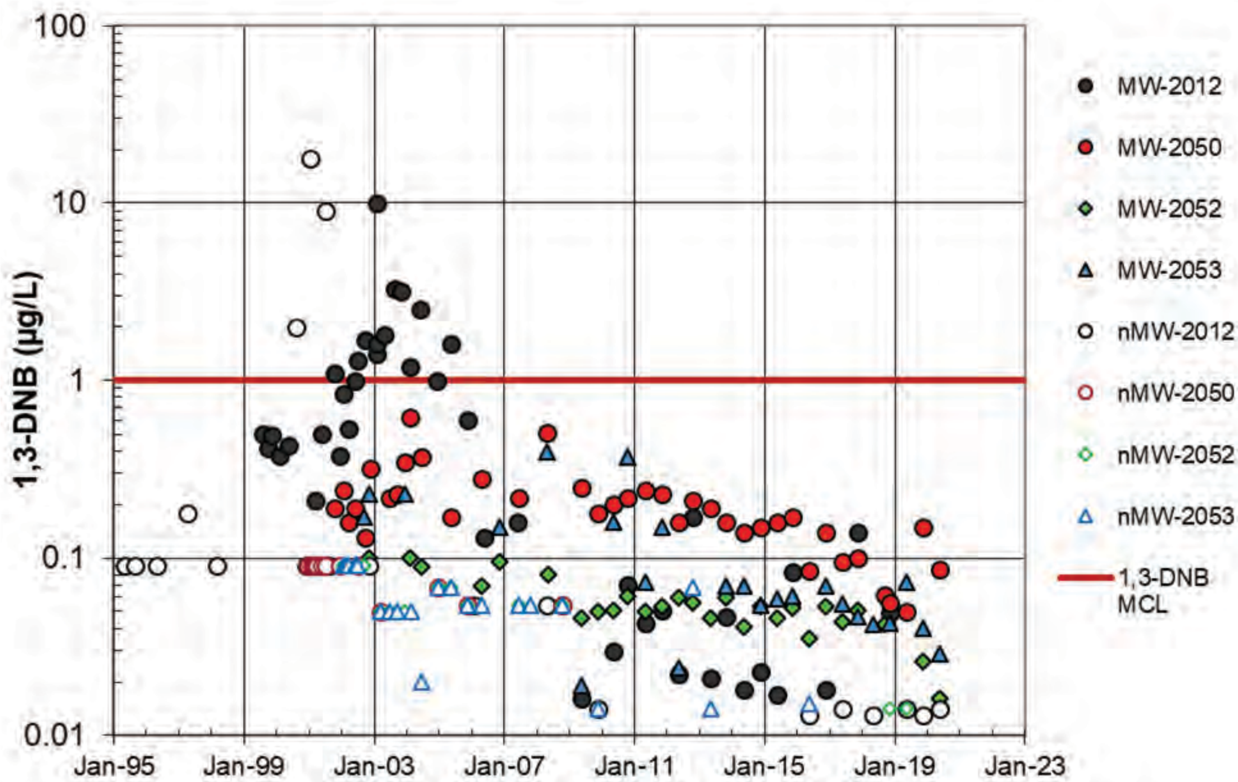


Figure 50. 1,3-DNB in Performance Monitoring Well MW-2012
(Data for MW-2050, MW-2052, and MW-2053 are plotted for comparison)

Detection monitoring location (Table 21) results for 1,3-DNB show that no downgradient migration of impacted groundwater has occurred from the area of known impact within the weathered unit (Figure 51). Fringe location MW-2051 has low concentrations of 1,3-DNB, and these concentrations are consistent with historical data. Fringe location MW-4039 had several low-level detects in 2017, 2019, and 2020 that were laboratory qualified as estimated (Figure 51). The data from the unweathered unit wells (Figure 52) indicate that the impacted groundwater in the overlying weathered unit has not moved downward. None of the concentrations reported exceeded the trigger levels set for the Objective 3 or 4 wells or the Objective 5 springs.

Table 21. 1,3-DNB Detection Monitoring Locations for GWOU Detection Monitoring Locations

Locations	Detection Monitoring Areas
Weathered Unit	
MW-2032	Fringe
MW-2051	Fringe
MW-4014	Downgradient
MW-4039	Fringe
MW-4041	Downgradient—far
Unweathered Unit	
MW-2022	Vertical extent
MW-2023	Vertical extent
MW-2056	Vertical extent
Springs	
SP-6301	Burgermeister Spring
SP-6303	Burgermeister Spring branch

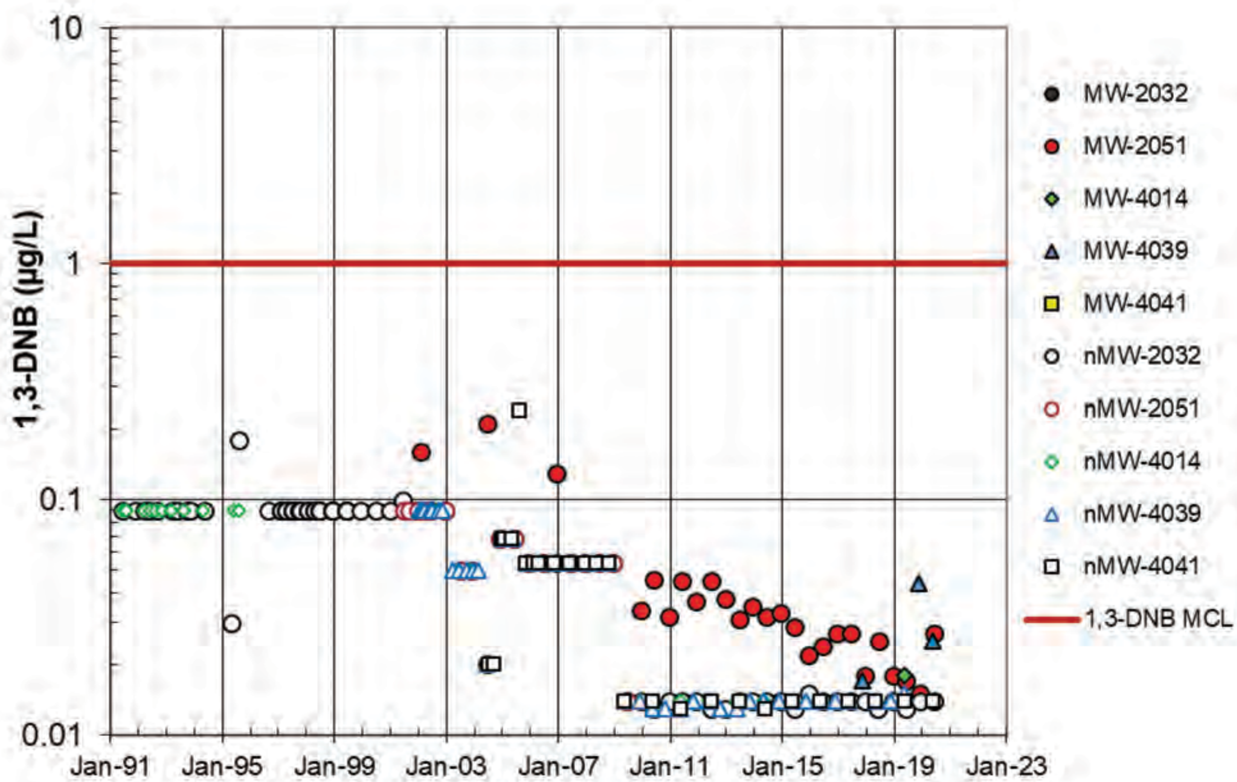


Figure 51. 1,3-DNB in Detection Monitoring Wells—Weathered Unit

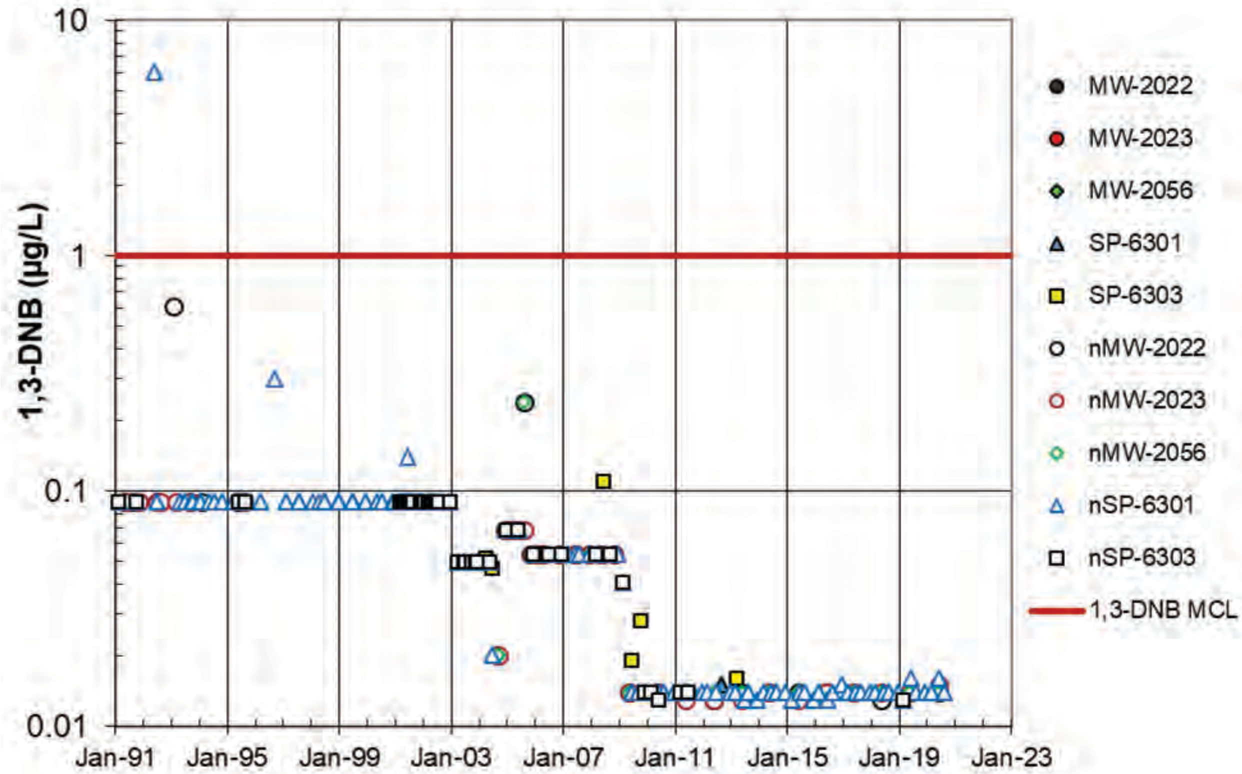


Figure 52. 1,3-DNB in Detection Monitoring Wells—Unweathered Unit and Springs

Nitrobenzene

The nitroaromatic compound NB has not been detected during the last 5 years. The cleanup standard for NB is 17 µg/L. No NB has been detected (without validation qualifiers) in any of the Objective 3, 4, or 5 detection monitoring locations since the MNA program began in 2004.

2,4,6-TNT Performance Monitoring Results

All yearly average 2,4,6-TNT concentrations reported at monitoring locations (Figure 53) from 2016 through 2020 were slightly above or below the cleanup standard of 2.8 µg/L (Table 22). Individual results at MW-2012 and MW-2053 are variable and were both above and below the cleanup standard for the past 5 years (Figure 54). A comparison of water levels and concentrations shows a slight inverse correlation, with lower concentrations when water levels are higher, suggesting dilution.

Table 22. Average 2,4,6-TNT from GWOU Performance Monitoring Wells

Location	2,4,6-TNT Concentration (µg/L)				
	2016	2017	2018	2019	2020
MW-2012	1.2	5.6	4.6	3.8	4.5
MW-2046	0.41	0.37	0.37	0.38	0.36
MW-2053	0.81	2.6	2.9	1.5	3.8

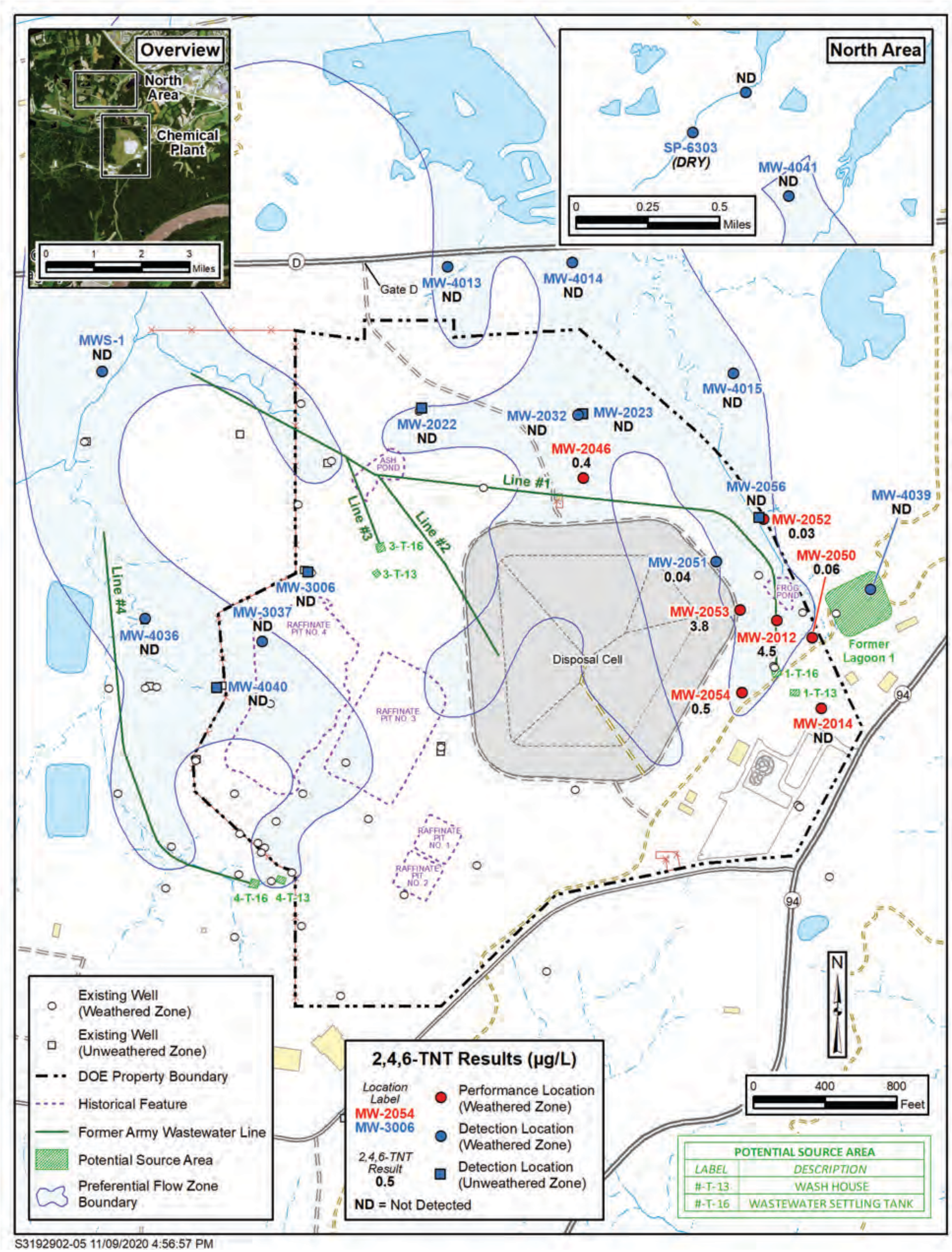


Figure 53. 2,4,6-TNT Monitoring Locations with 2020 Average Concentrations

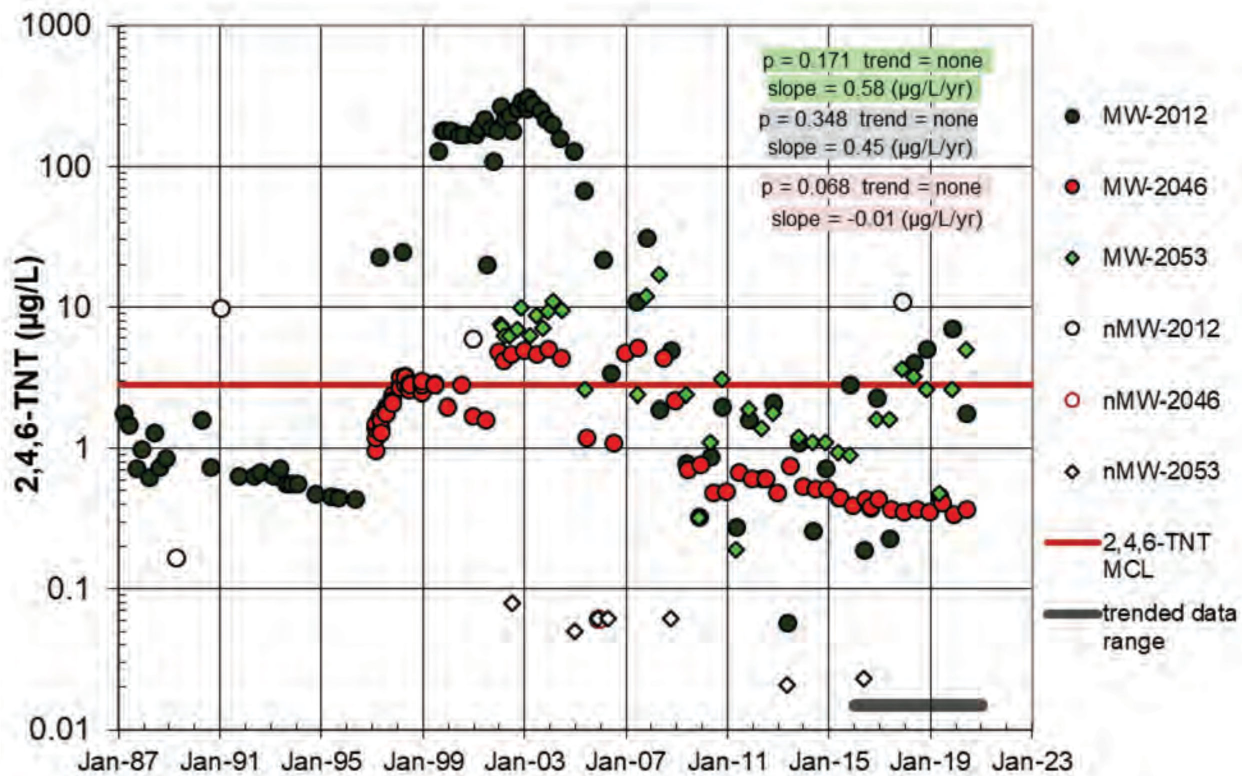


Figure 54. 2,4,6-TNT in Performance Monitoring Wells

2,4,6-TNT Detection Monitoring Results

The 2,4,6-TNT concentrations reported in weathered unit detection monitoring wells (Table 23) indicate that impacted water has not migrated downgradient beyond the area of known impact. All weathered unit wells have 2,4,6-TNT concentrations at or below the detection limit except MW-2051, which has detectable but low concentrations (Figure 55). No reportable concentrations of 2,4,6-TNT were detected in the unweathered unit wells during the past 5 years (Figure 56).

The concentrations reported in Burgermeister Spring have been below the detection limit for the past 10 years. Low-level estimated detections were reported at SP-6303 in 2013 and 2019, the only two times it has not been dry in the last 8 years (Figure 56). None of the concentrations reported exceeded the trigger levels set for the Objective 3 or 4 wells or the Objective 5 springs.

Table 23. 2,4,6-TNT GWOU Detection Monitoring Locations

Locations	2,4,6-TNT
	Detection Monitoring Areas
Weathered Unit	
MW-2032	Fringe
MW-2051	Fringe
MW-4014	Downgradient
MW-4039	Fringe
MW-4041	Downgradient—far
Unweathered Unit	
MW-2022	Vertical extent
MW-2023	Vertical extent
MW-2056	Vertical extent
Springs	
SP-6301	Burgermeister Spring
SP-6303	Burgermeister Spring branch

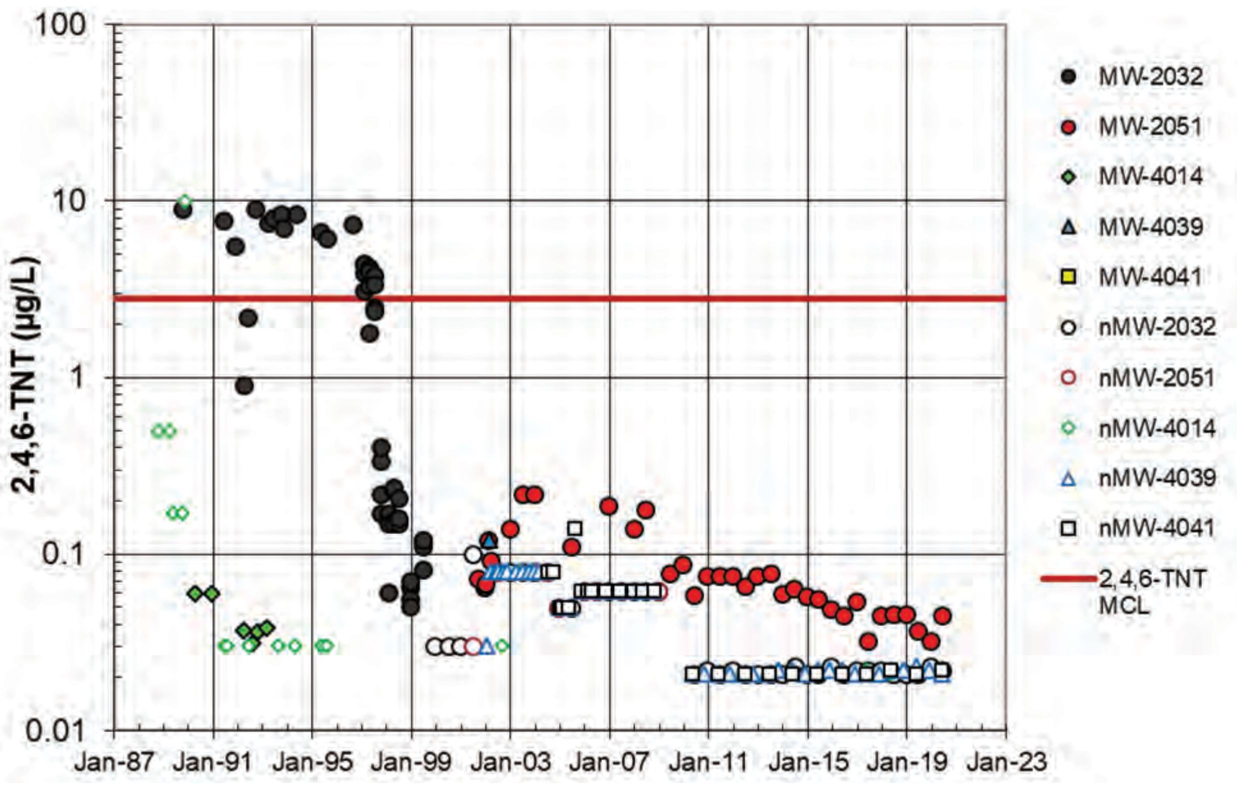


Figure 55. 2,4,6-TNT in Weathered Unit Detection Monitoring Wells

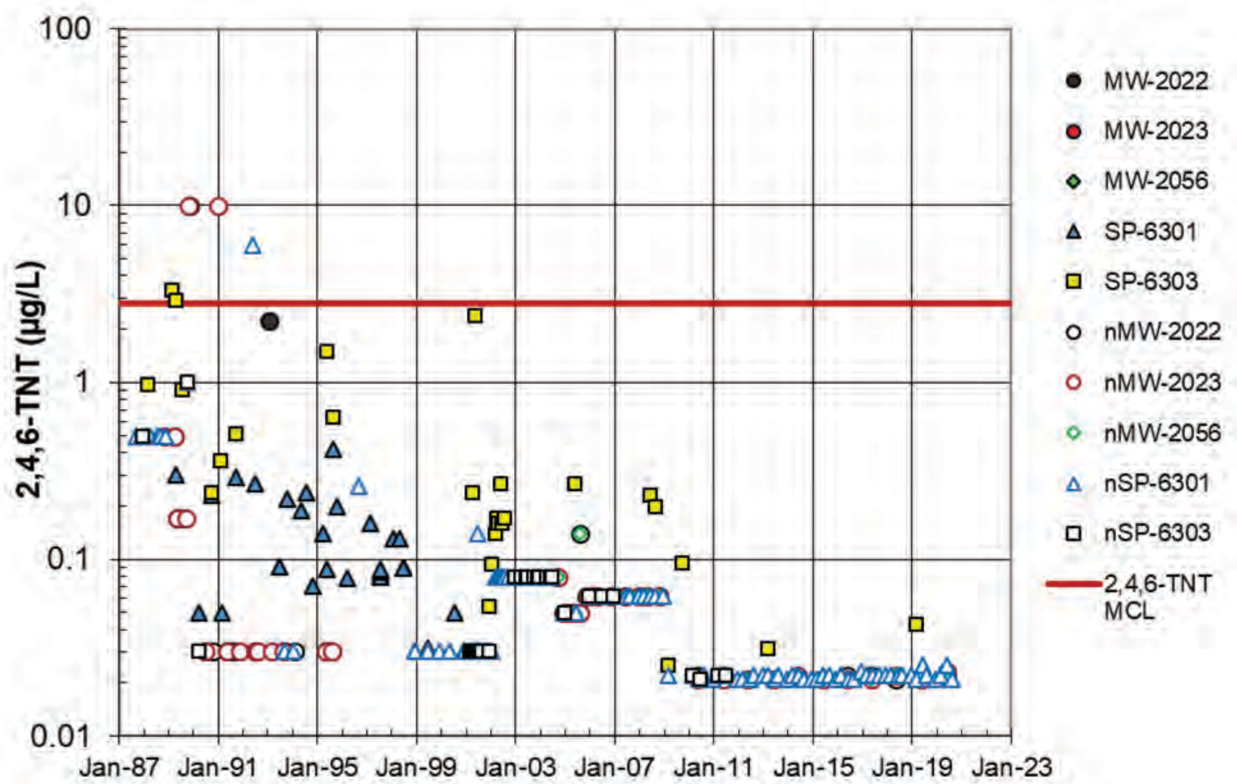


Figure 56. 2,4,6-TNT in Unweathered Unit Detection Monitoring Wells and Springs

2,4-DNT and 2,6-DNT Performance Monitoring

The most persistent nitroaromatic compounds in groundwater at the site are 2,4-DNT and 2,6-DNT. Figure 57 shows the locations of the performance and detection monitoring wells and average 2,4-DNT and 2,6-DNT concentrations for 2020. Data from the last few years indicate that concentrations of DNT have been variable in most of the Objective 2 wells (Table 24 and Table 25). The variability can be attributed to sporadic infiltration of surface water into the groundwater system. Concentrations of these compounds are typically higher during periods of low groundwater elevations and decrease as groundwater elevations rise. Surface water infiltration temporarily dilutes the concentrations in groundwater.

Table 24. Average 2,4-DNT from GWOU Performance Monitoring Wells in the Frog Pond Area

Location	2,4-DNT Concentration (µg/L)				
	2016	2017	2018	2019	2020
MW-2012	0.019 (U)	41	4.9	0.40	0.35
MW-2050	0.019 (U)	0.66	1.3	0.97	1.2
MW-2053	0.020 (U)	0.020 (U)	0.07	0.11	0.019(U)
MW-2014	0.13	0.15	0.11	0.12	0.12
MW-2052	0.023	0.049	0.029	0.02(U)	0.02(U)
MW-2054	0.082	0.075	0.072	0.07	0.64

Abbreviation:
(U) = analyte not detected above reporting limit for any samples during the year (2 samples per year)

Table 25. Average 2,6-DNT from GWOU Performance Monitoring Wells in the Frog Pond Area

Location	2,6-DNT Concentration (µg/L)				
	2016	2017	2018	2019	2020
MW-2012	2.2	66	19	2.3	2.0
MW-2050	18	12	6.0	6.9	7.8
MW-2053	1.7	2.8	1.5	1.7	1.9
MW-2014	0.24	0.43	0.34	0.30	0.30
MW-2052	0.099	0.21	0.055	0.022(U)	0.022(U)
MW-2054	0.20	0.22	0.25	0.23	0.38

Abbreviation:
(U) = analyte not detected above reporting limit for any samples during the year (2 samples per year)

Wells with higher 2,4-DNT and 2,6-DNT concentrations in the former Frog Pond area, downgradient of the TNT production buildings and Army Lagoon 1, are generally the most variable in that concentrations can be diluted when infiltration is high (Figure 58 and Figure 59). Lower-concentration wells are more stable because they are farther from the source area and dilution has little effect on already low concentrations (Figure 60 and Figure 61). Typically, the highest concentrations of these two compounds are reported in MW-2012; due to the variability, this is not always true. The highly variable 2,4-DNT concentrations in MW-2012 are typically related to water elevations (as are the 2,4,6-TNT concentrations); higher concentrations occur when water levels are low (Figure 62). Well MW-2050 is the most stable higher-concentration well, and it is the farthest upgradient from the former Frog Pond.

Concentrations of 2,4-DNT in lower-concentration wells MW-2014, MW-2052, and MW-2054 were below (MW-2052 and MW-2054) or near (MW-2014) the cleanup standard of 0.11 µg/L (Figure 60). Concentrations of 2,6-DNT in the lower-concentration wells were below the cleanup standard of 1.3 µg/L for all samples collected from 2016 through 2020 (Figure 61).

The calculated trends of MW-2012 and MW-2053 currently are not meaningful because the concentrations are highly variable. Although results need to be more stable before it is possible to estimate when cleanup standards will be reached, the high variability is accompanied by generally lower overall lower concentrations. The last 5 years of data from the stable higher-concentration wells MW-2050 and MW-2053 do not indicate any statistically significant trends. The lower-concentration wells are relatively stable with long-term decreasing concentrations of 2,4-DNT and 2,6-DNT. The only well with a statistically significant downward trend over the last 5 years of data was MW-2052 for 2,6-DNT. This downtrend was caused by the last four results being nondetects. MW-2052 is near an area where rapid infiltration occurs after times of heavy runoff (Figure 10). Water levels in MW-2052 increase as much as 5 ft within hours after significant precipitation events (Figure 18). MW-2052 is also scheduled for maintenance due to filter pack being present in much of the screened interval.

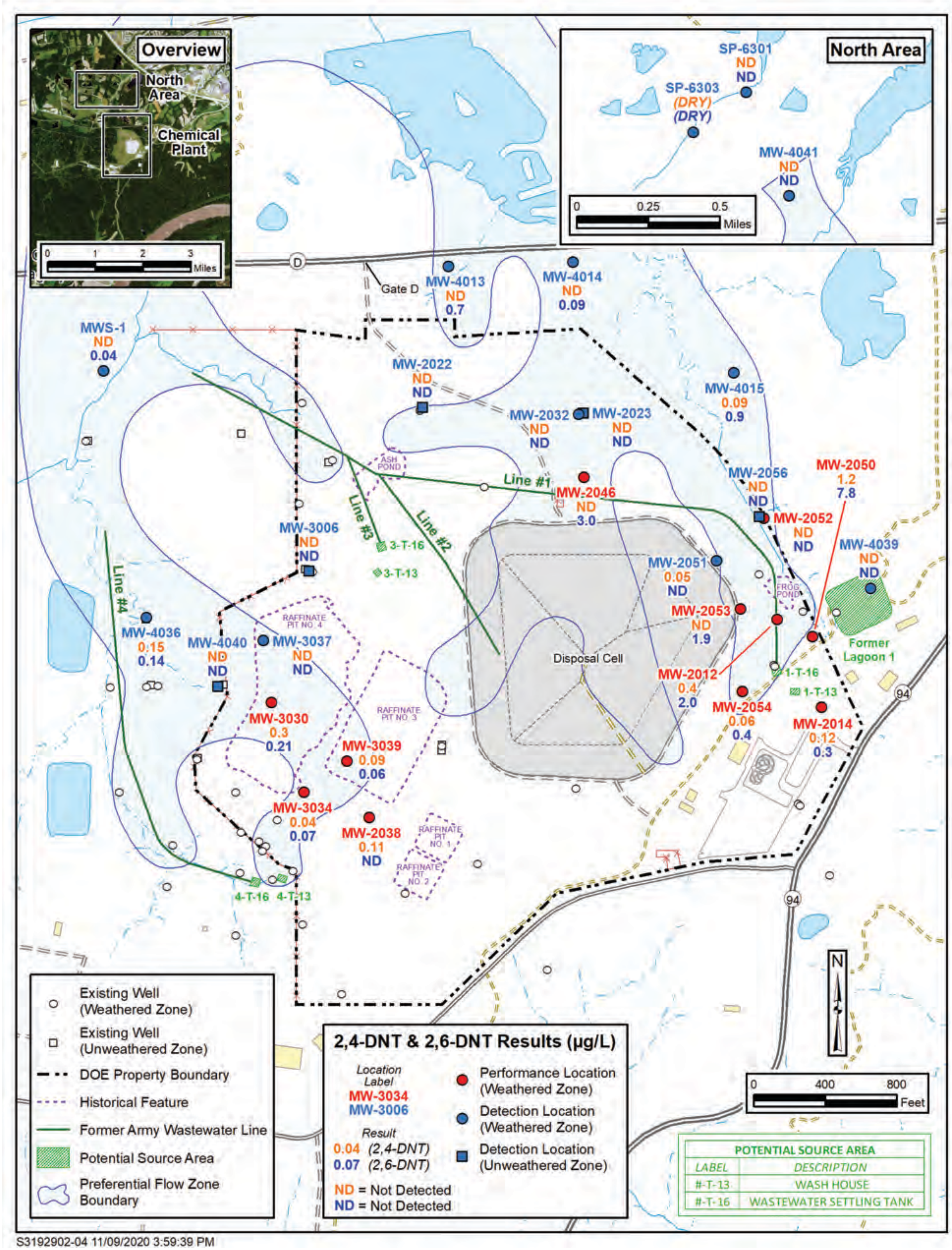


Figure 57. 2,4-DNT and 2,6-DNT Monitoring Locations with 2020 Average Concentrations

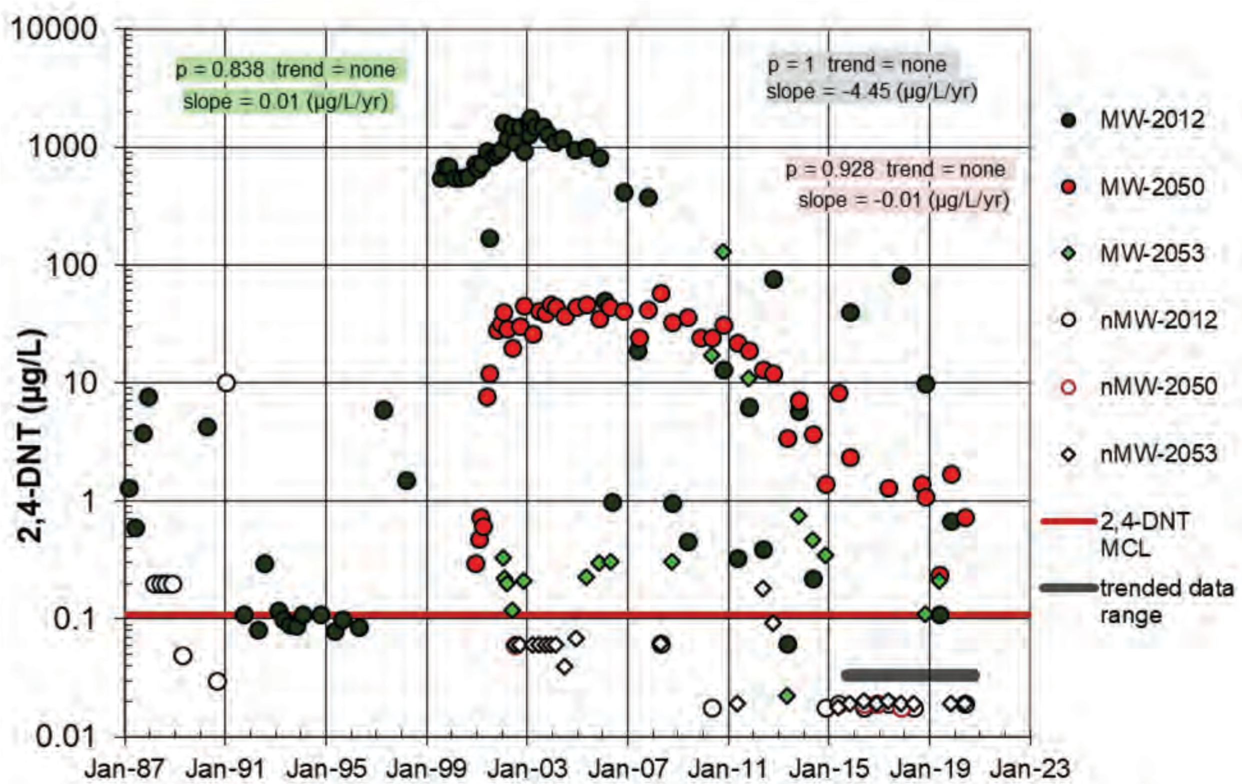


Figure 58. 2,4-DNT in Higher-Concentration Performance Monitoring Wells

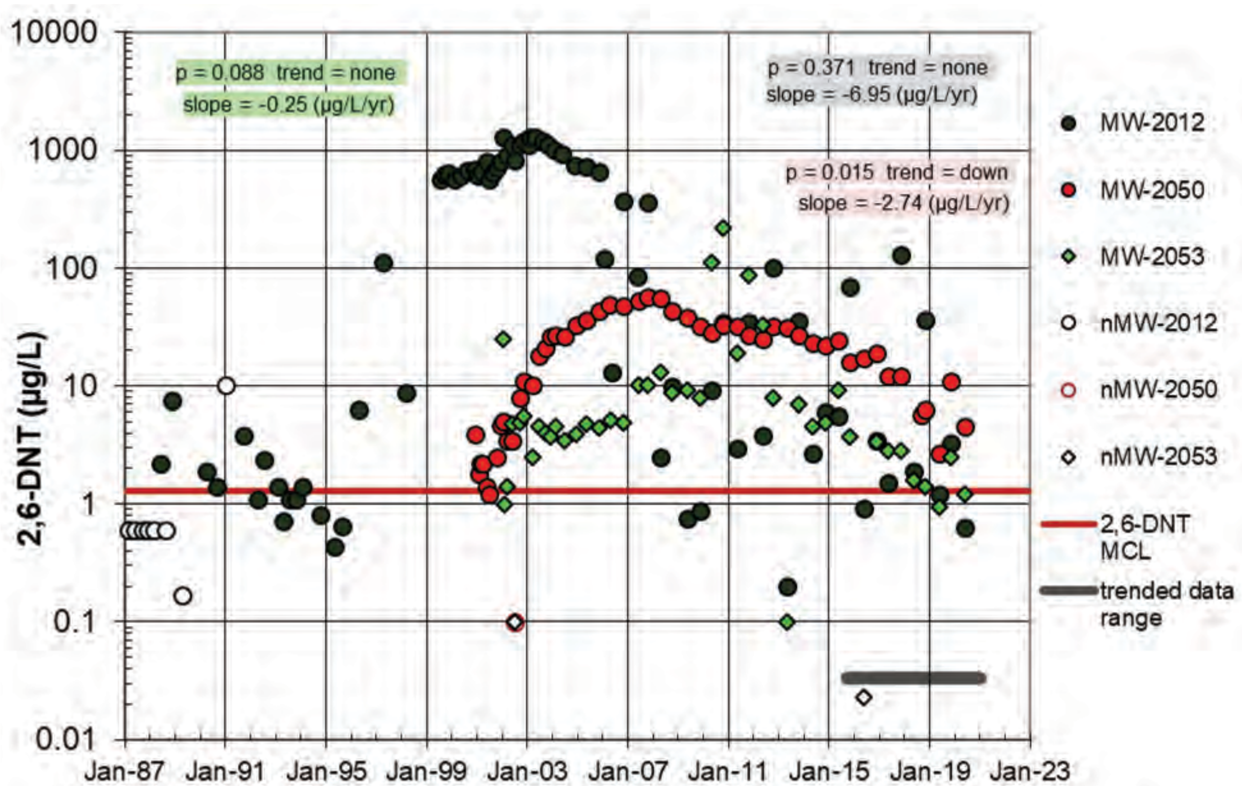


Figure 59. 2,6-DNT in Higher-Concentration Performance Monitoring Wells

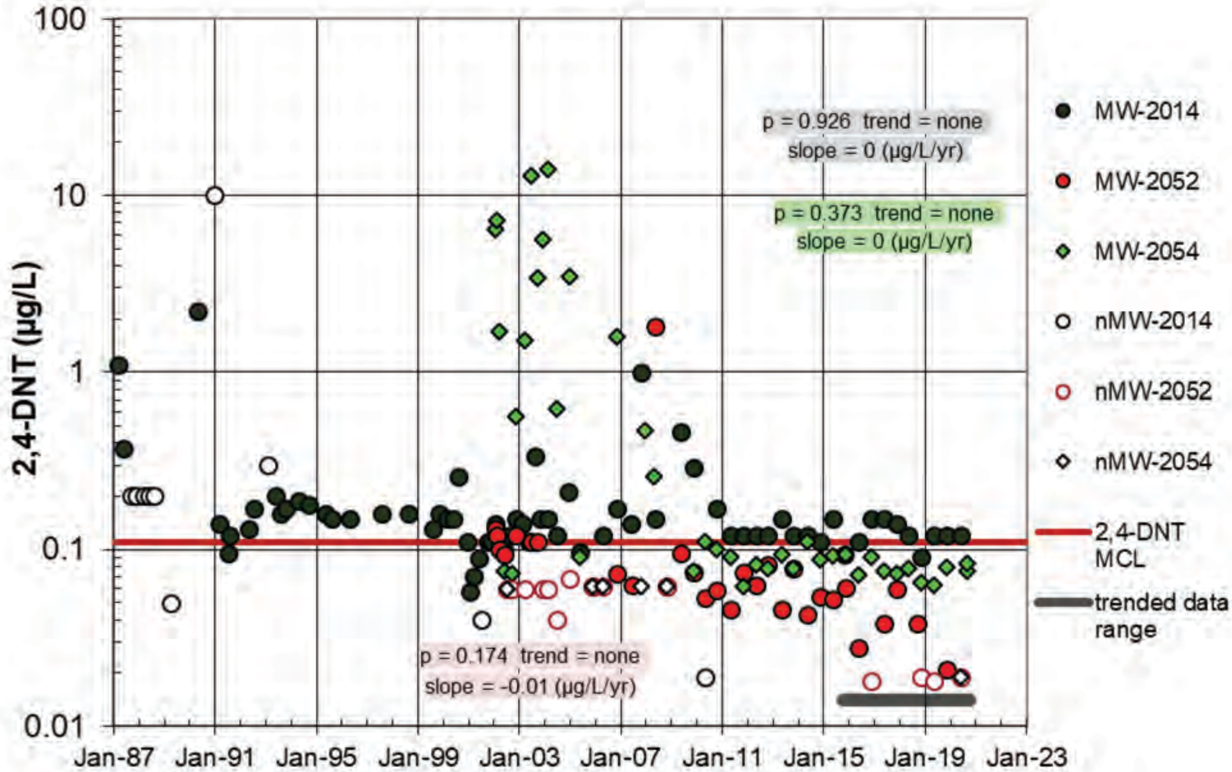


Figure 60. 2,4-DNT in Lower-Concentration Performance Monitoring Wells

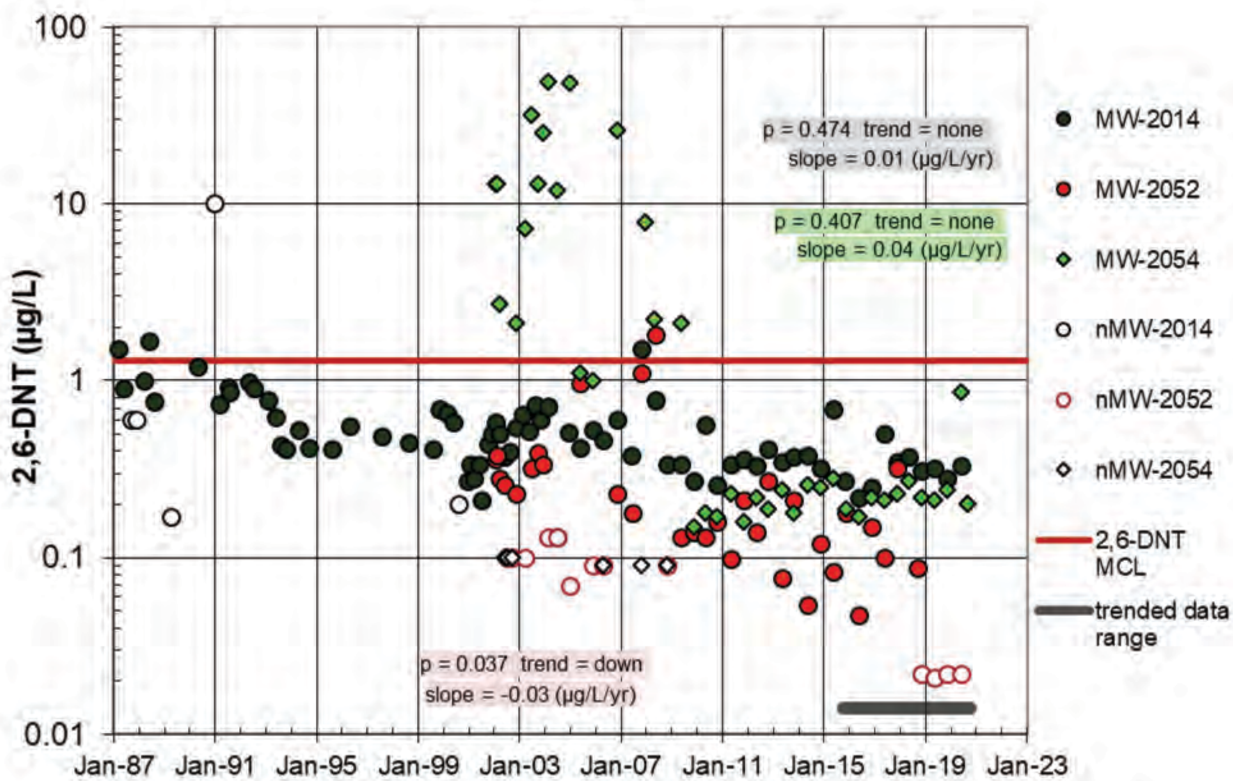


Figure 61. 2,6-DNT in Lower-Concentration Performance Monitoring Wells

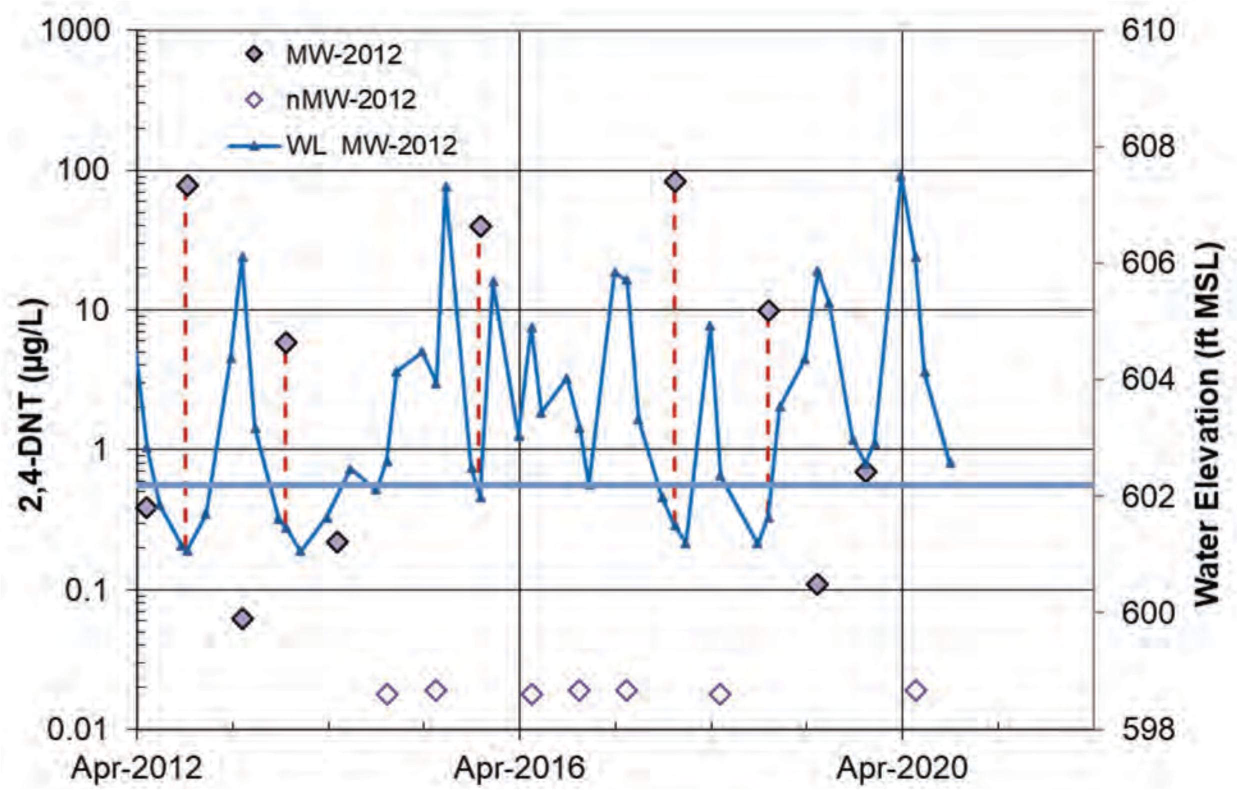


Figure 62. Variable 2,4-DNT Concentrations in MW-2012
(relatively high concentrations when water elevations are low)

2,4-DNT and 2,6-DNT Detection Monitoring

Migration of 2,4-DNT from the area of impact near the former Frog Pond has been limited, as evidenced by results at detection monitoring locations (Table 26) that are at or below the 0.11 µg/L cleanup standard for 2,4-DNT (Figure 63). None of the concentrations reported exceeded the 0.55 µg/L trigger level set for downgradient Objective 3 wells. The nondetect results from the unweathered unit wells (Figure 64) indicate that the impacted groundwater in the overlying weathered unit has not moved downward. The concentrations reported in Burgermeister Spring were negligible and are consistent with historical data (Figure 64). The 2,4-DNT detection reported in 2019 at SP-6303 was qualified by the lab as estimated. None of the concentrations reported exceeded the trigger levels set for the Objective 5 springs.

Table 26. 2,4-DNT and 2,6-DNT GWOU Detection Monitoring Locations—Frog Pond Area

Location	Detection Monitoring Area
Weathered Unit	
MW-2032	Fringe
MW-2051	Fringe
MW-4013	Downgradient
MW-4014	Downgradient
MW-4015	Downgradient
MW-4039	Fringe
MW-4041	Downgradient—far
Unweathered Unit	
MW-2023	Vertical extent
MW-2056	Vertical extent
Springs	
SP-6301	Burgermeister Spring
SP-6303	Burgermeister Spring branch

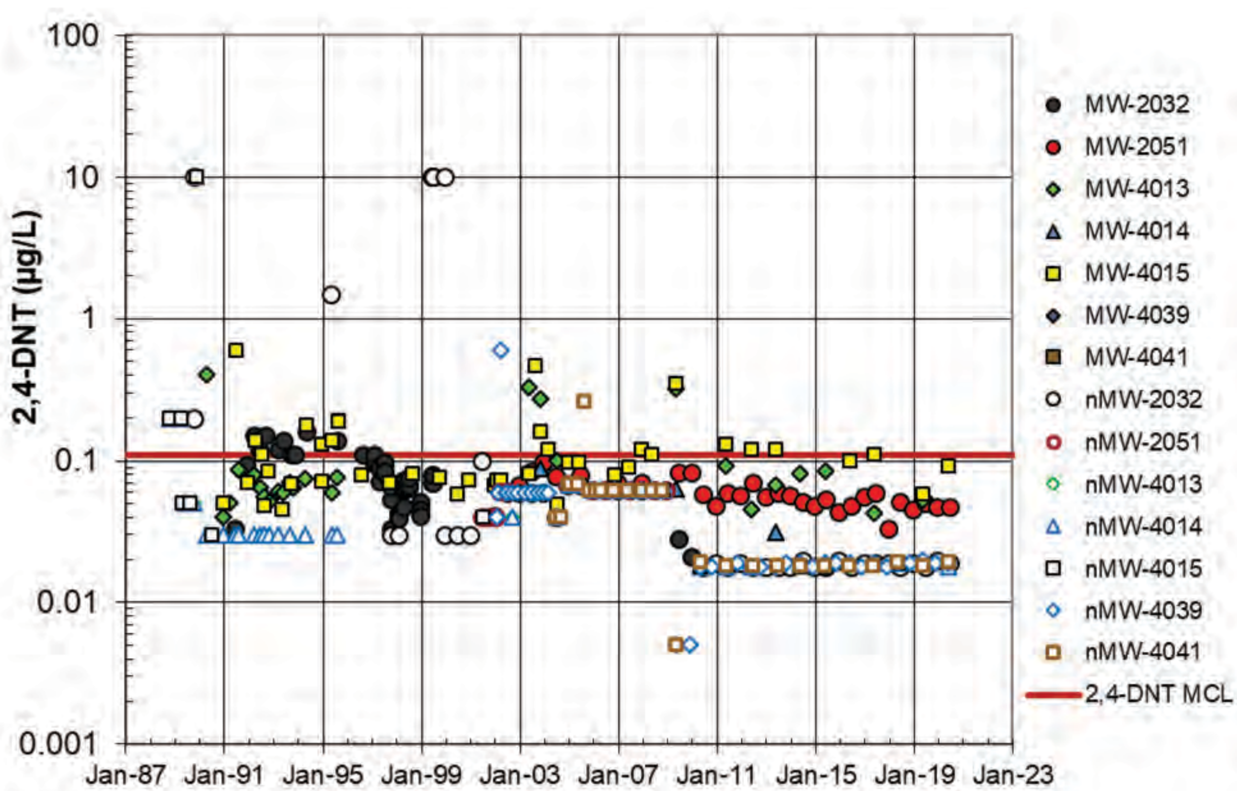


Figure 63. 2,4-DNT in Weathered Unit Detection Monitoring Wells

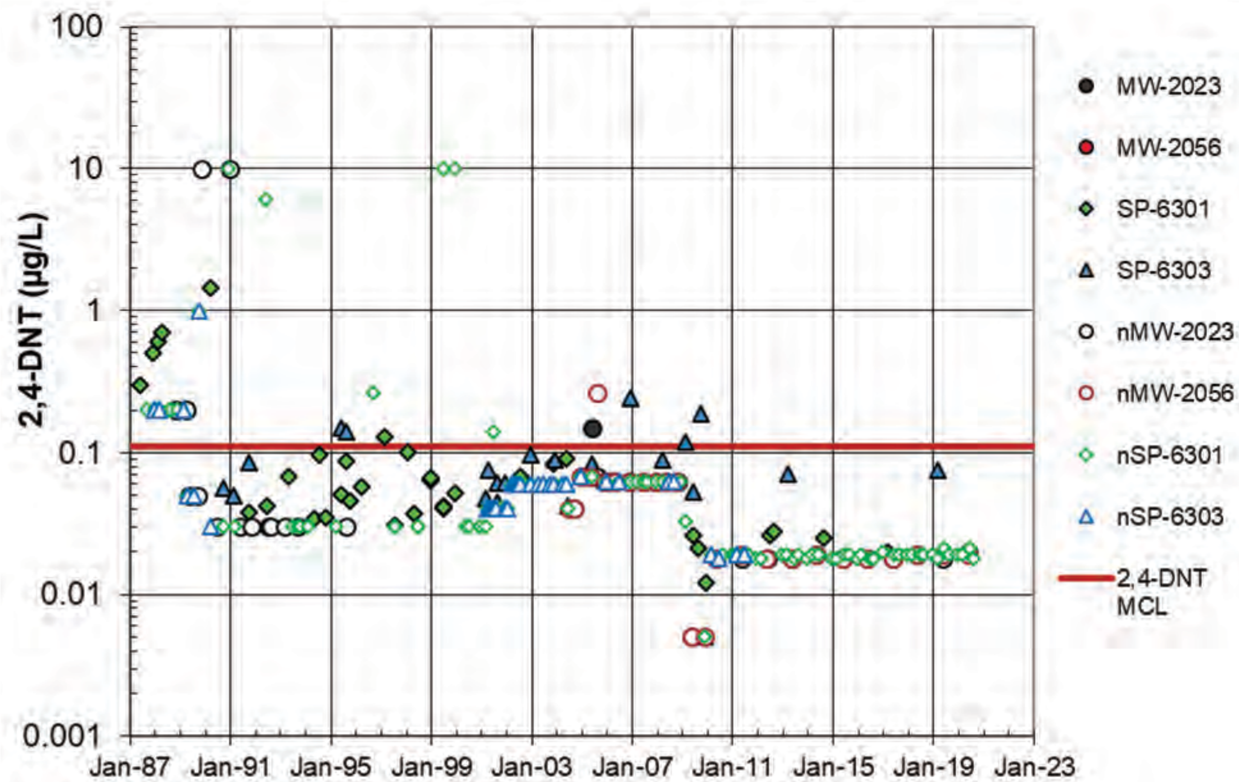


Figure 64. 2,4-DNT in Unweathered Unit Detection Monitoring Wells and Springs

The detections of 2,6-DNT in weathered unit wells MW-4013, MW-4014, and MW-4015 (Figure 65) have been low but persistent. The compound 2,6-DNT degrades more slowly than 2,4-DNT. Concentrations of 2,6-DNT in these wells are stable (within a historical range), though concentrations in MW-4014 can vary by about an order of magnitude. Results remain below the 1.3 µg/L cleanup standard for the three wells. Concentrations of 2,6-DNT in the other weathered unit wells were at the detection limit in 2020. No reportable concentrations of 2,6-DNT were detected in the wells in the unweathered unit (Figure 66). All low-level detections of 2,6-DNT reported at Burgermeister Spring (SP-6301) in the previous 5 years were qualified as estimated or nondetect except for the August 14, 2018, result of 0.10 µg/L.

There were 10 low-level detections of 2,6-DNT reported at Burgermeister Spring (SP-6301) in the previous 5 years, though only one was not qualified as estimated. Within the perspective of historical data, concentrations are decreasing at Burgermeister Spring. A 0.24 µg/L detection (below the 1.3 µg/L cleanup standard) was reported at SP-6303 in 2019. This was only the second sample collected at this spring in the previous 9 years. It is typically dry.

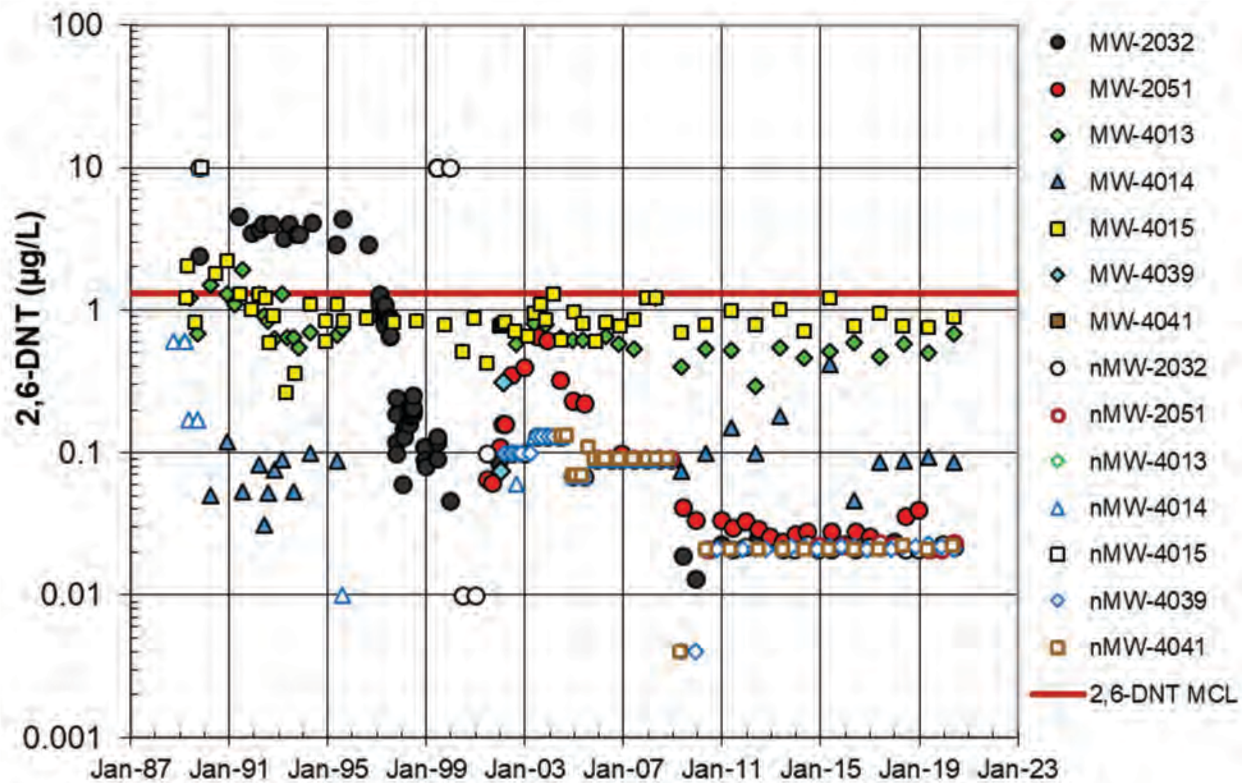


Figure 65. 2,6-DNT in Weathered Unit Detection Monitoring Wells

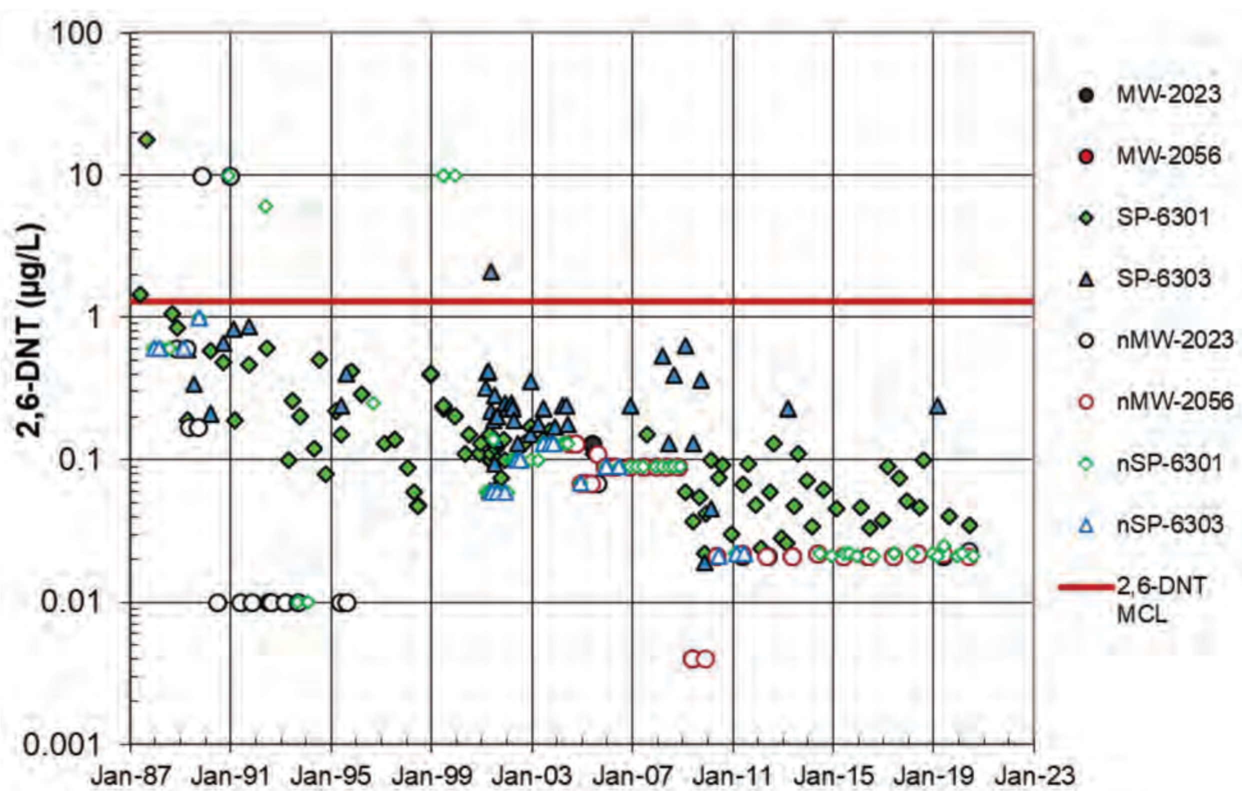


Figure 66. 2,6-DNT in Unweathered Unit Detection Monitoring Wells and Springs

The impact of nitroaromatic compounds in the former Frog Pond area is confined to the weathered unit of the Burlington-Keokuk Limestone. The concentrations of 2,4-DNT, 2,6-DNT, and 2,4,6-TNT are variable and generally decreasing over the long term. Concentrations of 1,3-DNB and NB are currently below the cleanup standard for all monitoring locations.

Nitroaromatic Compounds—Former Raffinate Pits Area

The other area of nitroaromatic compound impact at the Chemical Plant is in the former Raffinate Pits area where portions of TNT production Lines 3 and 4 were located. Groundwater in this area is impacted by 2,4-DNT in concentrations that exceed the cleanup standard of 0.11 µg/L. The impact of nitroaromatic compounds is limited to the weathered unit of the Burlington-Keokuk Limestone. Table 27 presents a summary of the 2,4-DNT data from the former Raffinate Pits area for the period of 2016 through 2020.

Table 27. Average 2,4-DNT from GWOU Performance Monitoring Wells in the Raffinate Pits Area

Location	2,4-DNT Concentration (µg/L)				
	2016	2017	2018	2019	2020
MW-2038	0.11	0.12	0.11	0.11	0.11
MW-3030	0.41	0.40	0.38	0.36	0.34
MW-3034	0.04	0.05	0.043	0.037	0.035
MW-3039	0.11	0.10	0.11	0.095	0.090

The highest 2,4-DNT concentrations in the former Raffinate Pits area are in well MW-3030 (Figure 67), which is in the footprint of former Raffinate Pit 4 (Figure 57). Concentrations in wells MW-2038, MW-3030, MW-3034, and MW-3039 have been consistently decreasing except for a temporary rebound in MW-3030 during 2009. Nitroaromatic compound results are significantly less variable in the former Raffinate Pits area than in the former Frog Pond area that can be subjected to rapid infiltration. The 2,4-DNT concentrations in MW-3034 have been less than or equal to the cleanup standard of 0.11 µg/L since 2009. Sample results at wells MW-3039 and MW-2038 have been hovering around the cleanup standard since 2013 and appear to be trending down over the long term.

Trend analysis based on the data from 2016 through 2020 indicates that 2,4-DNT concentrations in the former Raffinate Pits area are decreasing. A statistically significant downward trend was calculated for well MW-3030, though other wells are in a long-term declining trend. Concentrations of 2,4-DNT hover at the 0.11 µg/L cleanup standard. Concentrations in well MW-3034 are stable at low levels below the cleanup standard. If long-term trends continue, concentrations of 2,4-DNT at MW-2038 could be consistently below the 0.11 µg/L cleanup standard by 2025. The higher concentrations at well MW-3030 will probably take until 2040 to 2050 to reach the cleanup standard at the current rate.

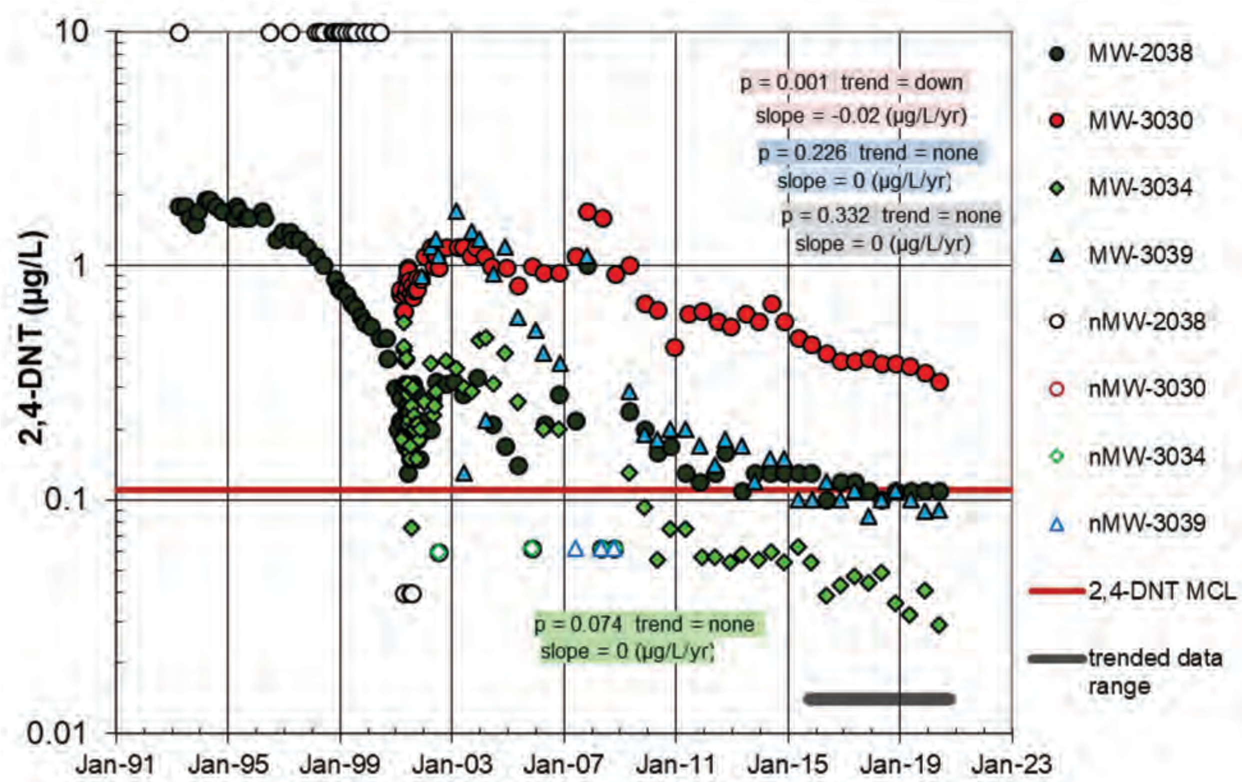


Figure 67. 2,4-DNT in Performance Monitoring Wells in the Former Raffinate Pits Area

Results from detection monitoring locations (Table 28) for the area of 2,4-DNT impact in the Raffinate Pits area show minimal nitroaromatic migration from this area. The source of low-level 2,4-DNT detected in well MW-4036 (Figure 68) may be the Chemical Plant site, the Army property, or both. All but one of the detections in MW-4036 were qualified as estimated. All sample results from the unweathered unit wells since the early 1990s are below detection limits and verify that the impacted groundwater in the overlying weathered unit has not migrated downward.

Table 28. 2,4-DNT and 2,6-DNT GWOU Detection Monitoring Locations—Raffinate Pits Area

Locations	Detection Monitoring Areas
Weathered Unit	
MW-3037	Fringe
MW-4036	Downgradient
MWS-1	Downgradient
Unweathered Unit	
MW-3006	Vertical extent
MW-4040	Vertical extent

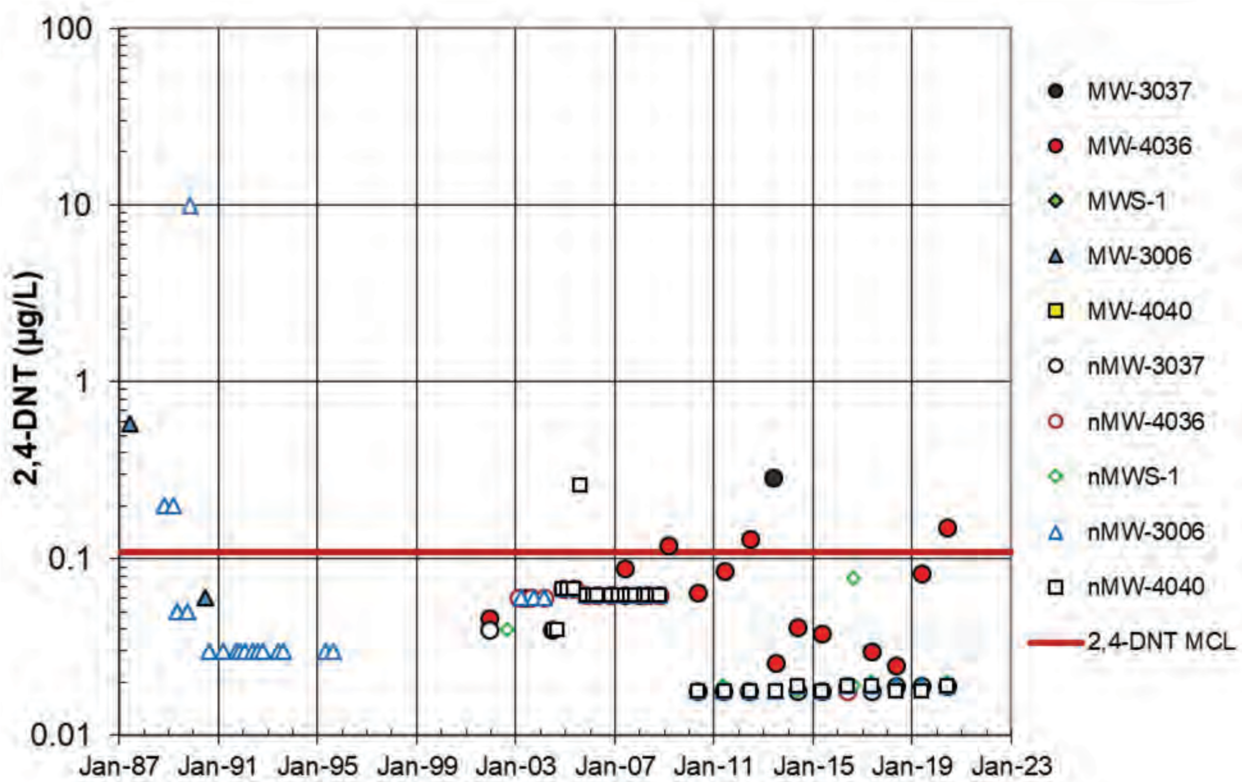


Figure 68. 2,4-DNT in Raffinate Pits Area Detection Monitoring Wells—Weathered Unit

4.2.2 Chemical Plant Surface Water

The surface water locations at Schote Creek, Dardenne Creek, and Busch Lakes 34, 35, and 36 (Figure 13) were sampled once during 2020 for total uranium. This monitoring was conducted to measure the effects of groundwater and surface water discharges from the site on the quality of downstream surface water.

Table 29 presents the results for the Chemical Plant surface water sampling along with the 5-year high. Figure 69 presents the historical results since 1987 along with results from SW-2007 (upstream location on Dardenne Creek) for comparison. The uranium levels at Busch Lake 34 continue to be higher than the other locations; however, uranium levels at the Busch Lake outlets have shown an overall decline since remediation at the Chemical Plant site. Busch Lake 34, the relatively highest uranium concentration pond, is immediately downgradient of Burgermeister Spring where much of the groundwater from the Chemical Plant flows. Busch Lake 36 and Busch Lake 35 are nearer the site but have lower uranium levels. Dye tracer injected in wells in the northern part of the site were detected at Burgermeister Spring, possibly under-flowing the Busch Lake 36 and Busch Lake 35 drainage. The Schote Creek and Dardenne Creek locations are downstream of the lakes and have always had relatively low levels because the Chemical Plant portion of the watershed is much smaller than the total watershed area. These results are generally consistent with data from previous years. Uranium concentrations in Dardenne Creek that are not influenced by Chemical Plant runoff (the SW-2007 location upstream of the confluence of Chemical Plant drainages with Dardenne Creek) are typically below 1 pCi/L.

Table 29. Total Uranium at Surface Water Locations

Location	Uranium (2020) (pCi/L)	Previous 5-Year High[a] (pCi/L)
SW-2004 (Busch Lake 34)	3.9 (June 8, 2020)	4.9 (2015)
SW-2005 (Busch Lake 36)	2.5 (June 8, 2020)	4.2 (2018)
SW-2012 (Busch Lake 35)	0.55 (June 8, 2020)	3.1 (2019)
SW-2016 (Dardenne Creek)	0.80 (June 8, 2020)	1.0 (2015)
SW-2024 (Schote Creek)	1.4 (June 8, 2020)	1.6 (2018)

Note:
[a] 2015–2019

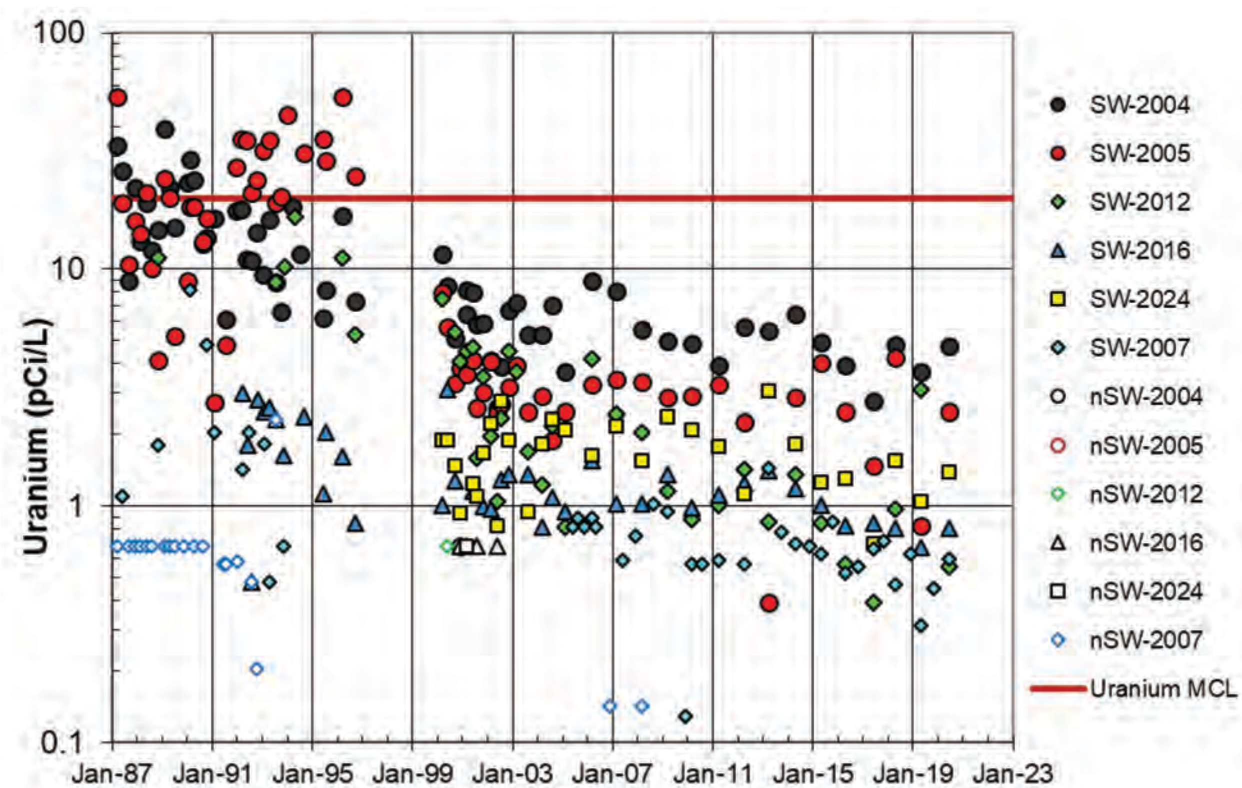


Figure 69. Total Uranium at Surface Water Locations at the Weldon Spring Chemical Plant Area

4.2.3 Disposal Cell Monitoring Program

The disposal cell groundwater detection monitoring network consists of one upgradient well (MW-2055), four downgradient wells (MW-2032, MW-2046, MW-2047, and MW-2051), one downgradient spring (SP-6301), and the disposal cell leachate. Semiannual detection monitoring began in mid-1998, after cell construction and waste placement activities had begun.

Under the monitoring program for the disposal cell, the monitoring wells, spring, and leachate are sampled semiannually (in June and December). Samples from the wells and spring are analyzed for the analytes listed in Table 30. Leachate was analyzed for the analytes listed in Table 31. Sampling was performed as specified in Appendix K of the LTS&M Plan (DOE 2008a).

Table 30. Disposal Cell Detection Monitoring—Groundwater and Spring Analyte List

Radiological	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Thorium-228 Thorium-230 Thorium-232	Arsenic Barium Chromium Lead Manganese Nickel Selenium Thallium Uranium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT NB	PCBs PAHs	pH Temperature Specific conductance

Abbreviations:
PAHs = polycyclic aromatic hydrocarbons
TNB = trinitrobenzene

Table 31. Disposal Cell Detection Monitoring—Leachate Analyte List

Radiological	Inorganic Ions	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Thorium-228 Thorium-230 Thorium-232	Chloride Fluoride Nitrate Sulfate	Arsenic Barium Chromium Cobalt Iron Lead Manganese Nickel Selenium Thallium Uranium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT NB	PCBs PAHs	pH Temperature Specific conductance COD TDS TOC Turbidity

Abbreviations:
COD = chemical oxygen demand
PAHs = polycyclic aromatic hydrocarbons
TDS = total dissolved solids
TNB = trinitrobenzene
TOC = total organic carbon

In accordance with the disposal cell groundwater monitoring plan, disposal cell performance is evaluated by signature parameter concentrations. Signature parameters are those constituents present in the leachate at concentrations at least 1 order of magnitude greater than in the underlying groundwater. The current signature parameters are barium and uranium. Under the monitoring program, signature parameter data from each monitoring event are compared to the baseline tolerance limits (BTLs) to trend general changes in groundwater quality and determine whether there is statistically significant evidence of contamination that could possibly be attributed to cell leakage. The BTLs of the signature parameters (uranium and barium) were recalculated using the dataset from 2003 through 2019 (demarcated by vertical black lines in Figure 70 and Figure 71) for this report. This was done in accordance with the recommendation in Appendix K of the LTS&M Plan (DOE 2008a), which suggests that the BTLs be recalculated on a regular basis to include the addition of new data. The data collected from 2003 through 2019 are noticeably less variable than the pre-2003 data collected during and soon after construction of the disposal cell (Figure 70 and Figure 71).

The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality near the disposal cell and to determine if there are changes in the groundwater system. Data are compared to the three most recent years of data to determine if statistically significant changes in concentrations are present. A measured concentration is considered statistically significant if it is greater than the arithmetic mean plus 3 times the standard deviation for a given location. Wells with data showing a statistically significant increase are resampled to confirm the exceedance. If the resampling results confirm the exceedance, historical leachate analytical data and volumes are evaluated to assess the integrity of the disposal cell. If the leachate data do not indicate that the exceedance could be the result of leakage from the cell, the analytical data are assessed, and sitewide monitoring data are reviewed. If the exceeding parameter is a COC for the GWOU, this information is evaluated under the monitoring program for that OU.

4.2.3.1 Disposal Cell Monitoring Results—Signature Parameters

The monitoring results for the signature parameters collected from 2016 through 2020 are presented in Table 32 and are shown in Figure 70 (uranium) and Figure 71 (barium) along with applicable BTLs (calculated 2003 through 2019 data). The results were less than the applicable BTLs except for uranium in MW-2032.

The December 2018 sample result (6.2 pCi/L) slightly exceeded the uranium BTL (4.6 pCi/L, calculated from 2003 through 2016 data at that time). The February 2019 resample was lower (5.1 pCi/L) but also exceeded the BTL. In response, a demonstration report was prepared and submitted in April 2019 documenting why the slight exceedance was unlikely the result of a disposal cell leak. For instance, neither result would have exceeded the 6.4 pCi/L BTL that was previously used (calculated from 1997 through 2002 uranium data) and are not dissimilar from groundwater in that area. The December 2019 uranium result (5.9 pCi/L) was also slightly above the 4.6 pCi/L BTL. The three exceeding results are below the recalculated BTLs for data from the 2003 through 2019 period. BTLs are recalculated every 5 years to include recent data. Filtered and nonfiltered samples were collected from MW-2032 during the December 2020 sampling event because the two previous December samples (2018 and 2019) were slightly elevated. This was done to test the possibility that fine solids or colloids near the bottom of the well were captured in the sample. MW-2032 has a short water column. Both December 2020 uranium sample results were low, just under 2 pCi/L.

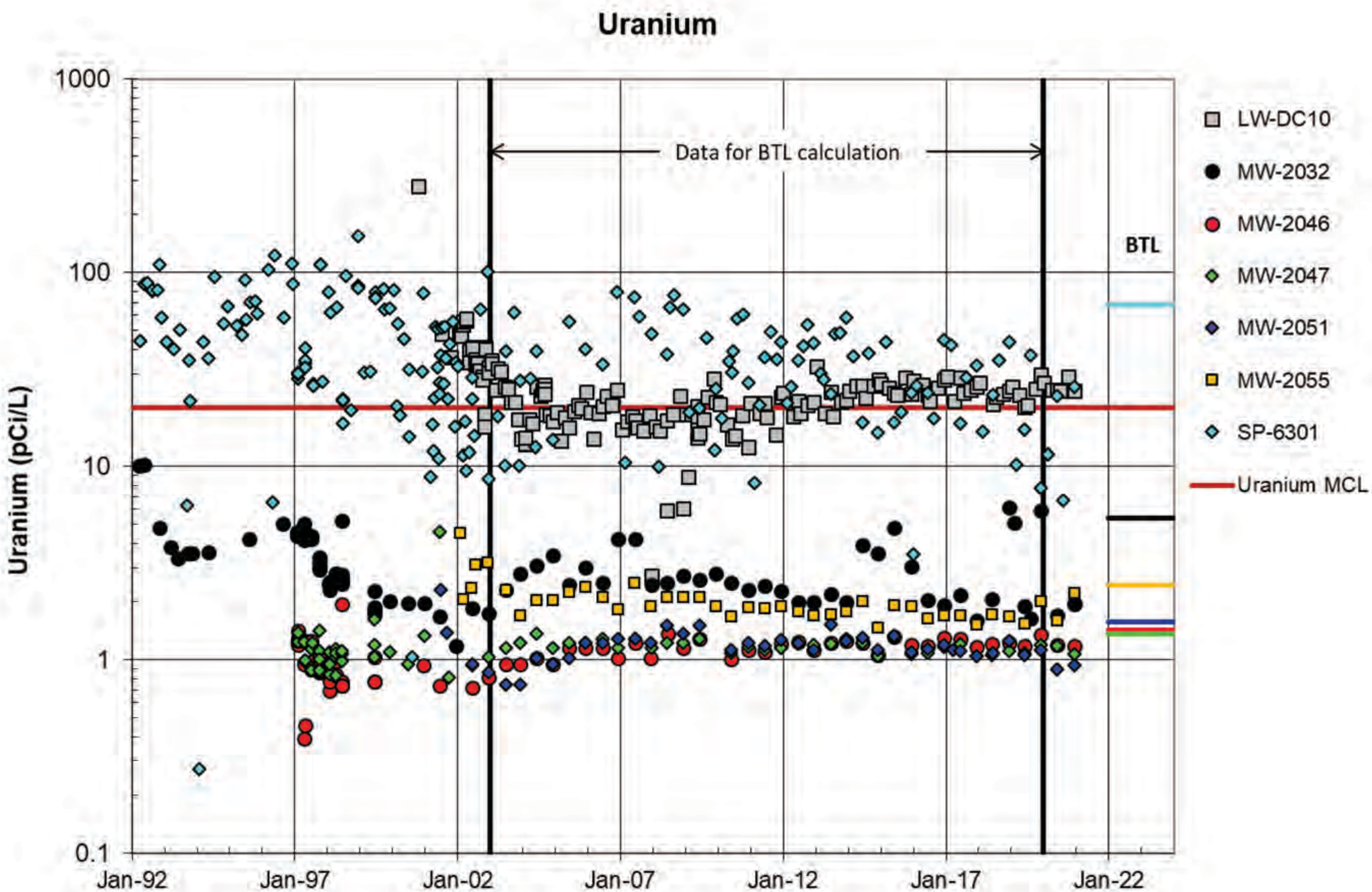


Figure 70. Uranium Concentrations—Disposal Cell Monitoring Wells with BTLs

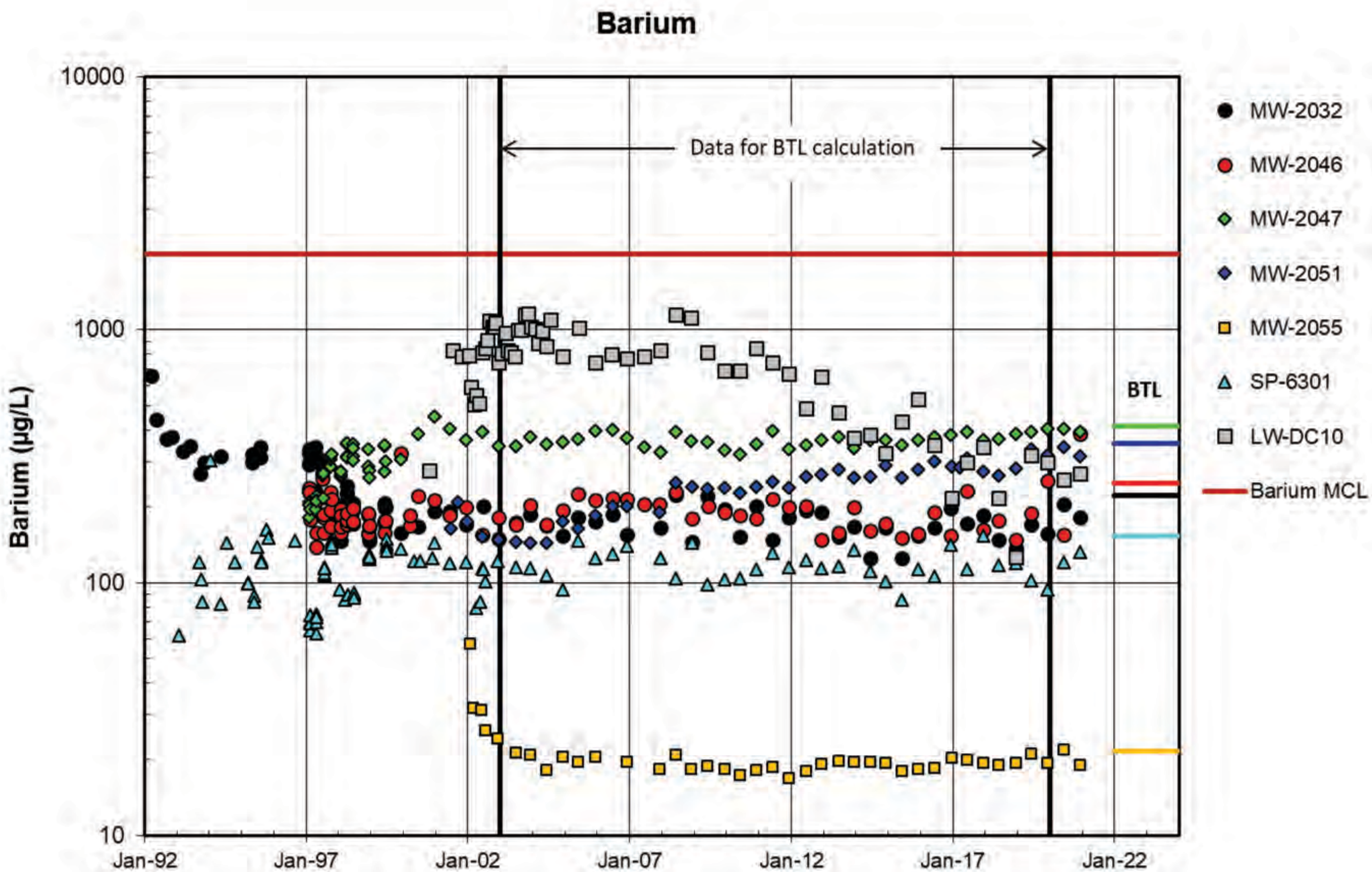


Figure 71. Barium Concentrations—Disposal Cell Monitoring Wells with BTLs

Table 32. Signature Parameter Results and Associated BTLs at Disposal Cell Monitoring Locations

Parameter	Location	BTL	Results									
			Jun 2016	Dec 2016	Jun 2017	Dec 2017	Jun 2018	Dec 2018	Jun 2019	Dec 2019	Jun 2020	Dec 2020
Barium (µg/L)	MW-2032	222	165	197	171	184	148	137	170	156	204	182
	MW-2046	248	190	154	231	162	177	148	188	254	155	387
	MW-2047	416	376	383	395	367	370	389	396	407	406	395
	MW-2051	354	301	289	310	274	264	282	336	319	344	316
	MW-2055	22	19	20	20	19	19	19	21	19	22	19
	SP-6301	153	106	141	113	153	117	119	102	94	121	132
	LW-DC10		349	216	300	343	216	126	320	299	255	271
Uranium (pCi/L)	MW-2032	5.4	2.1	1.9	2.2	1.6	2.1	6.2	1.9	5.9	1.7	2.0
	MW-2046	1.4	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.4	1.2	1.2
	MW-2047	1.4	1.1	1.2	1.2	1.1	1.1	1.1	1.1	1.2	1.2	1.1
	MW-2051	1.6	1.1	1.2	1.1	1.0	1.1	1.3	1.1	1.1	0.90	0.94
	MW-2055	2.4	1.9	1.7	1.7	1.7	1.7	1.5	1.5	2.0	1.6	2.2
	SP-6301	68	24	45	17	33	23	44	16	8	23	26
	LW-DC10		23	28	29	26	21	25	20	30	25	24

Notes:
BTLs calculated with data from 2003 through 2019.
LW-DC10 is untreated leachate.

Barium (the other current signature parameter) can no longer be used to evaluate cell leakage because concentrations in the untreated leachate (LW-DC10) have consistently declined since 2011 to levels that are now at or below those observed in monitoring wells (Figure 71). Manganese and iron are former signature parameters that had declined to levels that made them unusable for evaluating disposal cell leakage. Uranium is the only remaining cell parameter in leachate that is an order of magnitude greater in the leachate (steady at about 25 pCi/L) than that typically present in groundwater north of the disposal cell (2–3 pCi/L). It is recommended that barium continue to be monitored but discontinued as a signature parameter.

There is no evidence of leakage from the disposal cell into the groundwater. The general groundwater quality in the detection monitoring wells and Burgermeister Spring during this period was consistent with historical data. Leachate concentrations are shown in charts of disposal cell signature parameters for comparison.

Section 2.3.1.3 presents the monitoring results for the disposal cell leachate. The LCRS is sampled semiannually (Table 8), and the data are compared to corresponding concentrations in wells if elevated levels of constituents are identified in the groundwater. In general, the composition of the leachate has remained stable over the past 5 years, with the exception of barium, iron, manganese, and uranium. Leachate concentrations of barium, iron, and manganese have declined, while the uranium concentration has increased slightly. The increase in uranium concentrations in the leachate is attributed to less dilution as leachate flow volume has decreased from initially above 300 gpd in 2001 to about 50 gpd in 2020. The mass of uranium removed in the leachate flow has generally been consistent since about 2007.

4.2.3.2 Groundwater Flow

Groundwater flow rate and direction are evaluated annually as specified in Appendix K of the LTS&M Plan (DOE 2008a). The potentiometric surface map of the weathered unit shallow aquifer at the Chemical Plant indicates a generally northward groundwater flow direction (Figure 10). The configuration of the potentiometric surface has remained relatively unchanged since construction of the disposal cell. A groundwater divide is present near the southern boundary of the site. The average groundwater flow rate (average linear velocity) is calculated using Equation 1 below:

$$v = \left(\frac{K}{n}\right)\left(\frac{\mathrm{dh}}{\mathrm{dl}}\right) \qquad \text{(Eqn. 1)}$$

$$v = \left(\frac{20\ \mathrm{ft/day}}{0.10}\right)\left(\frac{606.3\ \mathrm{ft} - 583.0\ \mathrm{ft}}{2100\ \mathrm{ft}}\right) = 2.2\ \mathrm{ft/day}$$

where v = average linear velocity; K = average hydraulic conductivity
n = effective porosity; dh/dl = hydraulic gradient

The average hydraulic conductivity (K) of the weathered zone, using data from the cell monitoring wells, is 7×10^{-3} centimeters per second (20 ft/day) and ranges from 10^{-2} to 10^{-7} centimeters per second (DOE 2005a). An effective porosity (n) of 0.10 was selected to estimate the maximum groundwater flow rate in this area. The hydraulic gradient in the disposal cell area is 0.011 ft/ft and is based on water elevation data from MW-2055 (average of 606.3 ft above msl for the previous 5 years) and MW-2032 (average of 583.0 ft above msl for the previous 5 years), which are about 2100 ft apart. This approach is consistent with the calculations presented in Appendix K of the LTS&M Plan (DOE 2008a). The average flow velocity in 2020 was 2.2 ft/day, which is the same (within 5%) as the average flow velocity calculated since 2005. In a karst environment, it is possible that the effective porosity is somewhat lower, resulting in faster flow velocities. For instance, if the effective porosity is 0.05, the flow velocity would double to 4.4 ft/day.

4.2.4 Quarry Residuals Operable Unit

The removal of waste from the Quarry was completed in 1995. EPA signed the QROU ROD (DOE 1998a) on September 30, 1998. The QROU ROD specified long-term groundwater monitoring and ICs to limit groundwater use during the monitoring period. Groundwater north of the Femme Osage Slough will be monitored until a target level of 300 pCi/L for uranium is attained. In addition, groundwater south of the slough will be monitored to ensure protection of human health and the environment.

In 2000, DOE initiated a long-term monitoring program as outlined in the *Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit* (DOE 2000b). This network was modified to add wells upgradient of the Quarry (MW-1012), downgradient of the area of impact (MW-1028), and within the area of highest uranium impact (MW-1051 and MW-1052).

4.2.4.1 Hydrogeologic Description

The geology of the Quarry Area is separated into three units: upland overburden, Missouri River alluvium, and bedrock. The unconsolidated upland material overlying the bedrock consists of up to 30 ft of unsaturated silty-clay soil and loess deposits (DOE 1989). Three Ordovician formations constitute the bedrock: the Kimmswick Limestone, the limestone and shale of the Decorah Group, and the Plattin Limestone. The alluvium associated with the Missouri River consists of clays, silts, sands, and gravels above the bedrock. The alluvium thickness increases with distance from the edge of the river floodplain toward the river, where the maximum thickness is approximately 100 ft.

Alluvium at the Quarry is truncated by an erosional contact with the Ordovician bedrock bluff consisting of the Kimmswick, Decorah, and Plattin Formations. These formations also form the rim wall of the Quarry. The bedrock unit underlying alluvial materials north of Femme Osage Slough is the Decorah Group. Primary sediments between the bluff and the slough are intermixed and interlayered clays, silts, and sands. Organic material is intermixed throughout the sediments. The area between the bedrock bluff and Femme Osage Slough contains a naturally occurring oxidation-reduction front, which acts as a barrier to the migration of dissolved uranium in groundwater by inducing its precipitation. This reduction zone is the primary mechanism controlling uranium distribution south of the Quarry.

The uppermost groundwater flow systems at the Quarry are composed of alluvial and bedrock aquifers. Water levels in the alluvial aquifer are primarily controlled by surface water levels in the Missouri River and the infiltration of precipitation and overland runoff that recharges the bedrock aquifer.

Eight monitoring wells in the Darst Bottom area, about 1.5 miles south of the Quarry, were used to study the water quality of the Missouri River alluvium upgradient of the Quarry and provide a reference for background values of uranium. Several other bedrock wells were installed north of the Quarry to provide background values for uranium in the bedrock units. A summary of the uranium background values is provided in Table 33 (DOE 1998a).

Table 33. Background Uranium Levels for Units at the Quarry

Unit	Uranium (pCi/L)	
	Background Value (UCL_{95})	Background Range
Alluvium[a]	2.77	0.1−16
Kimmswick-Decorah[b]	3.41	0.5−8.5
Plattin[c]	3.78[d]	1.2−5.1

Notes:
[a] Based on data from Darst Bottom wells (U.S. Geological Survey and DOE).
[b] Based on data from MW-1034 and MW-1043 (DOE).
[c] Based on data from MW-1042 (DOE).
[d] This background value is lower than previously published as a result of recent data evaluation (DOE 1998b).

Abbreviation:
UCL_{95} = 95th percentile upper confidence limit of the mean concentration

4.2.4.2 Quarry Monitoring Program

Long-term monitoring at the Quarry is designed to (1) monitor uranium concentrations south of the slough to ensure that they remain protective of human health and the environment and (2) monitor uranium and 2,4-DNT levels within the area of groundwater impact north of the slough until they attain target levels that have been identified as having a negligible impact on the groundwater south of the slough (DOE 2000a).

The wells were categorized into monitoring lines to address these two monitoring objectives (Table 34 and Figure 72). Each line provides specific information relevant to long-term goals at the Quarry:

- The first line of wells (Line 1) monitors the area of impact within the bedrock rim of the Quarry proper. These wells (MW-1002, MW-1004, MW-1005, MW-1027, and MW-1030) are sampled to establish trends in contaminant concentrations within areas of higher impact.
- The second line of wells monitors the area of impact within alluvial materials and shallow bedrock south of the Quarry and north of Femme Osage Slough (MW-1006, MW-1007, MW-1008, MW-1009, MW-1013, MW-1014, MW-1015, MW-1016, MW-1028, MW-1031, MW-1032, MW-1045, MW-1046, MW-1047, MW-1048, MW-1049, MW-1051, and MW-1052). These wells are sampled to establish trends in contaminant concentrations within the area of higher impact and to monitor the oxidizing and reducing conditions within this area that limit uranium migration.
- The third line of wells monitors the alluvium directly south of the slough. These wells (MW-1017, MW-1018, MW-1019, MW-1021, MW-1044, and MW-1050) have shown no impact from Quarry contaminants and are monitored as the first line of warning for potential migration of uranium south of the slough.

- The fourth line of wells monitors the same portion of the alluvial aquifer that supplies the PWSD No. 2 (formerly St. Charles County) well field. These wells (RMW-1, RMW-2, RMW-3, and RMW-4) are sampled to monitor the groundwater quality of the productive portions of the alluvial aquifer and to detect occurrences of uranium outside the range of natural variation.

Table 34. Monitoring Line Categories for Wells at the Quarry

Background	Line 1[a]	Line 2[b]	Line 3[c]	Line 4[d]
MW-1012	MW-1004	MW-1032	MW-1017 (A)	RMW-1 (A)
	MW-1005	MW-1013	MW-1018 (A)	RMW-2 (A)
	MW-1027	MW-1048	MW-1019 (A)	RMW-3 (A)
	MW-1030	MW-1015	MW-1021 (A)	RMW-4 (A)
	MW-1002	MW-1031	MW-1044 (A)	
		MW-1028	MW-1050 (A)	
		MW-1046		
		MW-1047		
		MW-1008 (A)		
		MW-1051 (A)		
		MW-1014 (A)		
		MW-1006 (A)		
		MW-1052 (A)		
		MW-1007 (A)		
		MW-1016 (A)		
		MW-1009 (A)		
		MW-1045 (A)		
		MW-1049 (A)		

Notes: Ordering by line and medium is generally from high to low concentration.
[a] Semiannual sampling.
[b] Quarterly sampling.
[c] Quarterly, semiannual, or annual sampling.
[d] Sampled semiannually by independent contractor (see Section 4.2.4.3) and annually by DOE.

Abbreviation:
A = alluvial well

Monitoring well MW-1012 has been retained as a background location for the Quarry proper. This well, included with the Line 1 wells to show results, is north of the Quarry and is screened in the Kimmswick Limestone and Decorah Group.

The sampling frequency for each location was selected to provide adequate reaction time on the basis of travel times from the residual sources and areas of impact to potential receptors. The monitoring frequency of Line 1 wells (wells on the Quarry rim) was decreased from quarterly to semiannually in 2009 due to declining uranium levels. Monitoring wells between the Quarry and the Femme Osage Slough (Line 2 wells), the area of highest impact, are sampled quarterly. Locations south of the slough (Lines 3 and 4 wells) are sampled semiannually or annually. In 2019, all locations in the Quarry area were sampled for uranium, sulfate, and dissolved iron. A select group of wells north of the slough was sampled for nitroaromatic compounds.

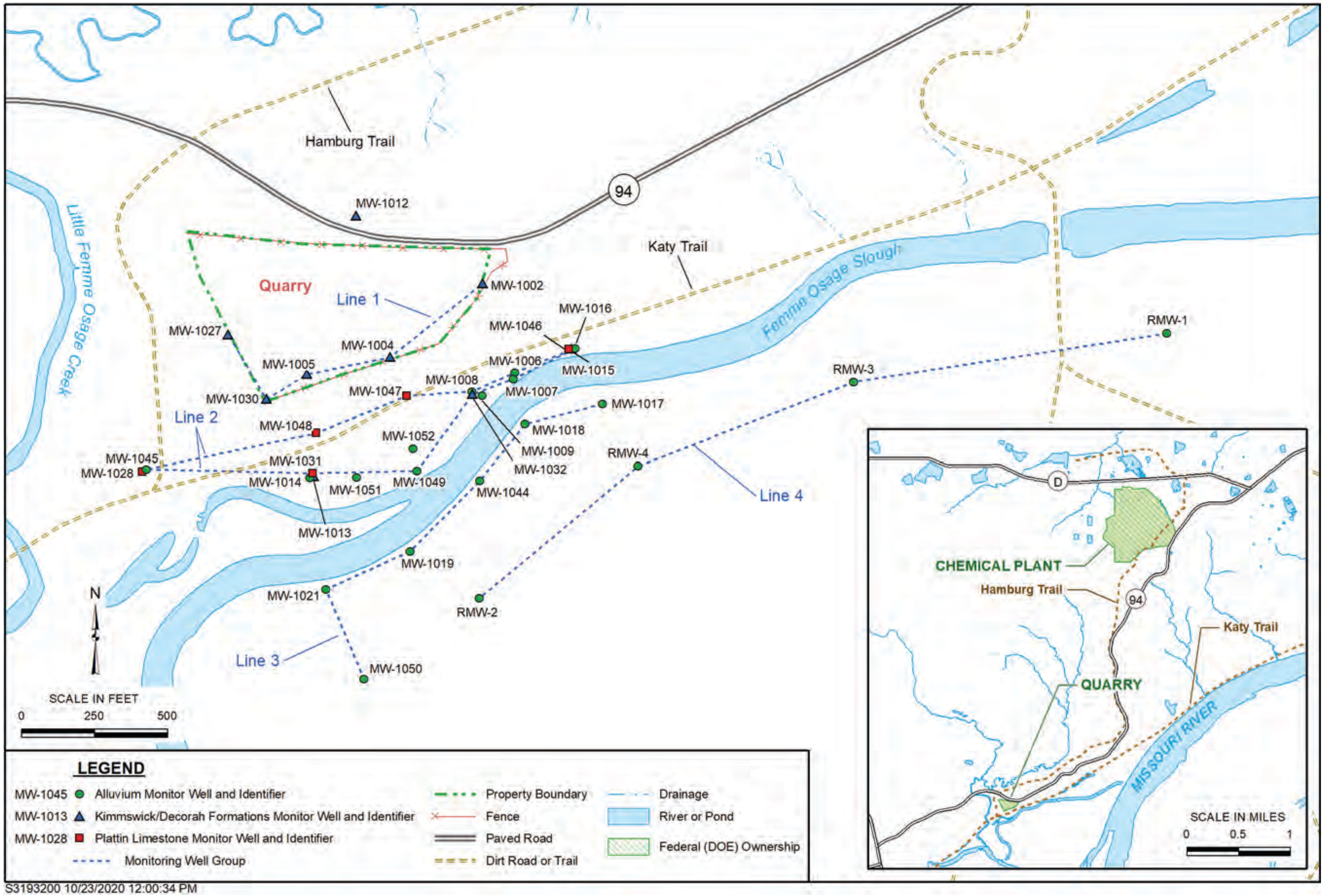


Figure 72. Groundwater Monitoring Well Locations at the Quarry Area

Testing for temporal trends using the Mann-Kendall method was performed for total uranium and 2,4-DNT data collected between 2016 and 2020. Results for the trend analysis are reported for wells in Lines 1 and 2 of the Quarry monitoring network (wells that monitor the area of groundwater impact). Trending is used as a general indicator of changes in the groundwater quality in this area.

4.2.4.3 Quarry Hydrogeologic Data Analysis

Groundwater flow at the Quarry is monitored using all the wells in the long-term monitoring network. The static groundwater levels of the monitoring network are measured at least quarterly to establish that groundwater flow has not changed significantly during the year (which could result in shifts in potential contaminant migration pathways). Groundwater flow is generally to the south from the bedrock bluff of the Quarry toward the Femme Osage Slough. The flow directions of the shallow groundwater have remained relatively unchanged from previous years despite varying overall groundwater elevations.

Groundwater elevations in the Quarry area fluctuate significantly (Figure 73), primarily in response to the level of the Missouri River. The bedrock wells along the Quarry rim (Line 1) are less influenced by river levels and have a smaller range of water level variability than wells near the slough and those screened in the Missouri River alluvium (Lines 2, 3, and 4). Water elevations are typically highest in the spring and lowest in the fall, though drought conditions or periods of unusually high precipitation can cause exceptions. For instance, several Line 2 wells were inaccessible at times due to flooding associated with high river levels in 2015, 2017, and 2019. Groundwater elevations in the spring and fall of 2020 are presented in Figure 74 and Figure 75.

4.2.4.4 Contaminants of Interest

Uranium and nitroaromatic compounds that leached from wastes in the Quarry proper contaminated the groundwater beneath and downgradient of the Quarry. Contaminant levels have decreased since removal of the wastes from the Quarry in 1995. The remaining sources of groundwater contamination are residual material in the fractures and uranium that has precipitated or sorbed onto the alluvial materials north of the Femme Osage Slough.

Uranium entered the shallow aquifer via migration through bedrock fractures in the Kimmswick Limestone and the Decorah Group that constitute the Quarry rock. Uranium migration in groundwater north of the slough is limited by naturally reducing conditions. Under reducing conditions, uranium migration is slowed by chemical processes that favor uranium adsorption onto aquifer materials and precipitation of stable uranium minerals. Figure 76 shows the average uranium concentrations in 2020.

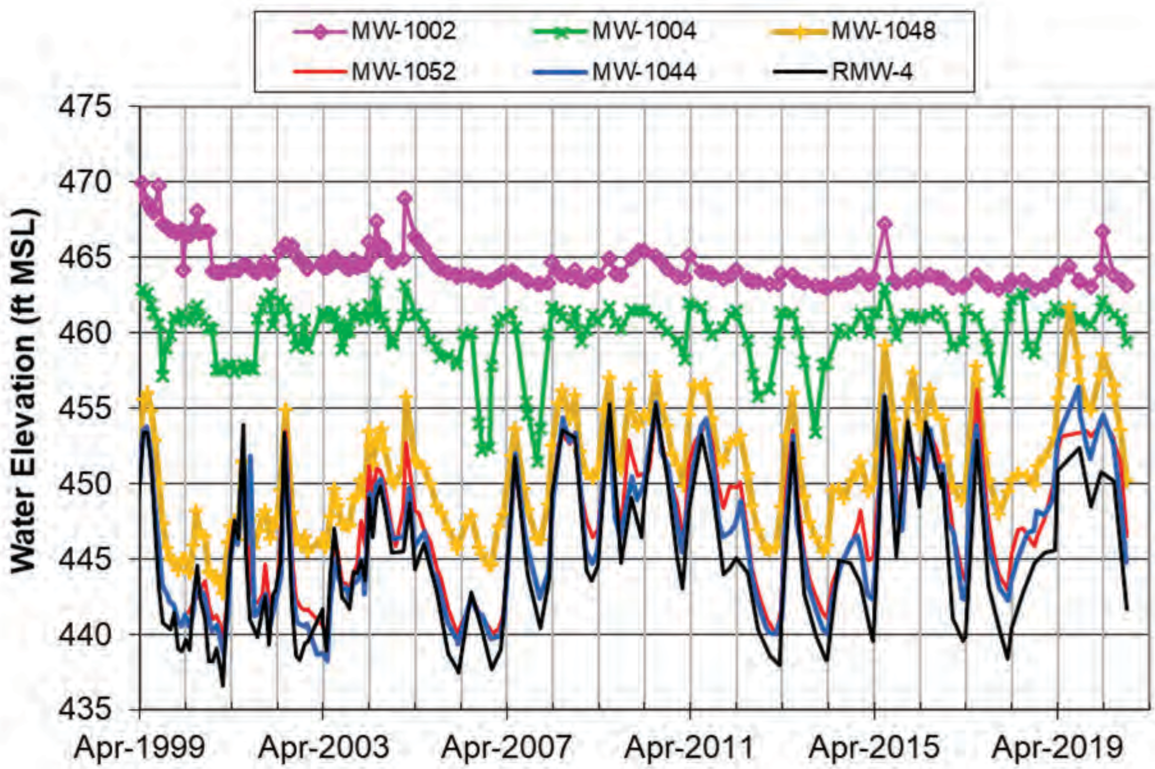


Figure 73. Groundwater Elevations in the Quarry Area (lines with no symbols are alluvial aquifer wells)

Nitroaromatic compounds in the groundwater system, primarily 2,4-DNT, resulted from the disposal of these wastes in the Quarry proper. Nitroaromatic compounds entered the shallow aquifer via migration through bedrock fractures in the Quarry. The mobility of nitroaromatic compounds in the bedrock aquifer is relatively high because these compounds do not tend to sorb to bedrock materials. The potential exists for microorganism activity to transform and degrade TNT and DNT in the alluvial materials north of the slough. Nitroaromatics have decreased to nondetect levels in many of the Quarry wells, and a reduced sampling frequency will be recommended.

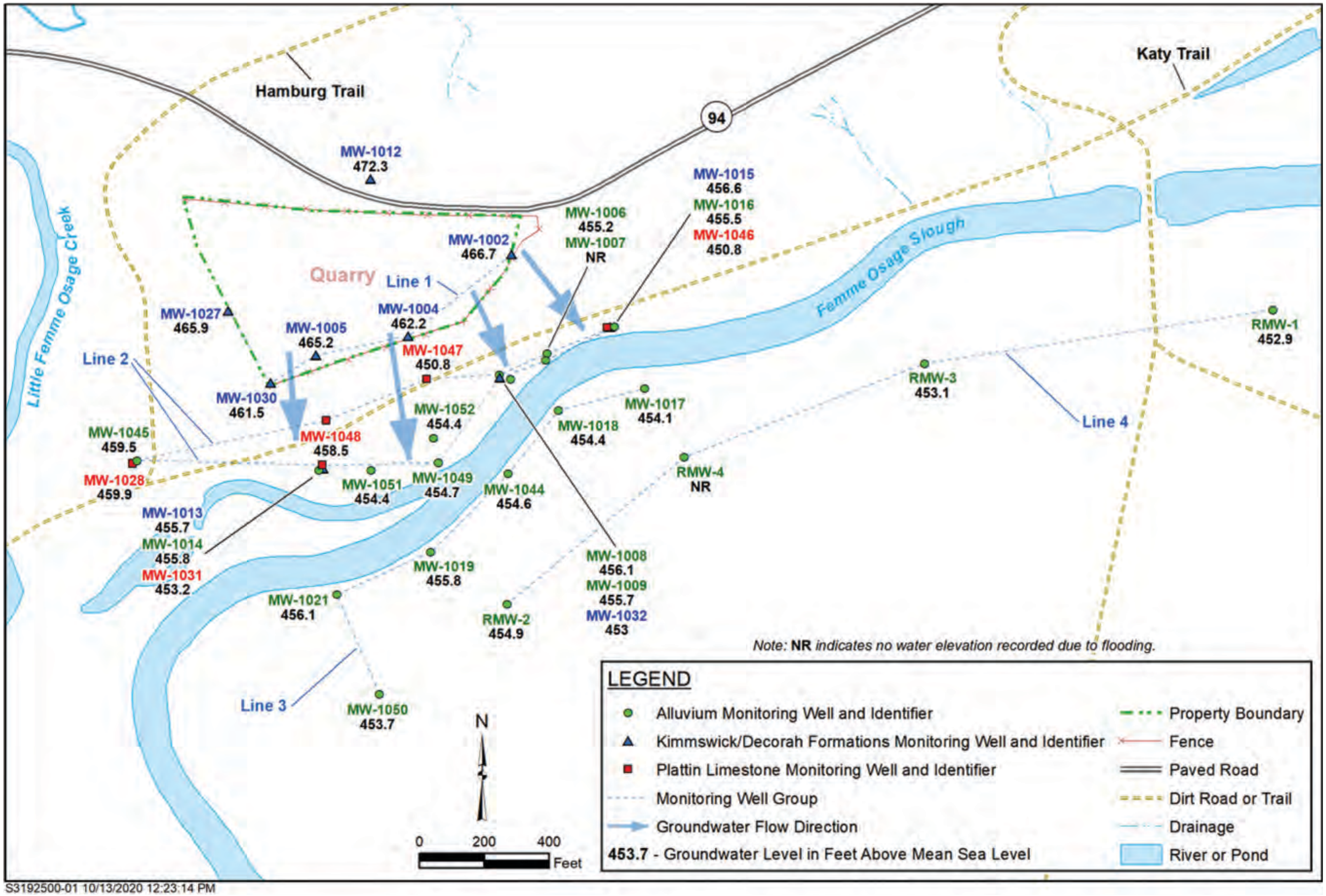


Figure 74. Groundwater Elevations at the Quarry (measurements taken March 23, 2020)

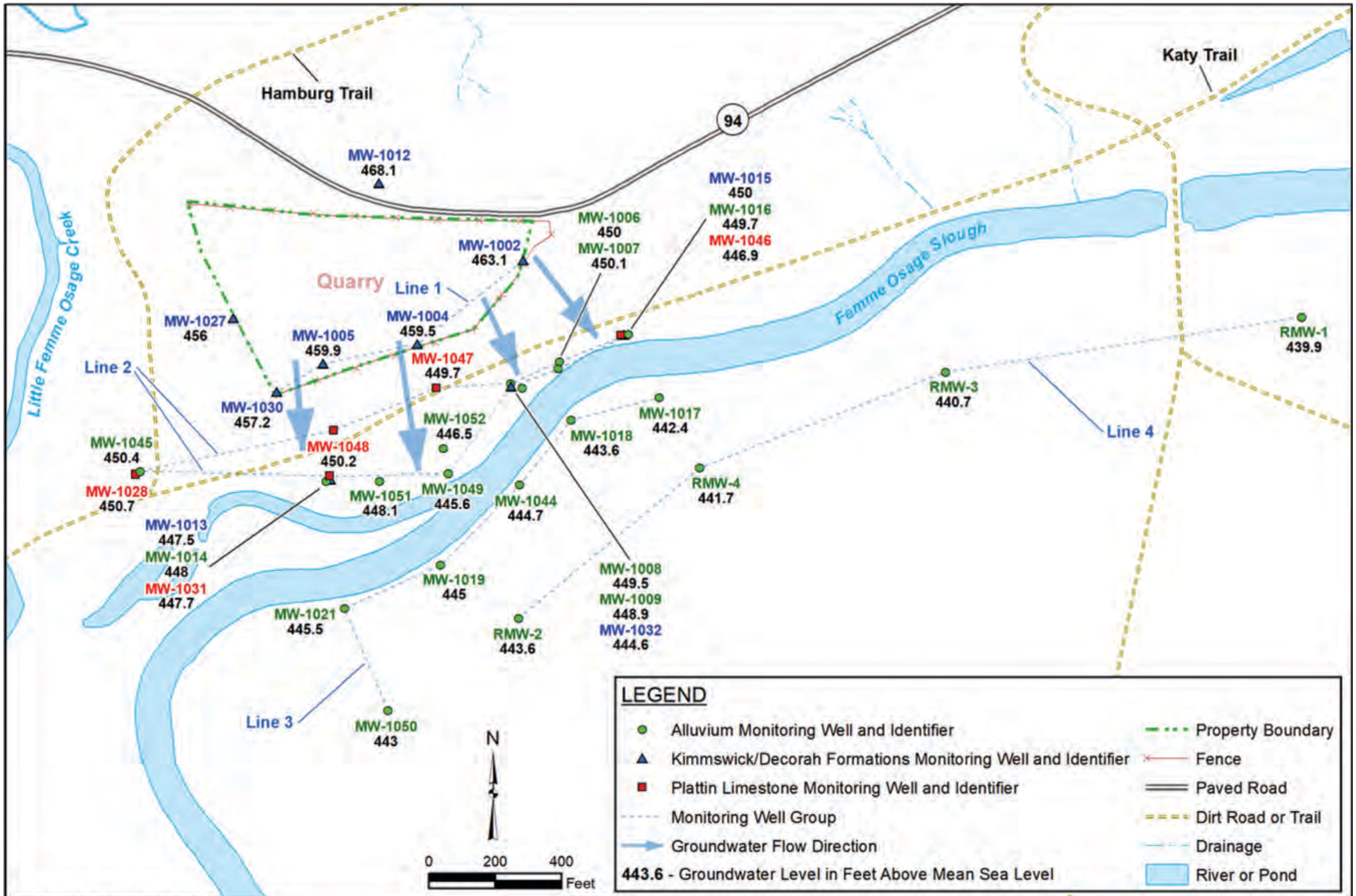


Figure 75. Groundwater Elevations at the Quarry (measurements taken September 28, 2020)

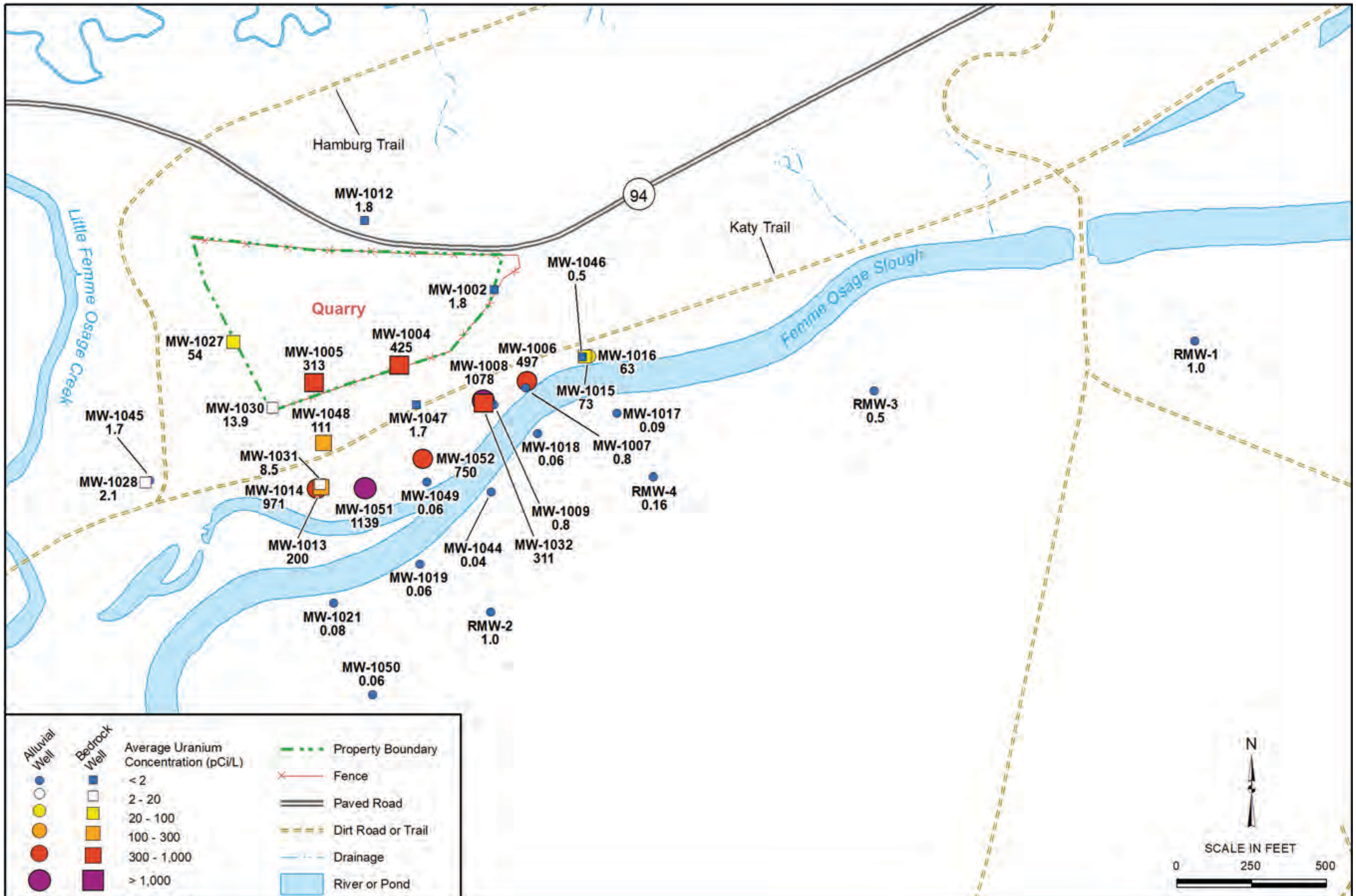


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Figure 76. 2020 Average Uranium Concentration in Quarry Area Wells

4.2.4.5 Monitoring Results for Groundwater in the Area of Impact at the Quarry

Contaminant concentrations in the area of uranium and 2,4-DNT impact are monitored using 24 wells north of the Femme Osage Slough (1 background, 5 Line 1, and 18 Line 2) screened in either the bedrock or alluvial materials. The data are discussed in the following sections.

Uranium Results Line 1 Wells

Uranium is monitored in both the bedrock and the adjoining alluvial materials north of the Femme Osage Slough. These wells are monitoring the declining concentrations in groundwater north of the slough until there is a negligible potential for impact on the groundwater south of the slough.

Uranium concentrations in the Line 1 wells along the Quarry rim (Table 35) continue to be high. The concentrations in wells with current higher uranium values are shown in Figure 77. The average uranium levels in MW-1004 and MW-1005 exceeded the target level of 300 pCi/L (DOE 1998), though many recent uranium results from MW-1005 were near the target level. The uranium concentrations of wells with lower uranium values are shown in Figure 78. Uranium levels in the Line 1 wells have generally been decreasing. Since 2006, the annual uranium averages in MW-1002, MW-1027, and MW-1030 have been lower than the 300 pCi/L target level established for groundwater north of the Femme Osage Slough. Uranium levels in MW-1002 and MW-1030 have consistently been below the MCL of 20 pCi/L since 2001, though recently MW-1030 has had sporadic increases followed by gradual declines. The increases appear to be related to an increased water elevation. Well MW-1030 is at the southwestern exit of the Quarry, and it would not be unexpected that it would have varying uranium concentrations. The results for well MW-1027, at the center of the western exit of the Quarry (Figure 76), vary about an order of magnitude but have been steadily decreasing and are still plotted with the higher Line 1 uranium concentration wells (Figure 77). This conclusion is from observation of the overall dataset, since the Mann-Kendall analysis does not indicate a “statistically significant” downward trend for the last 5 years of data which is highly variable.

Table 35. Average Total Uranium in the QROU Line 1 Wells

Location	Line	Geologic Unit	Average Uranium (pCi/L)				
			2016	2017	2018	2019	2020
MW-1004	1	Kimmswick-Decorah	**462**	**428**	**418**	**418**	**425**
MW-1005	1	Kimmswick-Decorah	**333**	**313**	**306**	292	**313**
MW-1027	1	Kimmswick-Decorah	45	59	46	35	54
MW-1030	1	Kimmswick-Decorah	10.5	5.2	3.2	12.4	13.9
MW-1002	1	Kimmswick-Decorah	2.2	2.2	2.0	1.9	1.8
MW-1012	1	Kimmswick-Decorah	1.8	2.1	2.0	1.7	1.8

Notes:
Concentrations in **bold** exceed the target level of 300 pCi/L.
MW-2012 is an upgradient location.

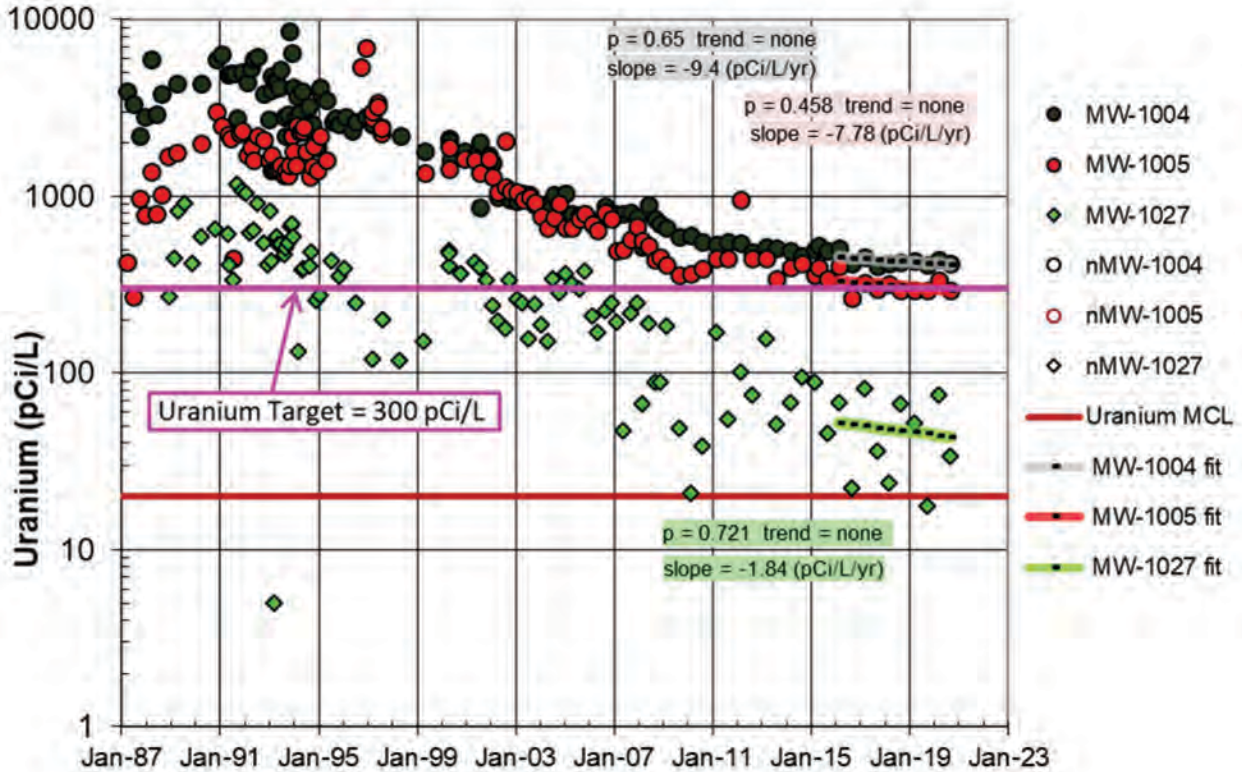


Figure 77. Uranium in Line 1 Monitoring Wells—Higher Concentrations

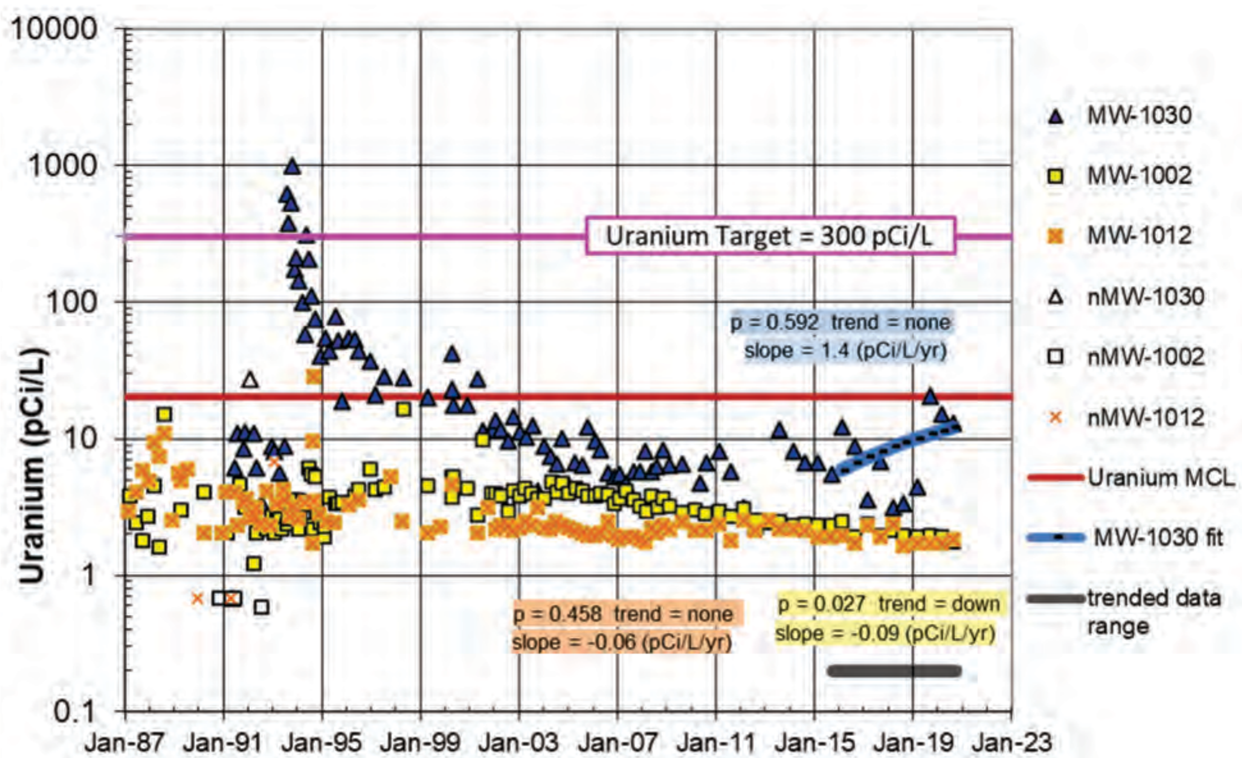


Figure 78. Uranium in Line 1 Monitoring Wells—Lower Concentrations

The results of trend analysis for the Line 1 wells (Figure 77 and Figure 78) indicate that uranium concentrations have been decreasing in most of the wells in recent years, as indicated by negative slopes. Analysis of the last 5 years of data indicates that only MW-1002 has a statistically downward trend based on Mann-Kendall analysis, though MW-1002 is already at low levels. The previous long-term downward trends in uranium at MW-1004 and MW-1005 have significantly slowed over the last 5 to 10 years.

Uranium Results Line 2 Bedrock Wells

Bedrock wells located between the Quarry rim and Femme Osage Slough continue to have elevated uranium levels. The annual averages for uranium from 2016 through 2020 are summarized in Table 36. Two monitoring wells had yearly average concentrations that occasionally exceeded the target level of 300 pCi/L (MW-1013 one time, and MW-1032 four times) during the previous 5 years. Uranium concentrations in wells with historically higher concentrations (Figure 79) have generally been decreasing since 2000. Uranium concentrations in MW-1013 have mostly been below 300 pCi/L since 2010, though it exhibits more variability than most other wells and is occasionally above 300 pCi/L. The wells with higher uranium concentrations are all screened in the shallower Kimmswick-Decorah (well depths 25–35 ft) except for MW-1048, which is screened in the deeper Plattin Formation. MW-1048 is directly south and downgradient of the Quarry.

Table 36. Average Total Uranium in QROU Line 2 Bedrock Wells

Location	Line	Geologic Unit	Average Uranium (pCi/L)				
			2016	2017	2018	2019	2020
MW-1032	2	Kimmswick-Decorah	**324**	**304**	**308**	297	**311**
MW-1013	2	Kimmswick-Decorah	252	**384**	245	218	200
MW-1048	2	Plattin	198	135	120	129	111
MW-1015	2	Kimmswick-Decorah	84	67	76	75	73
MW-1031	2	Plattin	8.6	9.4	8.9	8.9	8.5
MW-1028	2	Plattin	2.5	2.4	2.5	2.6	2.1
MW-1046	2	Plattin	0.6	0.47	0.40	0.47	0.48
MW-1047	2	Plattin	3.2	2.3	7.2	3.2	1.7

Note:
Concentrations in **bold** exceed the target level of 300 pCi/L.

All the lower uranium concentration wells are screened in the Plattin Formation (well depths 47 to 55 ft), and all are below the 20 pCi/L uranium MCL (Figure 80). Uranium concentrations in MW-1047 began to be erratic in 2013, rising suddenly and then dropping off, with one result above the 20 pCi/L MCL. The sudden increases coincide with periods of lower (about 5 ft) than normal water levels. MW-1047 is south and directly downgradient of the Quarry (as is higher-concentration well MW-1048), so it would not be unexpected for it to occasionally have higher concentrations. The downtrend for MW-1046 is beginning to stabilize as it approaches background levels.

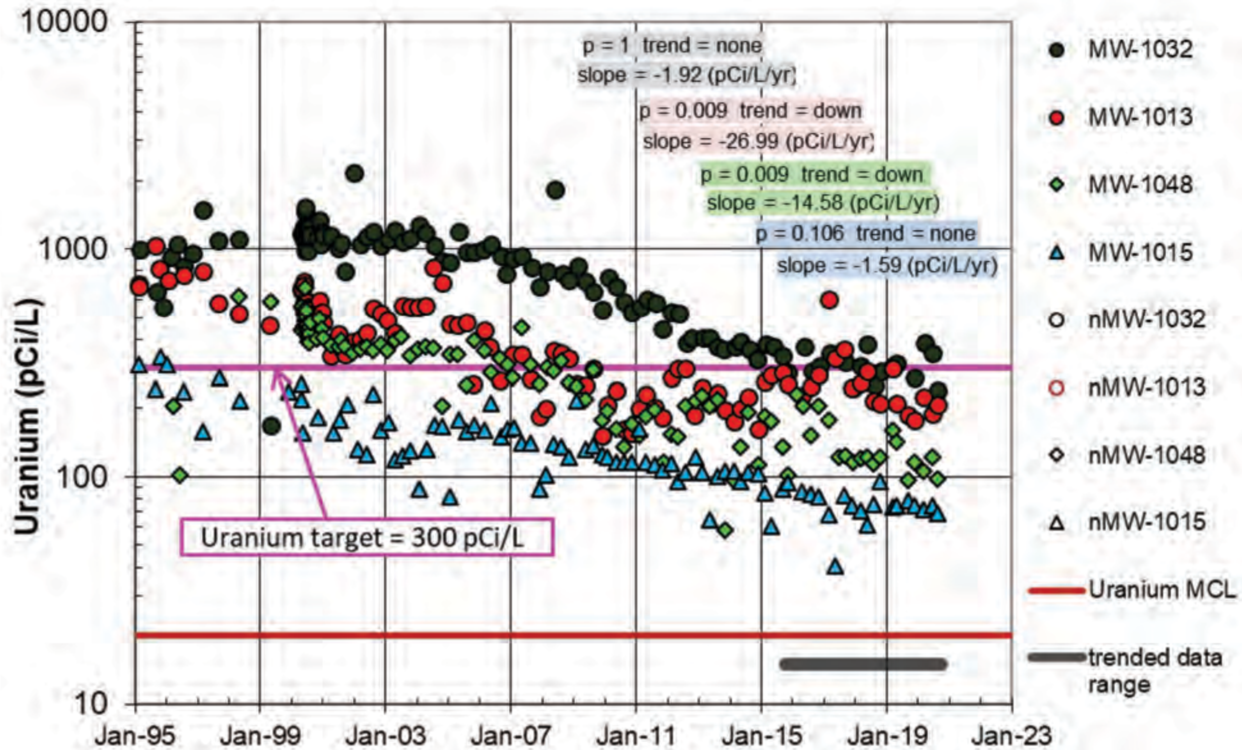


Figure 79. Uranium in Line 2 Bedrock Wells—Higher Concentrations

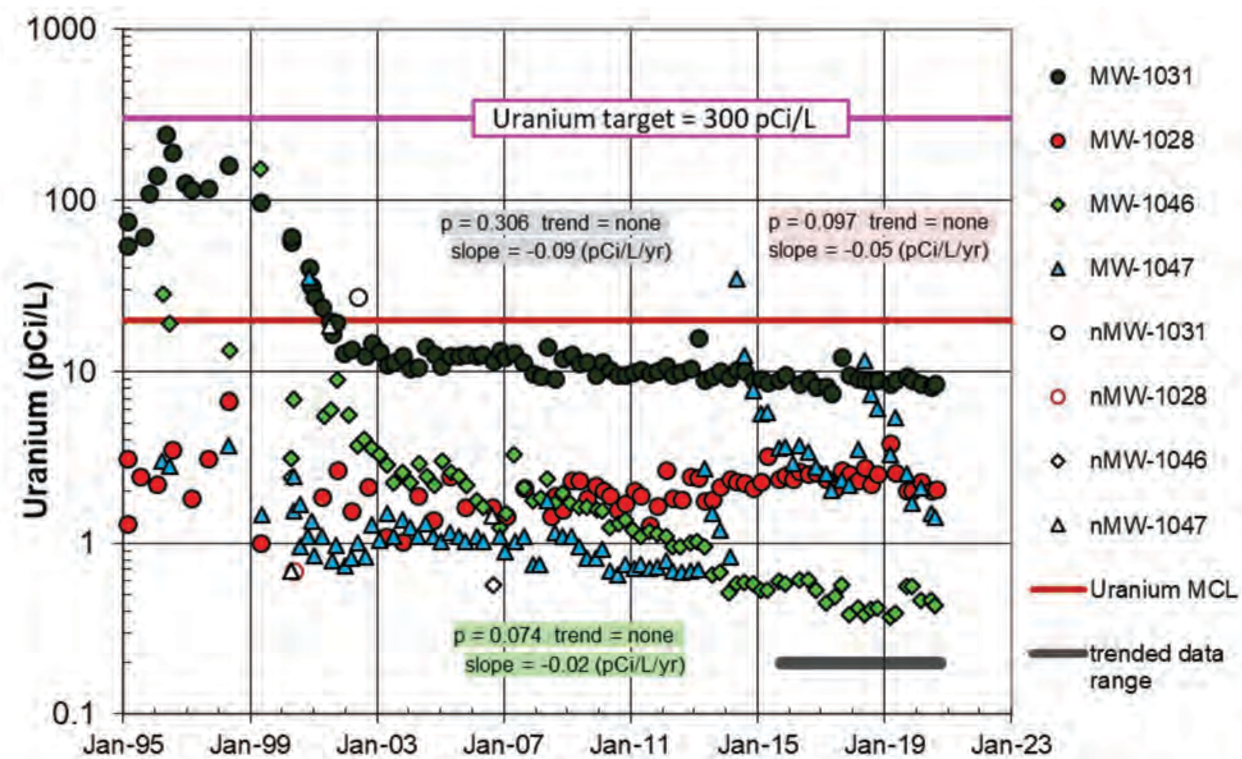


Figure 80. Uranium in Line 2 Bedrock Wells—Lower Concentrations

Uranium levels in the Line 2 bedrock wells have generally decreased since 2000 (Figure 79). The highest levels of uranium are in MW-1032, which is beneath the area of highest uranium impact in the overlying alluvium. It is expected that average uranium concentrations in all Line 2 bedrock wells will be under the target level of 300 pCi/L by 2025, with the possible exception of MW-1032.

Statistically significant downward trends for the last 5 years of data were identified in two of the eight bedrock wells (MW-1013 and MW-1048). The downtrend for MW-1048 is a continuation of its long-term downtrend that dropped below the 300 pCi/L goal 10 years ago. If the downtrend at MW-1032 continues, it will be consistently below the 300 pCi/L goal by 2025. Visual inspection of the total dataset for Line 2 bedrock wells indicates that the wells with historically higher uranium concentrations are all in a long-term downward trend.

Uranium Results Line 2 Alluvial Wells

The highest levels of uranium in groundwater are in the alluvial aquifer between the Quarry rim and Femme Osage Slough (Figure 76). The annual averages for uranium in the Line 2 alluvial wells from 2015 through 2019 are summarized in Table 37. Uranium concentrations in the wells above the 300 pCi/L target level (Figure 81) have been relatively stable for over 25 years with no long-term increasing or decreasing trends, though concentrations routinely vary by an order of magnitude. The highly variable uranium concentrations in well MW-1052 typically, though not always, are lower when water levels are low (Figure 82). The extreme variability of MW-2052 concentrations in 2000 (Figure 81) was related to multiple samples being collected during pump-and-treat testing after its installation in 2000.

Table 37. Average Total Uranium in QROU Line 2 Alluvial Wells

Location	Line	Geologic Unit	Average Uranium (pCi/L)				
			2016	2017	2018	2019	2020
MW-1008	2	Alluvium	**1748**	**2326**	**2791**	**2133**	**1078**
MW-1051	2	Alluvium	**1113**	**1158**	**958**	**1210**	**1139**
MW-1014	2	Alluvium	**1102**	**1153**	**1068**	**910**	**971**
MW-1006	2	Alluvium	**816**	**700**	**1054**	**535**	**497**
MW-1052	2	Alluvium	**1151**	**836**	**324**	**621**	**750**
MW-1007	2	Alluvium	11	16	9.7	46	0.82
MW-1016	2	Alluvium	86	86	76	56	63
MW-1009	2	Alluvium	14	5.6	2.4	0.88	0.77
MW-1045	2	Alluvium	3.6	4.1	3.0	2.4	1.7
MW-1049	2	Alluvium	NA	0.084	0.058	0.065	0.057

Note:
Concentrations in **bold** exceed the target level of 300 pCi/L.

Abbreviation:
NA = most or all results were below detection or qualified as estimated

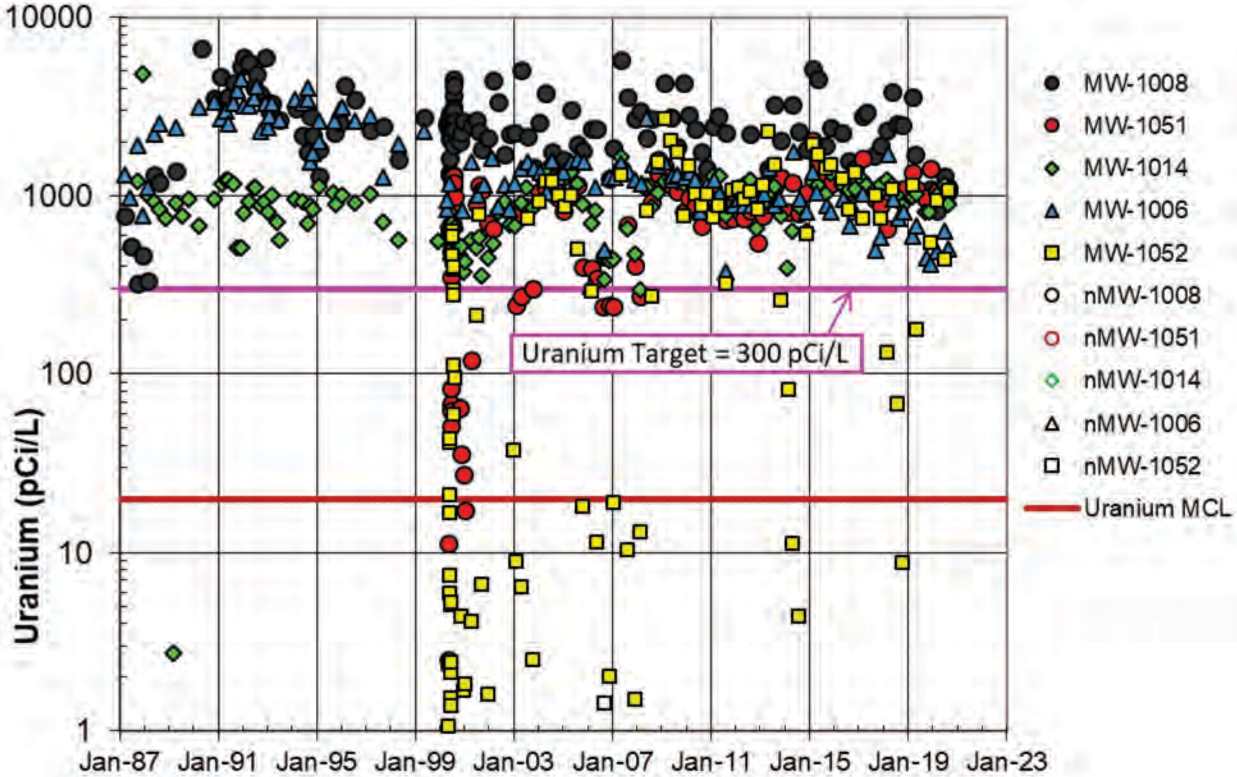


Figure 81. Uranium in Line 2 Alluvial Wells—Higher Concentrations

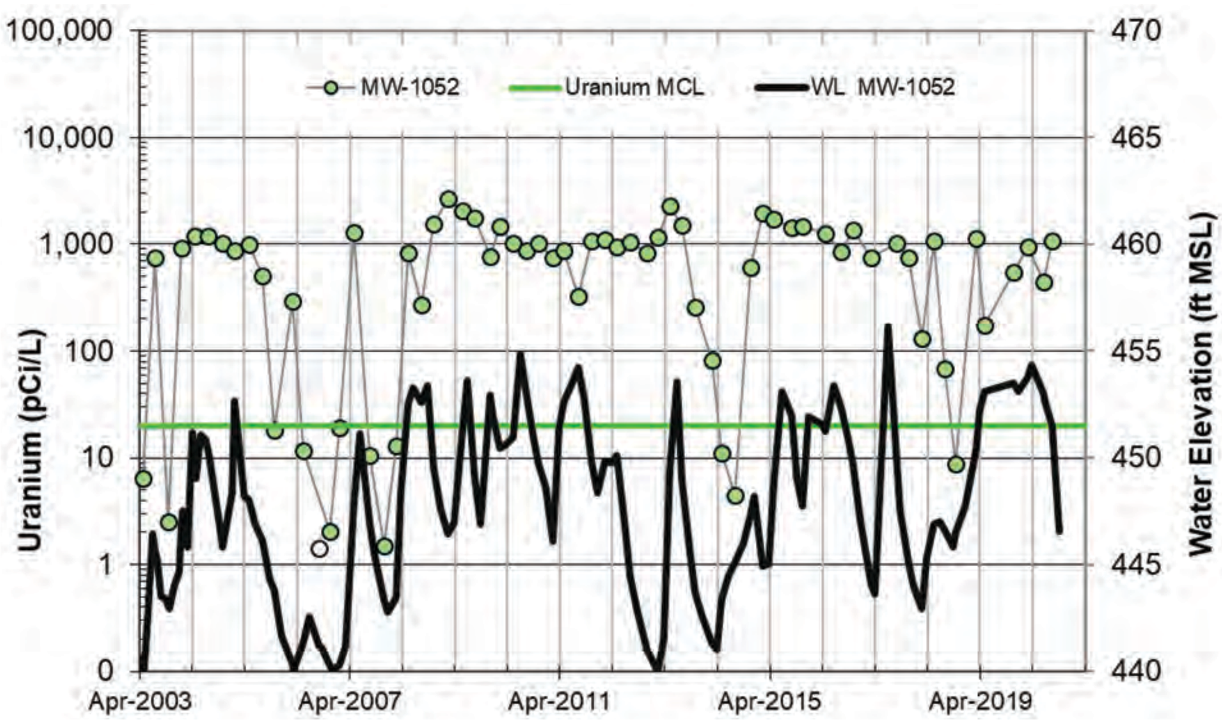


Figure 82. Variable Uranium Concentrations in MW-1052

Uranium concentrations in wells below the 300 pCi/L target level (Figure 83) have been range bound (no long-term upward or downward trend) over the past 25 years, with most varying over an order of magnitude. Uranium in well MW-1007 varies over 3 orders of magnitude (Figure 83) and occasionally exceeds the target level. Low concentrations in MW-1007 appear to be correlated with water levels, at least when water levels are extreme (e.g., after flooding events). MW-1007 is only 10 ft deep and adjacent to the slough. When the slough water level is high, MW-1007 often floods (it did in 2015, 2017, and 2019), and subsequent samples are temporarily diluted. Uranium results in well MW-1049 have mostly been below the uranium detection limit for more than the past 10 years. It is 15 ft deeper (total depth is 37 ft) than any of the other alluvial wells.

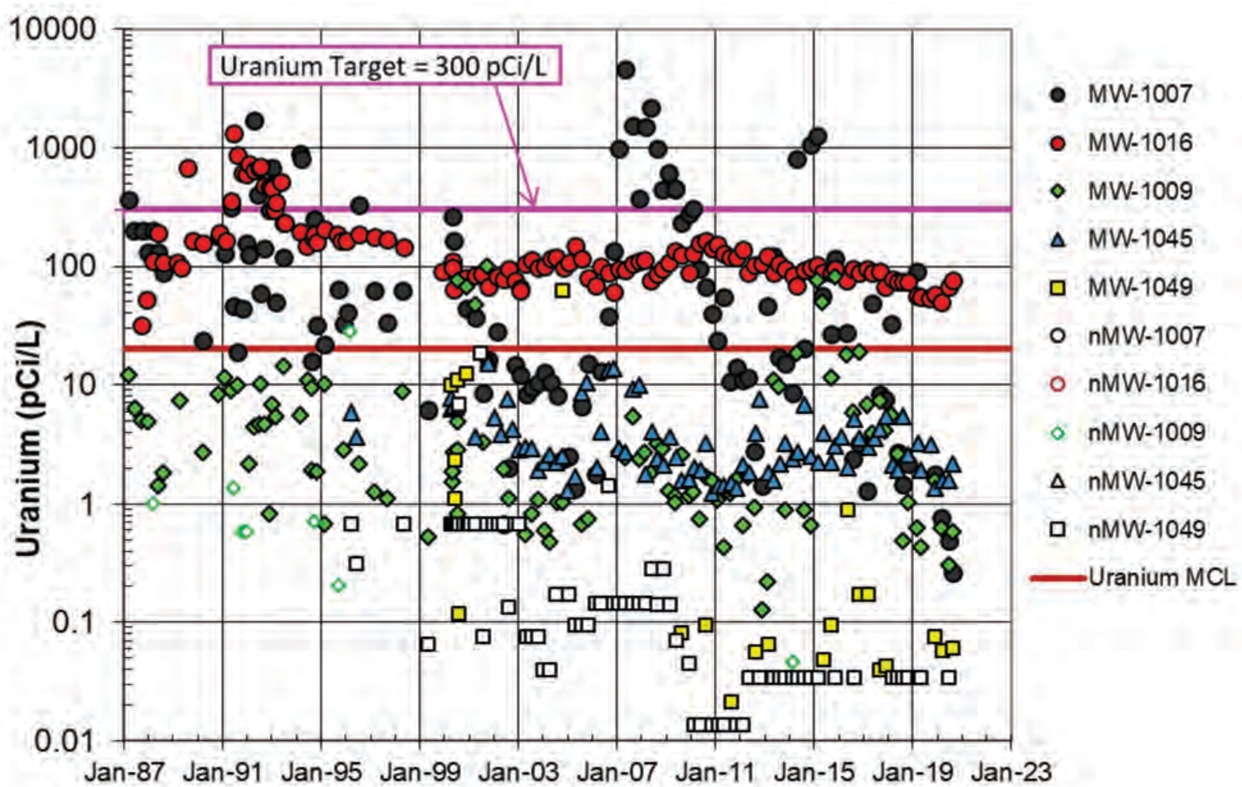


Figure 83. Uranium in Line 2 Alluvial Wells—Lower Concentrations

A visual inspection of the data from Line 2 alluvial wells indicates long-term range-bound uranium concentrations accompanied by significant variability. None of these wells exhibit long-term trends. The alluvial wells are screened primarily in the shallow, oxidized portion of the groundwater system, where changes in groundwater elevations have typically affected the uranium levels measured in the wells. Geochemical data from these wells support the presence of dissolved uranium in the groundwater. The geochemistry of the groundwater in this area exhibits high oxidation-reduction potential (ORP) values, high sulfate concentrations, and low dissolved iron concentrations, all indicators of an oxidizing environment.

Uranium Attainment Objectives

The attainment objective for the long-term monitoring of uranium in groundwater north of the slough is that the 90th percentile of data within a monitoring year is below the 300 pCi/L target level and that data from each well will also be trended to establish that uranium concentrations north of the slough are decreasing (DOE 2000b).

The average uranium levels in eight wells north of the slough exceeded the target level in 2020 (three bedrock wells and five alluvial wells). The 90th percentile in the data combined from Line 1 and 2 wells was 1051 pCi/L. This is a median value for the 5-year period from 2016 through 2020 and is similar to the 2018 and 2019 values (Figure 84). Examining the 90th percentile for Lines 1 and 2 separately indicates that the metric is dominated by uranium variability in Line 2 wells, specifically, the alluvial wells. Concentrations in these wells have historically varied about an order of magnitude or more (Figure 81 and Figure 83). In general, uranium concentrations in Line 1 and the Line 2 bedrock wells have decreased over the long term, whereas the concentrations in the Line 2 alluvium remain within the historical range.

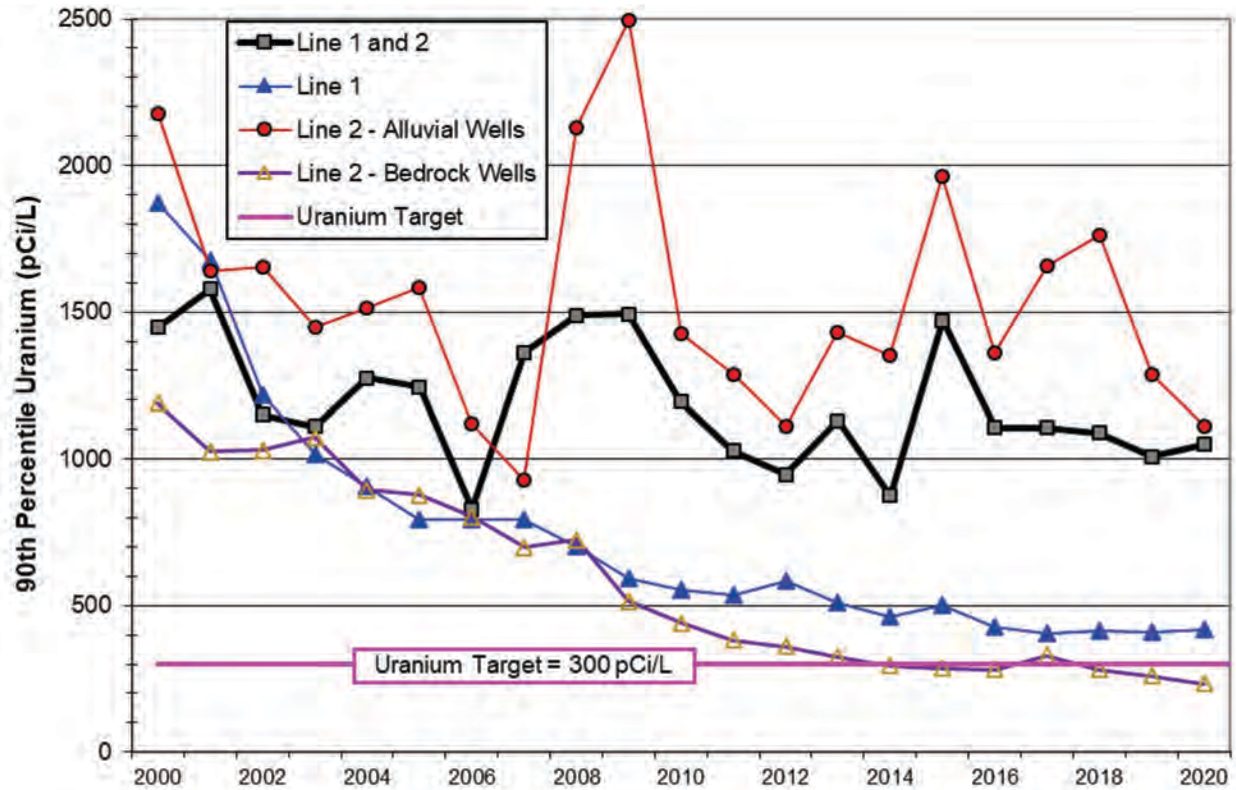


Figure 84. 90th Percentile of Uranium in Line 1 and 2 Wells (2000–2020)

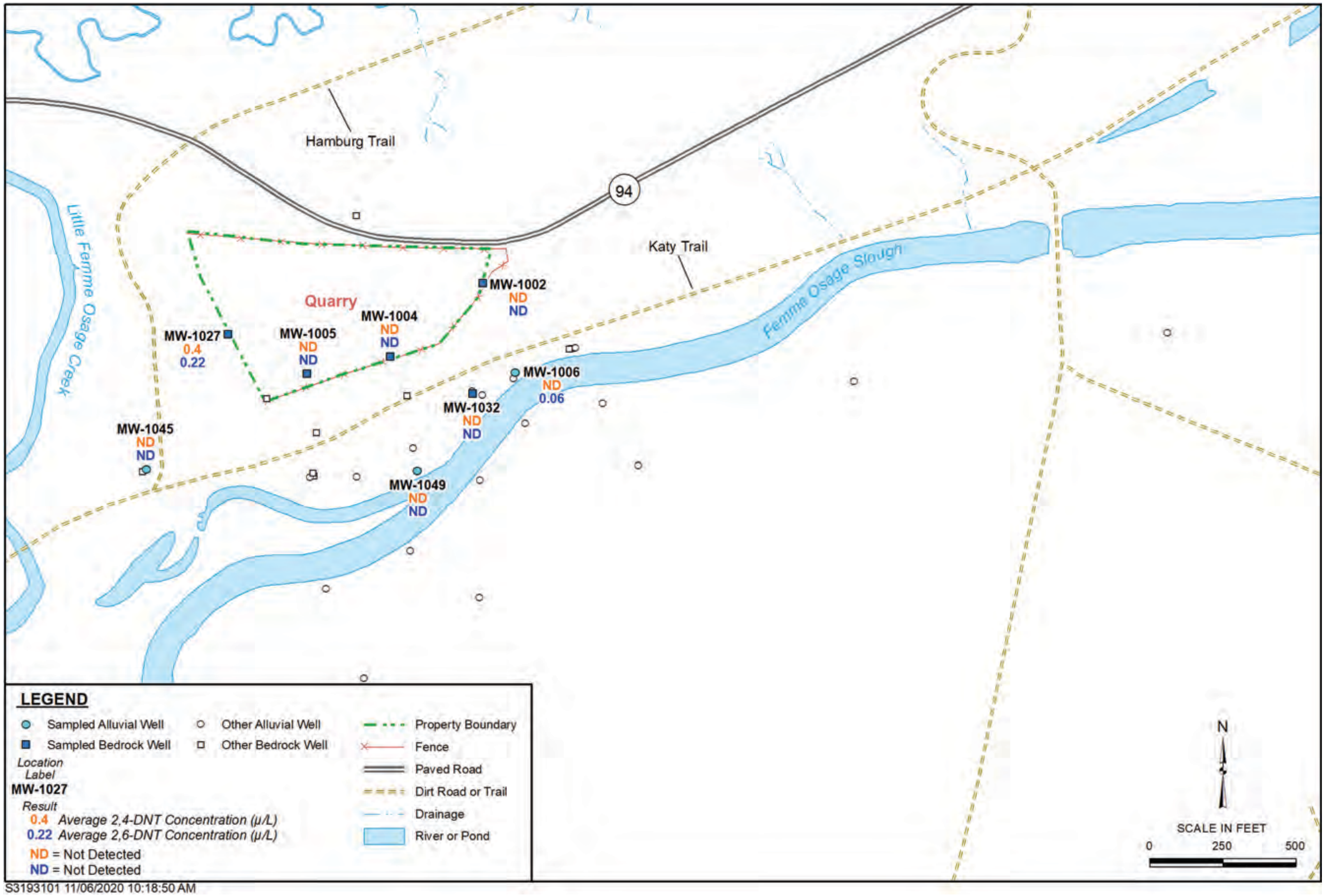
Overall, the decreasing uranium concentrations in the Quarry rim and area north of the Femme Osage Slough are the result of bulk waste removal and restoration activities in the Quarry proper. Remedial activities in the Quarry have reduced infiltration of precipitation and storm water into the residually contaminated fracture system in the Quarry proper. Uranium does not bind as readily to the bedrock as it does to the alluvial materials; therefore, decreases should occur more readily in the bedrock as groundwater flushes through the system. The distribution of uranium in groundwater is still predominantly controlled by the precipitation of uranium along the oxidizing-reducing front north of the Femme Osage Slough. Sample results from wells screened in the reducing portion of the area north of the slough indicate that uranium levels continue to remain low.

Nitroaromatic Compounds

Samples from eight monitoring wells were analyzed for the nitroaromatic compounds 2,4-DNT and 2,6-DNT (Figure 85). Two of these monitoring wells, MW-1027 and MW-1006, have historically had 2,4-DNT concentrations above the 0.11 µg/L MCL, though the levels at MW-1006 have been below 0.11 µg/L target level since 2015 (Figure 86). Levels in these wells are variable, and occasional results above the cleanup standard are to be expected. For example, 2,4-DNT concentrations at well MW-1027 (at the mouth of the quarry) vary by as much as 3 orders of magnitude, from nondetects (i.e., less than the 0.019 µg/L detection limit) to over 20 µg/L.

The remaining wells monitor upgradient and downgradient water quality along the Quarry rim or between the Quarry and Femme Osage Slough. Historical results of 2,4-DNT (Figure 87) and 2,6-DNT (Figure 88) of all eight selected monitoring wells document the success of the bulk waste removal from the Quarry. The 2019 2,6-DNT results in all eight wells were below the 1.3 µg/L MCL.

It is recommended that the sampling frequency in the six wells that have been at nondetect for the last 5 years be reduced to annual for a period of 5 years. A semiannual sampling frequency is recommended for the two wells (MW-1027 and MW-1006) that have had detects during the last 5 years.



Note: 0.019 µg/L is a typical detection limit.

Figure 85. 2020 Average 2,4-DNT and 2,6-DNT in Quarry Wells

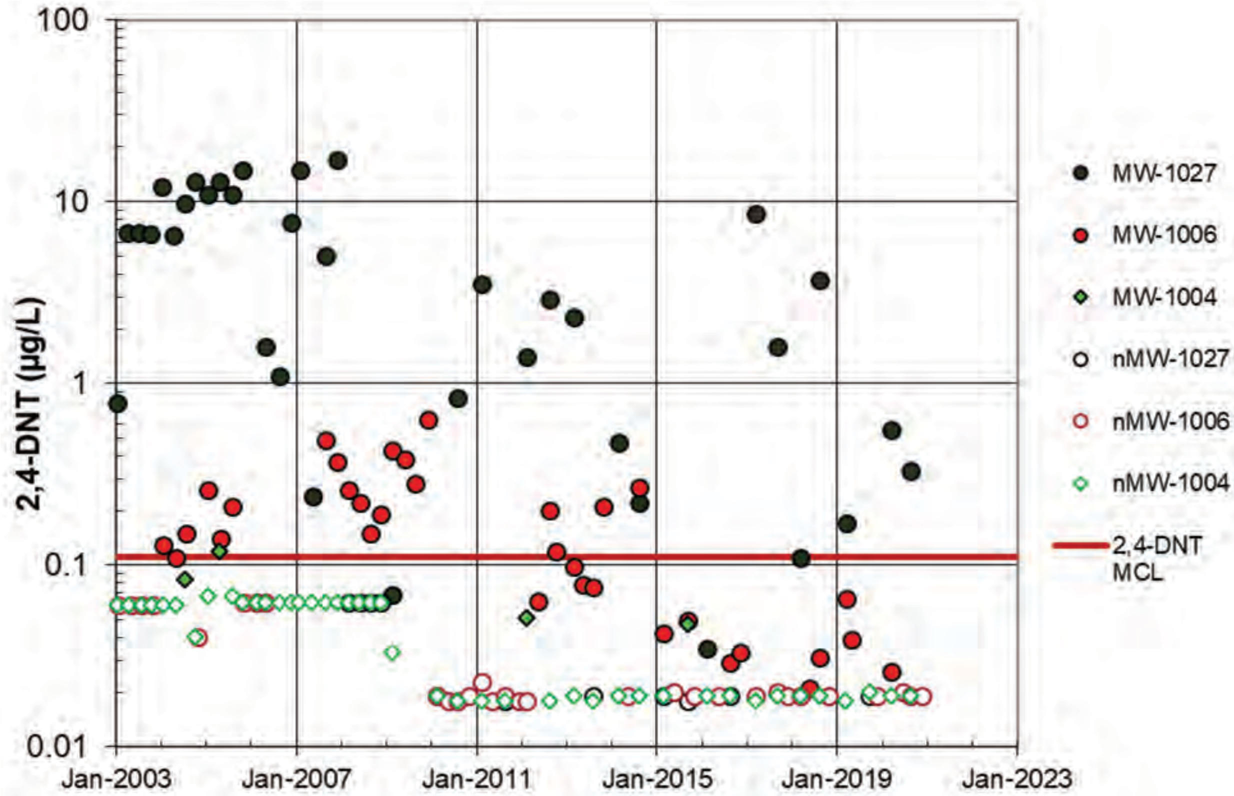


Figure 86. 2,4-DNT in MW-1027, MW-1006, and MW-1004

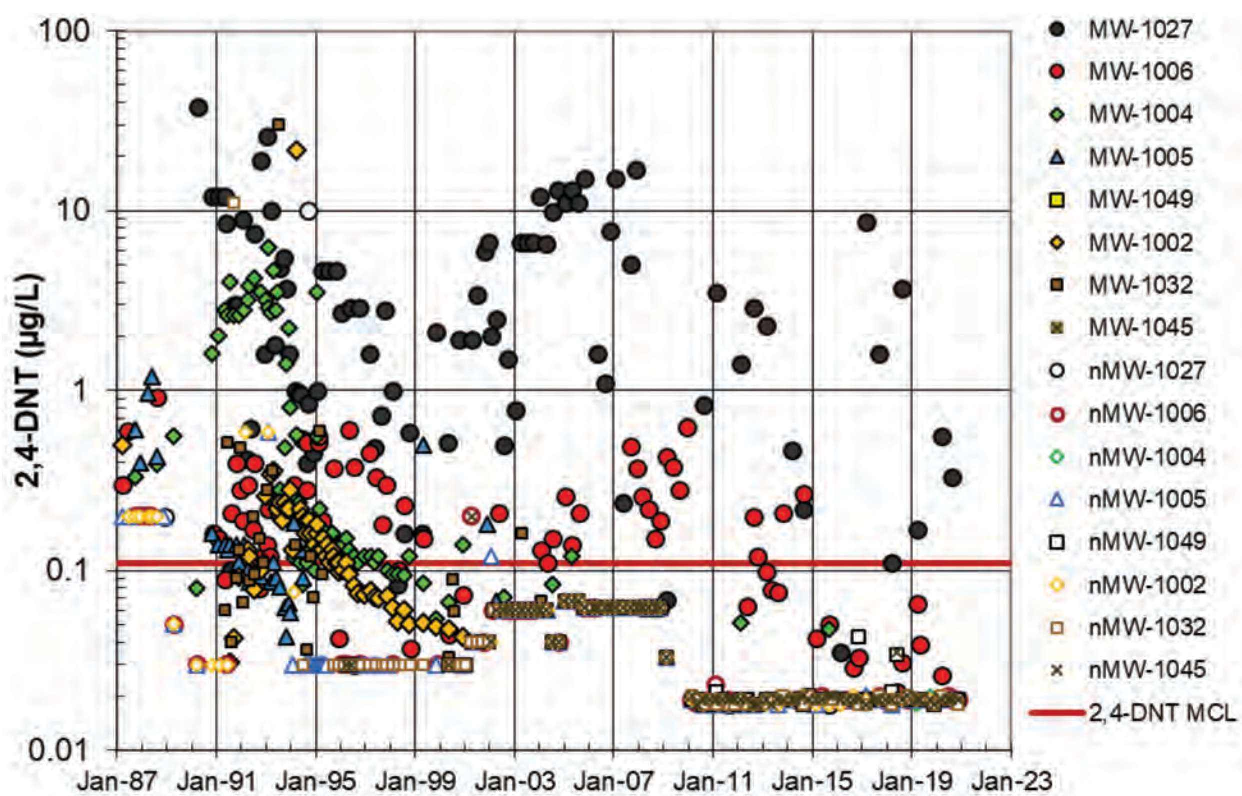


Figure 87. Historical 2,4-DNT Results for the Eight Selected Monitoring Wells

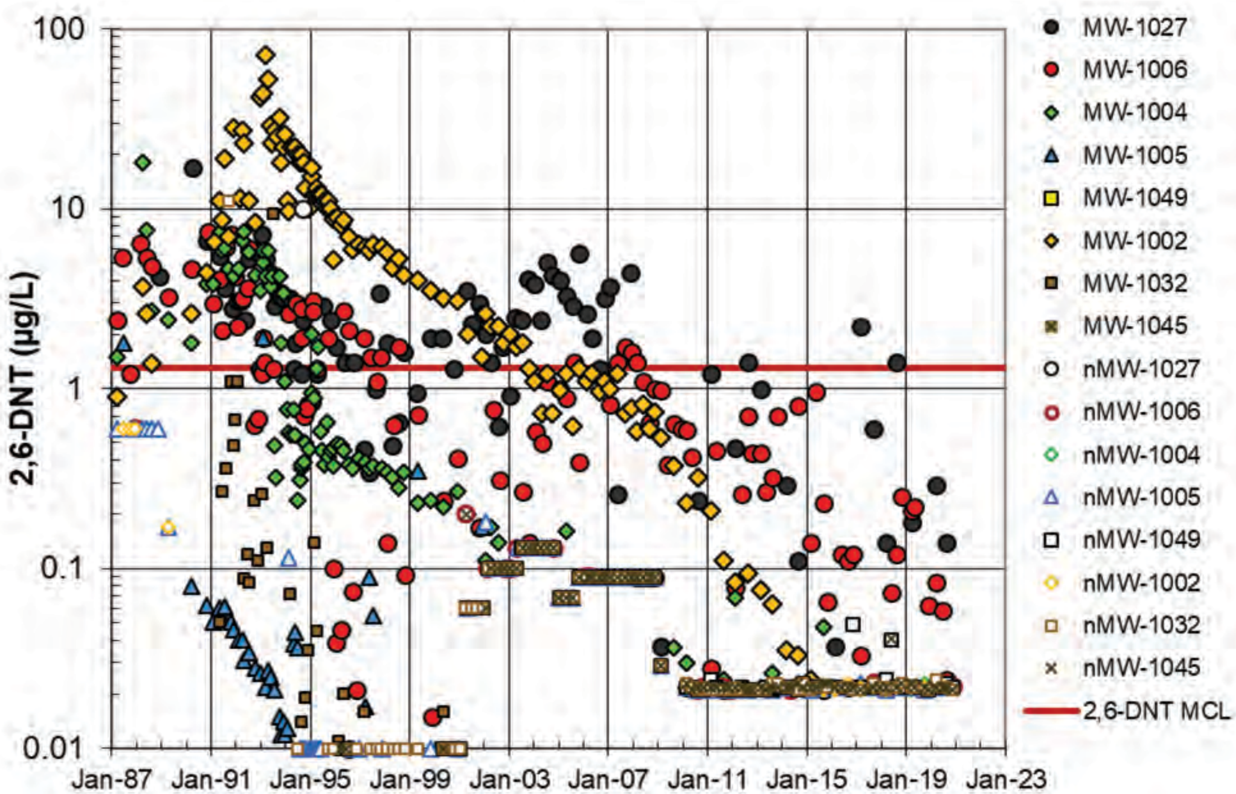


Figure 88. Historical 2,6-DNT Results for the Eight Selected Monitoring Wells

The attainment objective for the long-term monitoring of 2,4-DNT in groundwater north of the slough is that the 90th percentile of the data within a monitoring year be below the target level of 0.11 µg/L and that data from each well will be trended to establish that 2,4-DNT concentrations north of the slough are decreasing (DOE 2000b). Results from the eight monitoring wells selected for continued long-term monitoring were used to calculate this metric. The 90th percentile associated with the data from the eight wells was below the objective in the 6 most recent years. These values continue to be at the low end of the historical range (Figure 89). The three wells where 2,6-DNT steadily declined to background levels (MW-1002, MW-1004, and MW-1005 in Figure 88) are bedrock wells along the southern rim of the quarry. Present groundwater concentrations pose little potential impact to groundwater in the Missouri River alluvium.

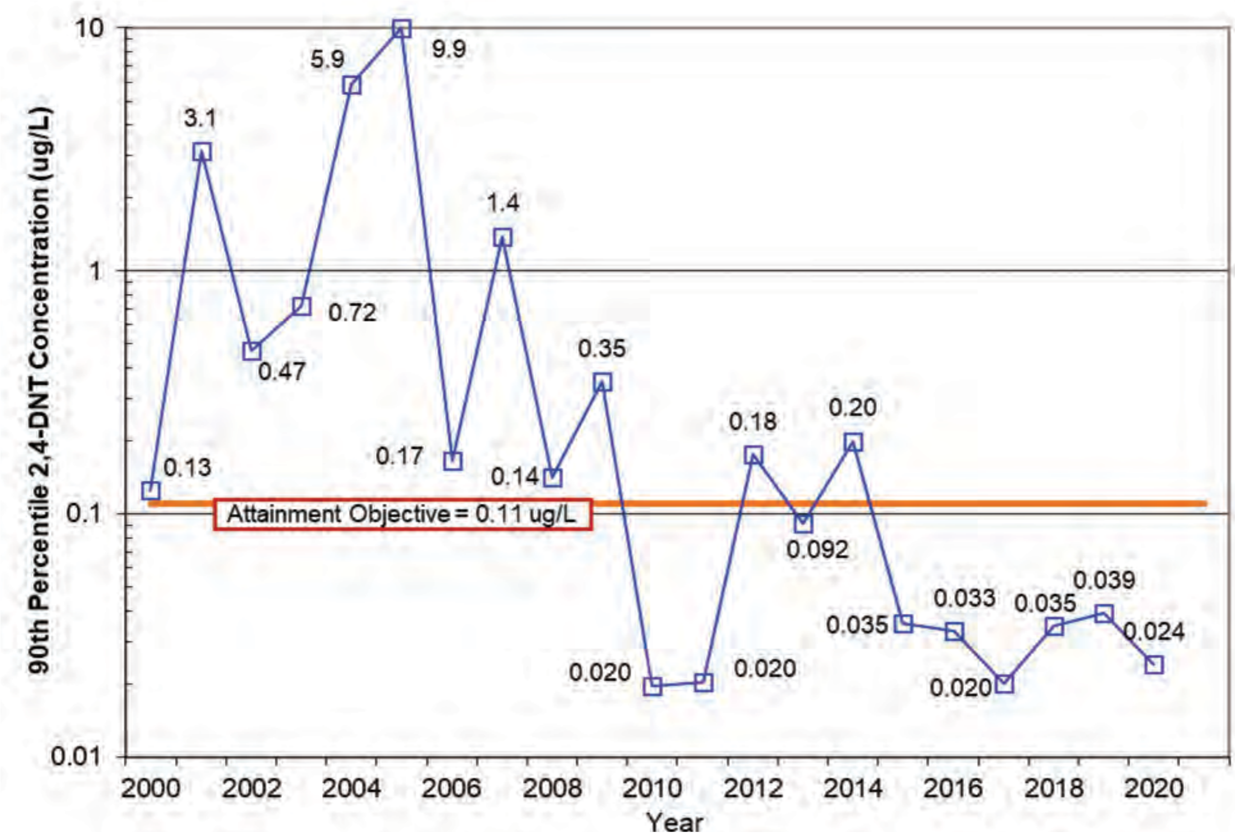


Figure 89. 90th Percentile of 2,4-DNT in Long-Term Monitoring Wells

Geochemical Parameters

The geochemistry of the shallow aquifer is monitored to verify the presence of the reduction zone and to confirm that the reduction zone is capable of the ongoing attenuation of uranium in groundwater. Groundwater is analyzed for sulfate, dissolved iron, ferrous iron, and *E*h (a measure of the oxidation-reduction state of groundwater constituents). Sulfate is monitored as an indicator of oxidation-reduction conditions in the groundwater near the Quarry. Higher sulfate concentrations generally indicate an oxidizing environment. Sulfate concentrations will typically track uranium concentrations in wells with variable uranium concentrations (high sulfate, high uranium and low sulfate, low uranium). Iron (total dissolved and ferrous) is also monitored as an indicator of oxidation-reduction conditions in the groundwater. Dissolved iron concentrations typically increase in a reducing environment. These results generally correlate with observed uranium concentrations upgradient and downgradient of the reduction zone, as uranium is typically more mobile in an oxidizing environment and precipitates in a reducing environment. Table 38 presents the 2020 geochemical parameter averages for Line 1 and Line 2 monitoring locations. Figure 90 through Figure 94 present the historical sulfate values. The results from well MW-1052, an alluvial well screened across a depth from 10 to 20 ft, illustrate the correlation between uranium and sulfate levels, and their inverse relationship to dissolved iron (Figure 95). Figure 96 through Figure 99 present the historical dissolved iron values.

Table 38. Average Geochemical Parameter Data at the Quarry in 2020

Location	Line	Geologic Unit	Average Values			
			Sulfate (mg/L)	Dissolved Iron (µg/L)	Ferrous Iron (µg/L)	ORP[a] (mV)
MW-1004	1	Kimmswick-Decorah	87	265	100	140
MW-1005	1	Kimmswick-Decorah	54	970	75	91
MW-1027	1	Kimmswick-Decorah	45	ND	70	142
MW-1030	1	Kimmswick-Decorah	26	4,460	3180	133
MW-1002	1	Kimmswick-Decorah	63	ND	10	143
MW-1012[b]	1	Kimmswick-Decorah	34	26	10	157
MW-1032	2	Kimmswick-Decorah	85	143	98	73
MW-1013	2	Kimmswick-Decorah	58	3,223	6338	–4
MW-1048	2	Plattin	51	1,313	780	33
MW-1015	2	Kimmswick-Decorah	57	72	163	82
MW-1031	2	Kimmswick-Decorah	28	ND	135	125
MW-1028	2	Plattin	24	ND	40	93
MW-1046	2	Plattin	51	54	645	98
MW-1047	2	Plattin	75	3,923	840	1
MW-1008	2	Alluvium	90	1,049	288	42
MW-1051	2	Alluvium	126	188	153	89
MW-1014	2	Alluvium	100	113	303	97
MW-1006	2	Alluvium	50	6,725	2013	–4
MW-1052	2	Alluvium	27	11,373	2683	–15
MW-1007	2	Alluvium	1	52,200	8808	–106
MW-1016	2	Alluvium	73	36	215	107
MW-1009	2	Alluvium	9	38,450	2103	–92
MW-1045	2	Alluvium	24	ND	10	64
MW-1049	2	Alluvium	8	48,750	7045	–93

Notes:
[a] Convert ORP to *E*h by adding 200 mV to the ORP value.
[b] MW-1012 is upgradient.
Typical dissolved iron detection limits are 22–30 µg/L.

Abbreviations:
mV = millivolts
ND = all samples below detection or estimated

A review of the geochemical data indicates that although the area of highest impact has an oxidizing environment, reducing conditions are prevalent along the northern edge of the slough, as shown by data in wells MW-1007, MW-1009, and MW-1049. This is consistent with the uranium data where low levels are detected, especially in MW-1049 where very low sulfate and high dissolved iron concentrations are also observed. The location of this reduction area was consistent during the review period, and the attenuation of uranium in this area continues.

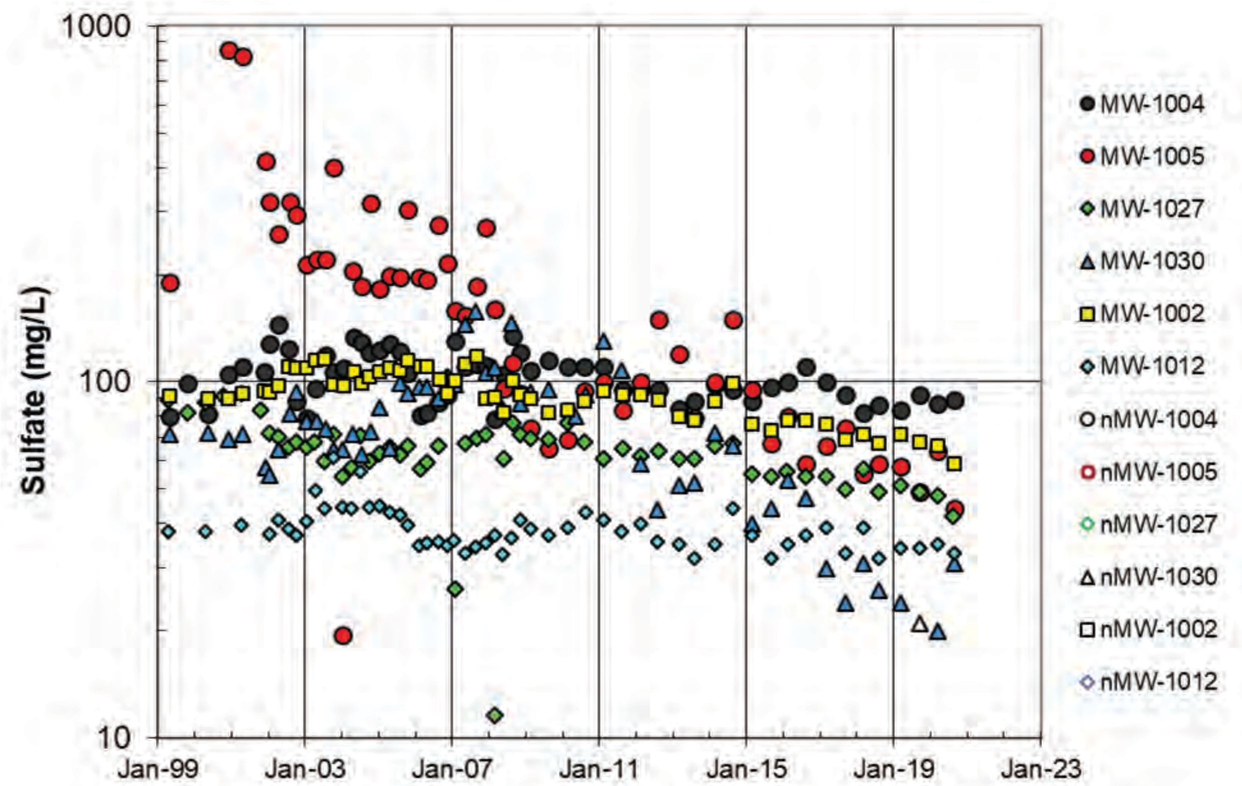


Figure 90. Sulfate in Line 1 Wells (Bedrock)—MW-1012 Is Upgradient

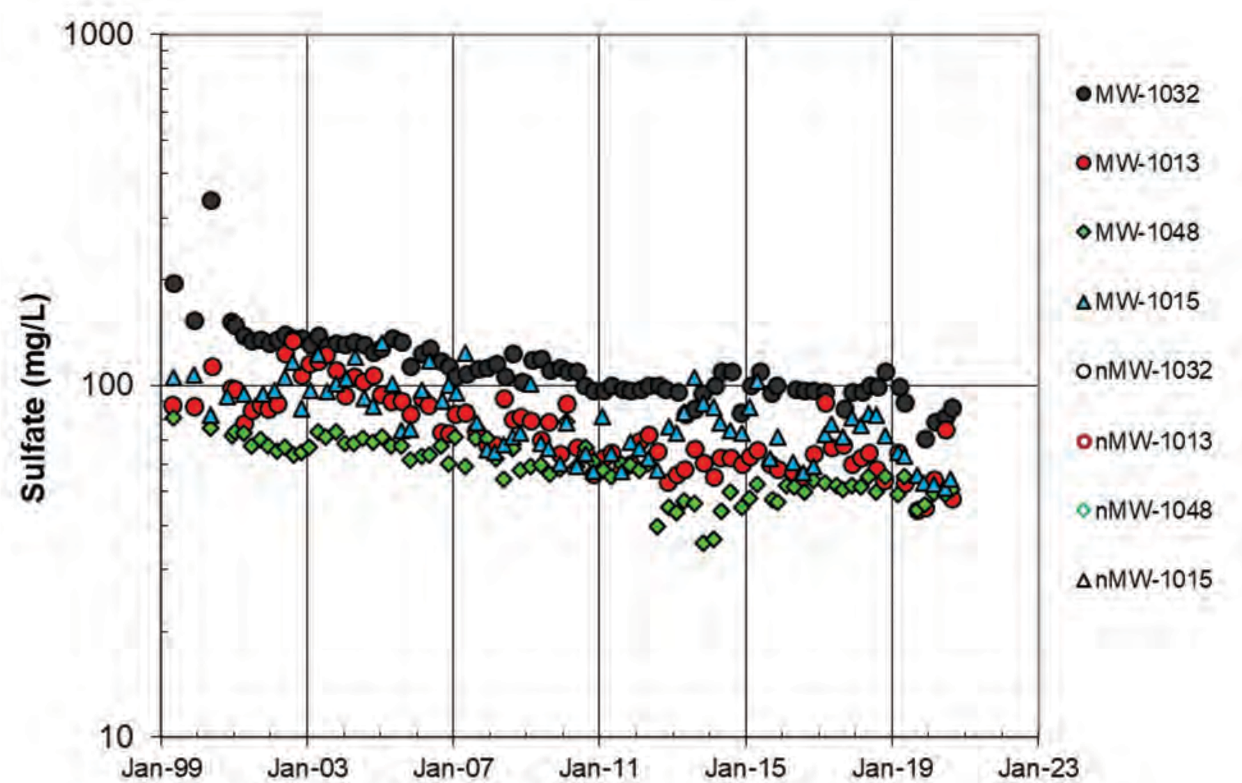


Figure 91. Sulfate in Line 2 Bedrock Wells—Wells with Higher Uranium Concentrations

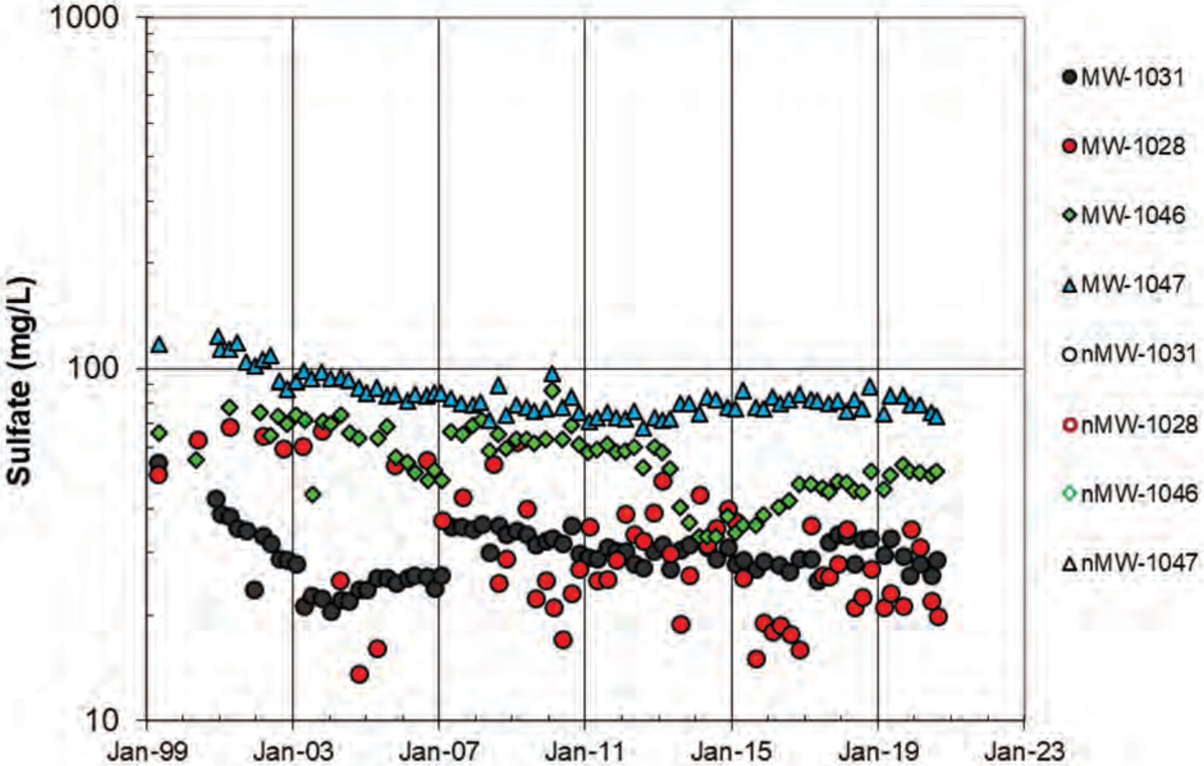


Figure 92. Sulfate in Line 2 Bedrock Wells—Wells with Lower Uranium Concentrations

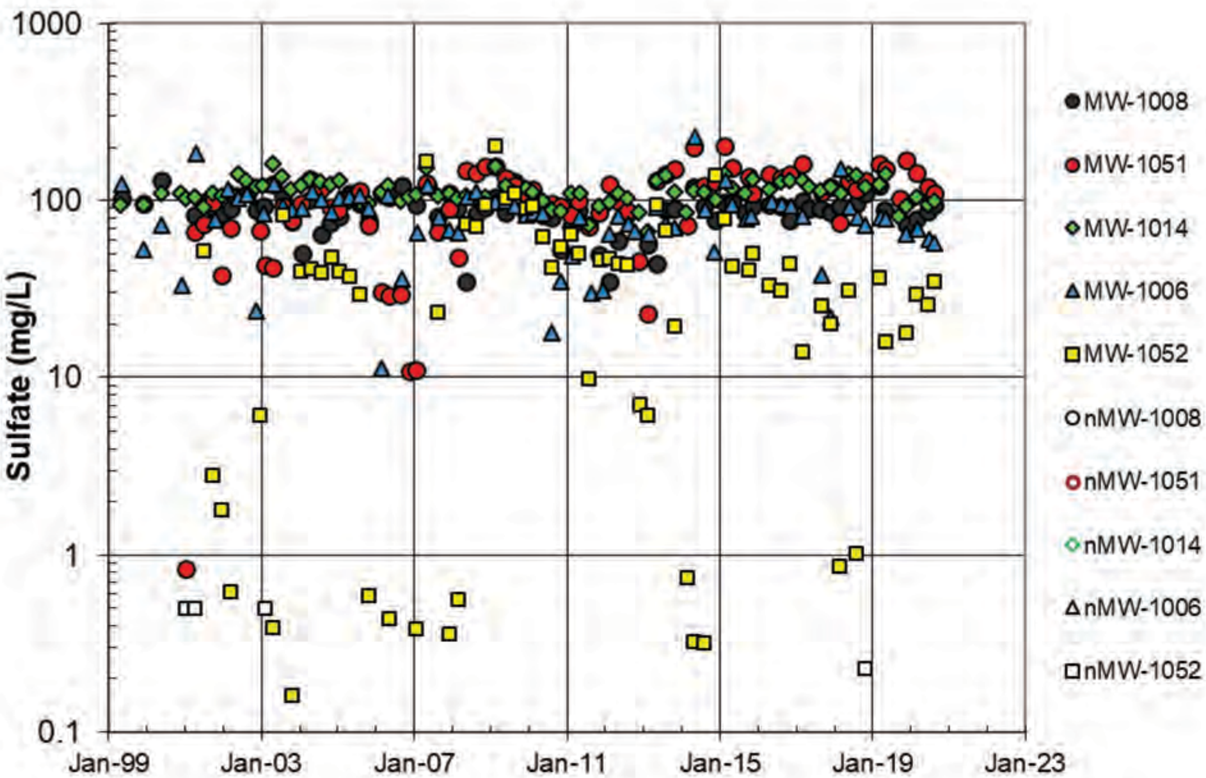


Figure 93. Sulfate in Line 2 Alluvial Wells—Wells with Higher Uranium Concentrations

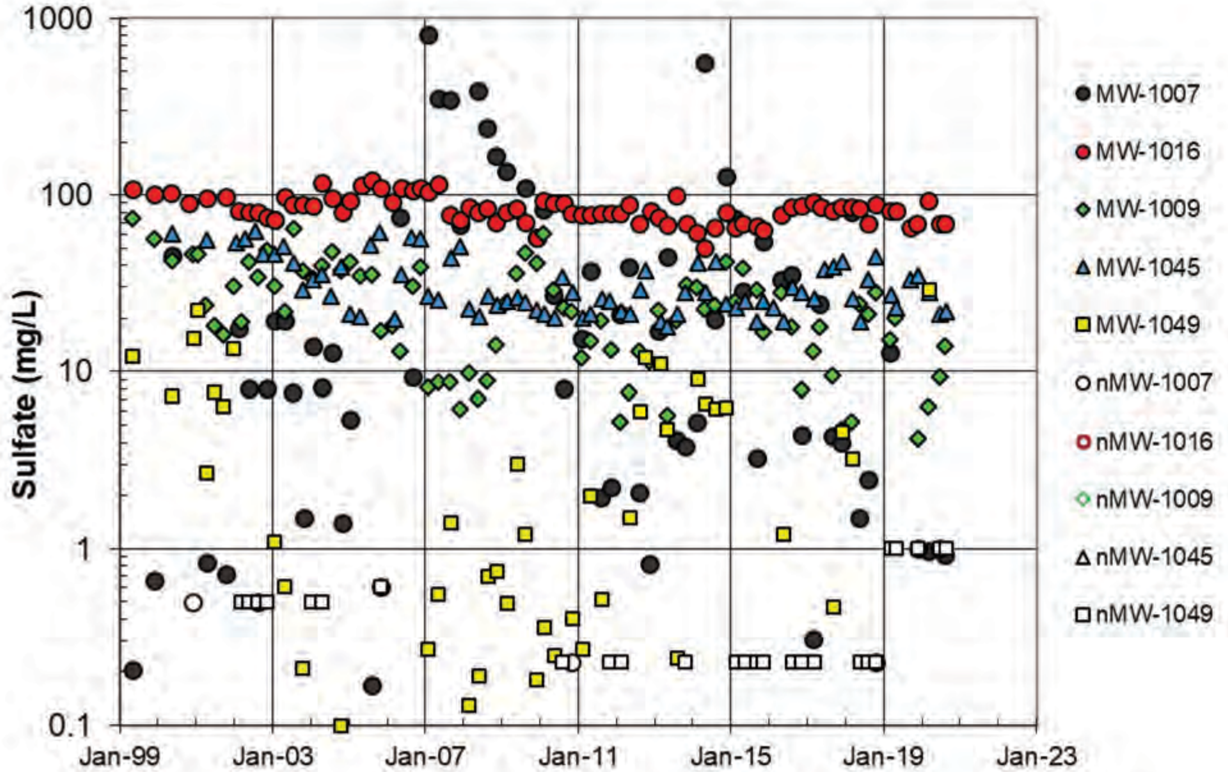


Figure 94. Sulfate in Line 2 Alluvial Wells—Wells with Lower Uranium Concentrations

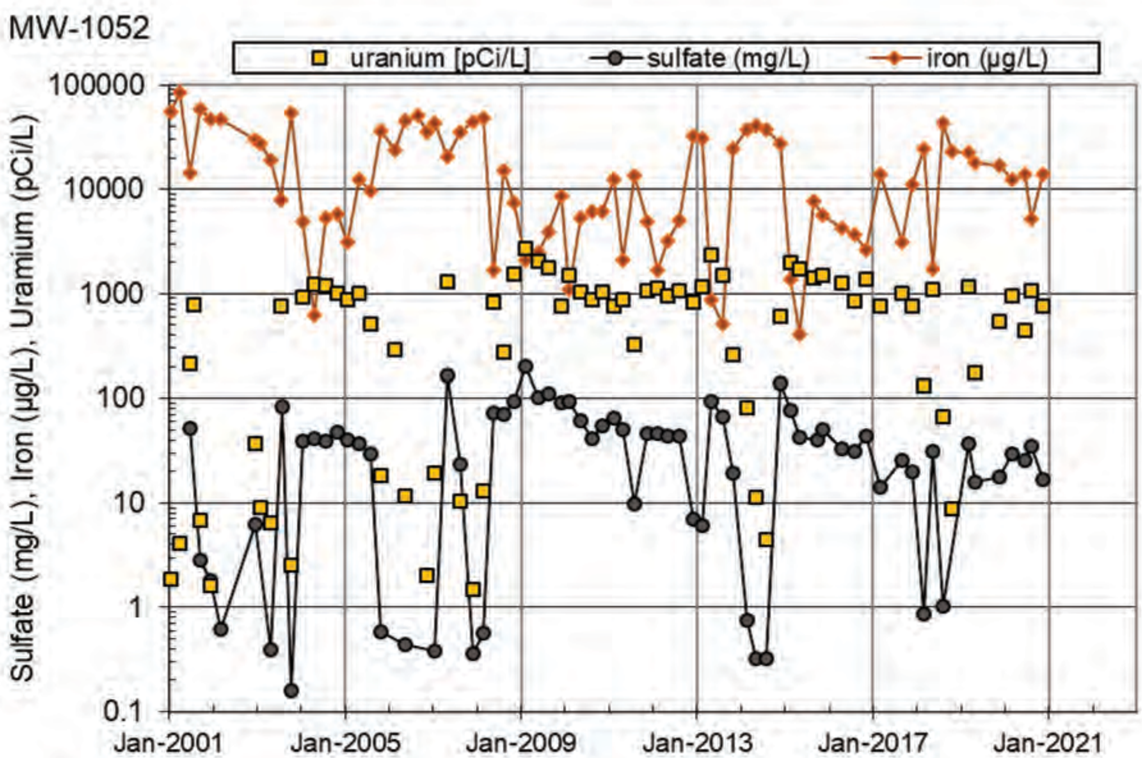


Figure 95. Sulfate and Uranium Variability in MW-1052

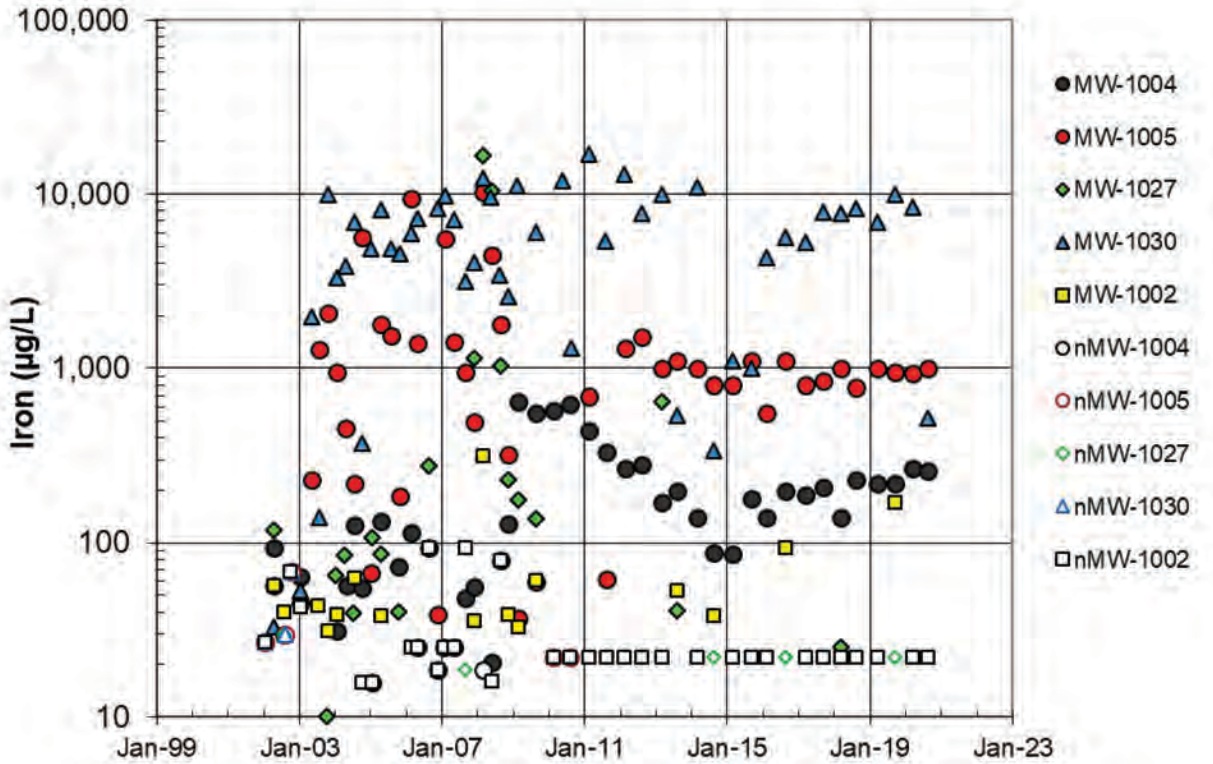


Figure 96. Dissolved Iron in Line 1 Bedrock Wells

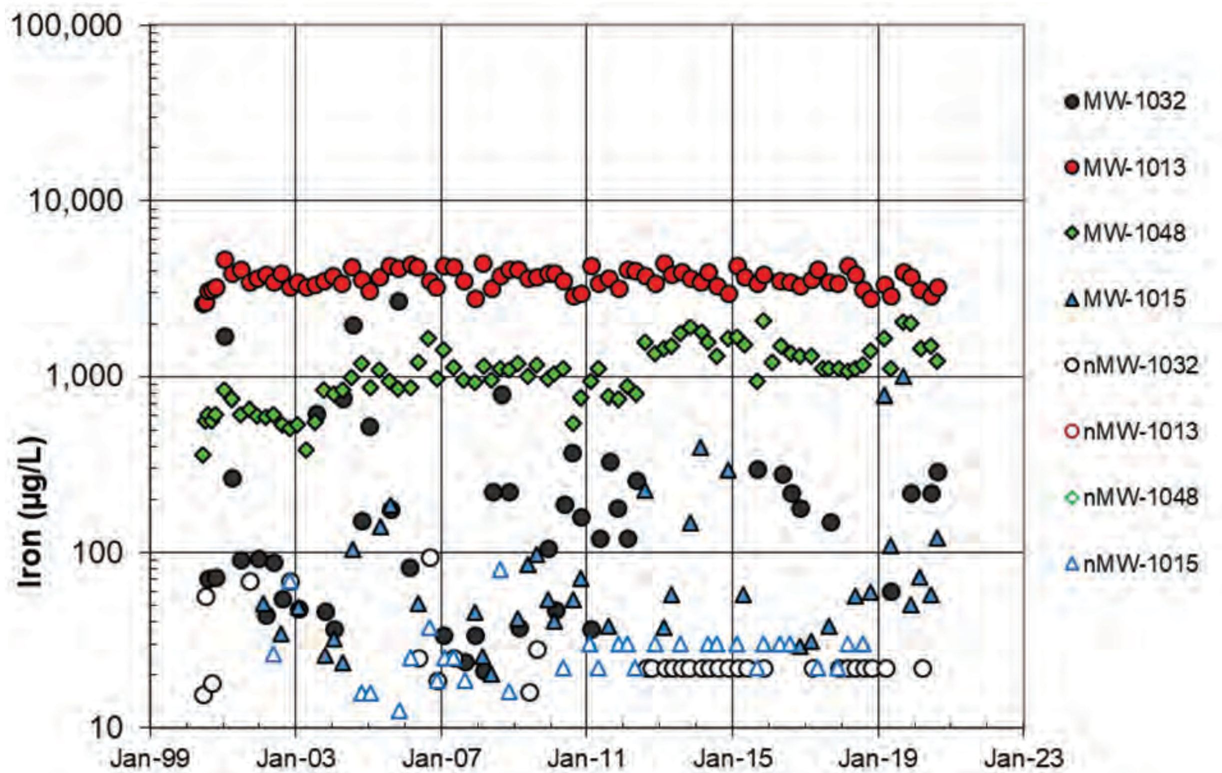


Figure 97. Dissolved Iron in Line 2 Bedrock Wells—Higher Uranium Concentration Wells

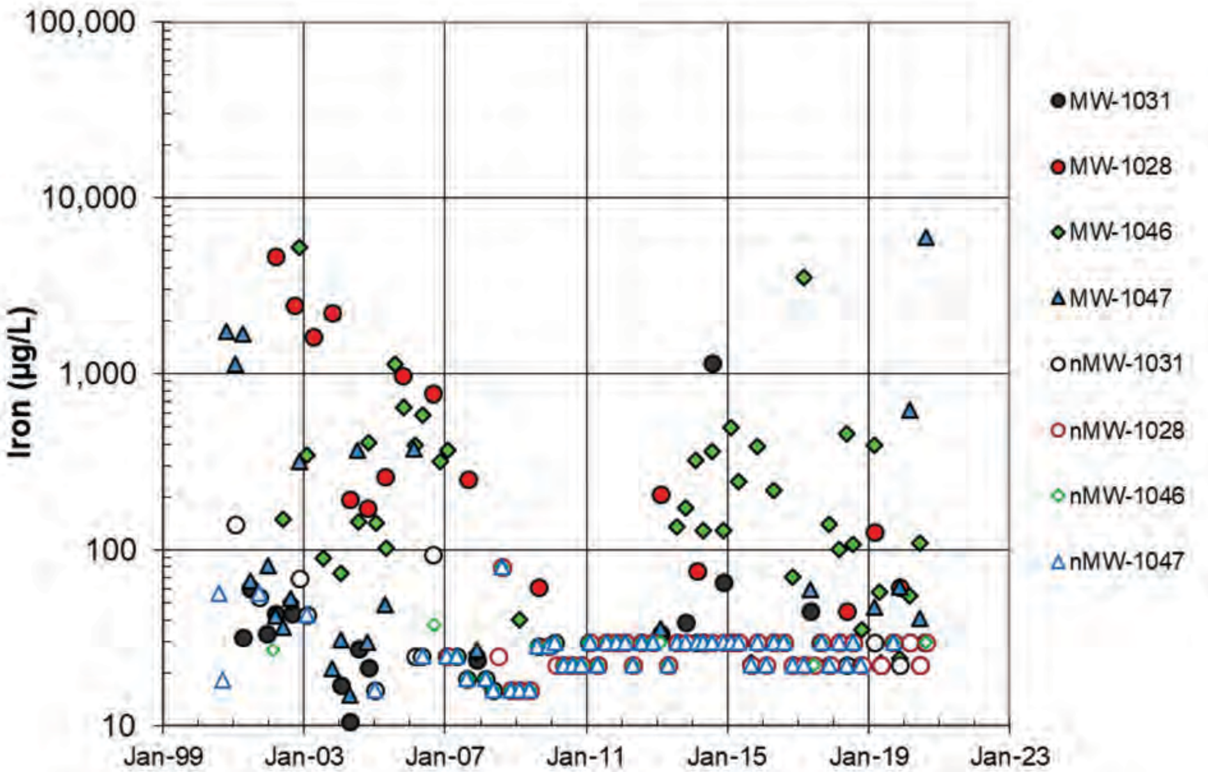


Figure 98. Dissolved Iron in Line 2 Bedrock Wells—Lower Uranium Concentration Wells

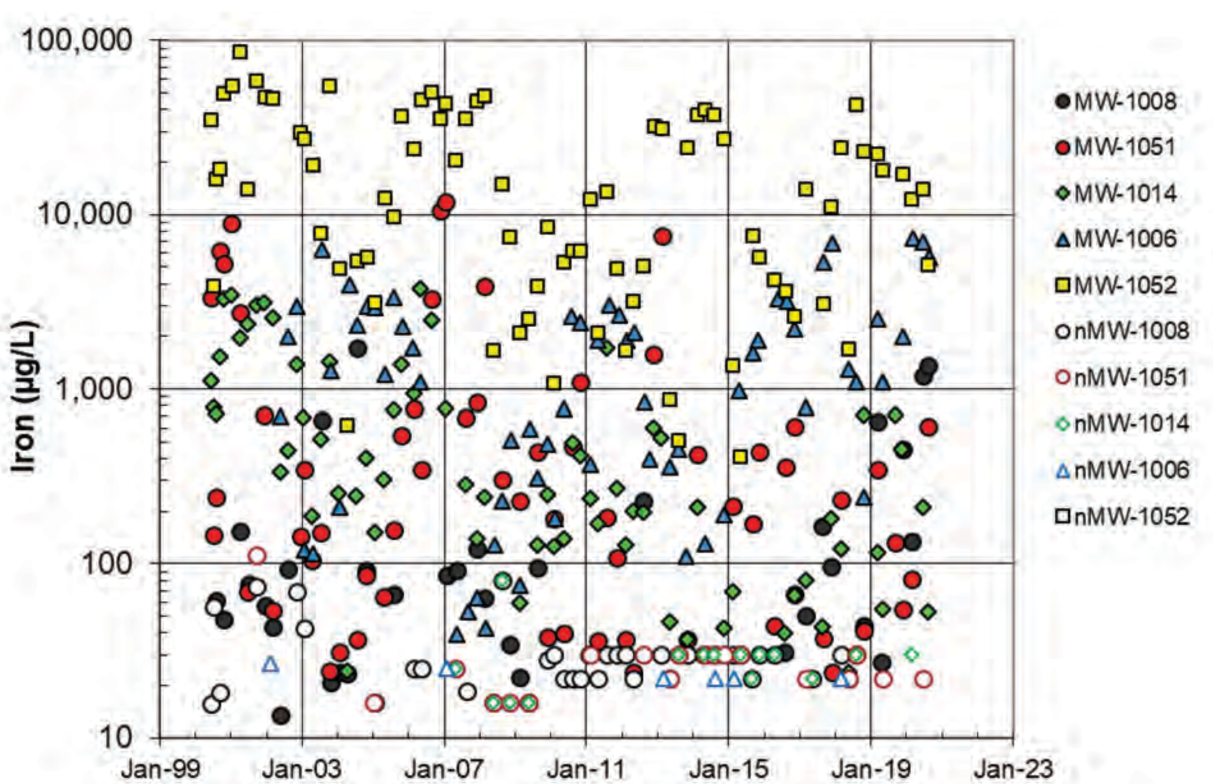


Figure 99. Dissolved Iron in Line 2 Alluvial Wells—Higher Uranium Concentration Wells

4.2.4.6 Monitoring Results for the Missouri River Alluvium

Groundwater quality in the Missouri River alluvium is monitored using 10 wells (Figure 100) screened in the alluvial materials. These wells are sampled for uranium and geochemical parameters (Table 39) to verify that water quality remains protective of human health.

Table 39. 2020 Uranium and Geochemical Parameter Data in the Missouri River Alluvial Aquifer

Location	Average Values				
	Uranium (pCi/L)	Sulfate (mg/L)	Dissolved Iron (µg/L)	Ferrous Iron (µg/L)	ORP[a] (mV)
MW-1017	0.094	39	20,850	9630	–43
MW-1018	0.063	1.5	34,150	8150	–110
MW-1019	0.055	0.37	12,750	2900	–42
MW-1021	0.081	2.7	11,650	3580	–76
MW-1044	0.079	3.3	9,430	2300	–78
MW-1050	0.057	0.45	15,350	6445	–51
RMW-1	1.0	15	6,300	2370	117
RMW-2	1.2	16	10,000	2940	30
RMW-3	0.49	15	21,000	3080	13
RMW-4	0.16	41	24,000	1840	30

Note:
[a] Convert ORP to *E*h by adding 200 millivolts to the oxidation-reduction value.

Abbreviation:
mV = millivolts

Uranium

The six monitoring wells immediately south of the slough (Line 3) and the four RMW series wells (Line 4) are sampled to verify that uranium levels remain within the range of natural variation in Missouri River alluvium. Figure 76 shows the well locations along with the 2020 (10/1/2019–10/1/2020) average uranium values. The results indicate that the average uranium levels were below the statistical background value in the alluvium (Table 33). All of the locations south of the slough have uranium levels far below the drinking water standard of 20 pCi/L. Uranium in samples from Line 3 wells is consistently either not detected or estimated to be at levels below the reporting limit (Figure 101). Line 4 wells have continued their long-term trend of decreasing uranium concentrations observed over the past 5 years (Figure 102).

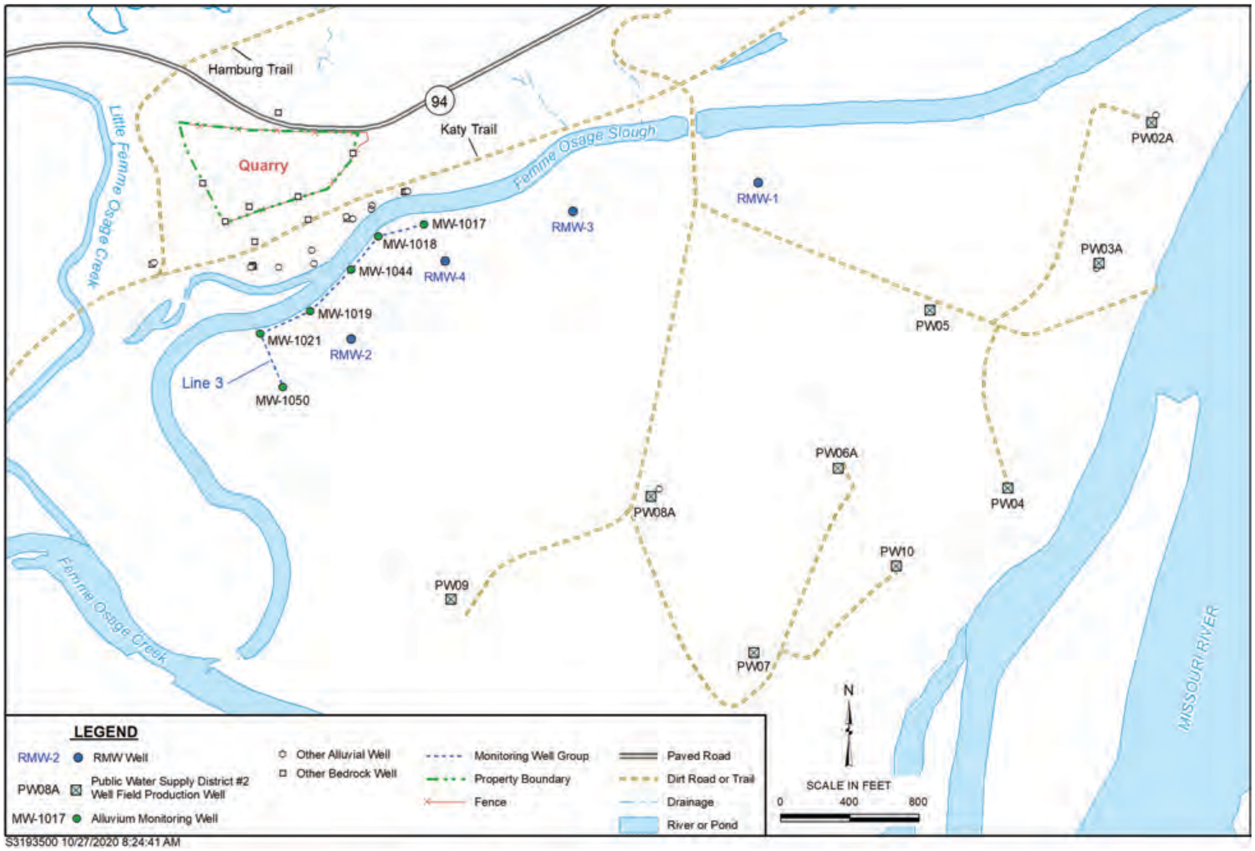


Figure 100. Line 3 and Line 4 (RMW) Wells, and PWSD No. 2 Water Supply Wells

PWSD No. Wellfield Sampling

PWSD No. 2, under a grant provided by DOE, hires a subcontractor to provide independent sampling of water supply wells completed in the Missouri River alluvium south of the slough: PW04, PW05, PW07, PW09, PW10, PW02A, PW03A, PW06A, and PW08A (Figure 100). Up to five of nine water supply wells (selected wells vary monthly) and the Water Plant effluent are sampled monthly. Monitoring wells RMW-1, RMW-2, RMW-3, and RMW-4 are sampled twice a year (typically during the first and third quarters). DOE also samples these wells annually. Samples are analyzed monthly for uranium, quarterly for nitroaromatics, and twice a year for arsenic and gross alpha and beta activity (typically during the second and fourth quarters). Sample results have all been either nondetect or show contaminants present at very low levels; uranium is present at less than 1 pCi/L. Sampling results are available from PWSD No. 2.

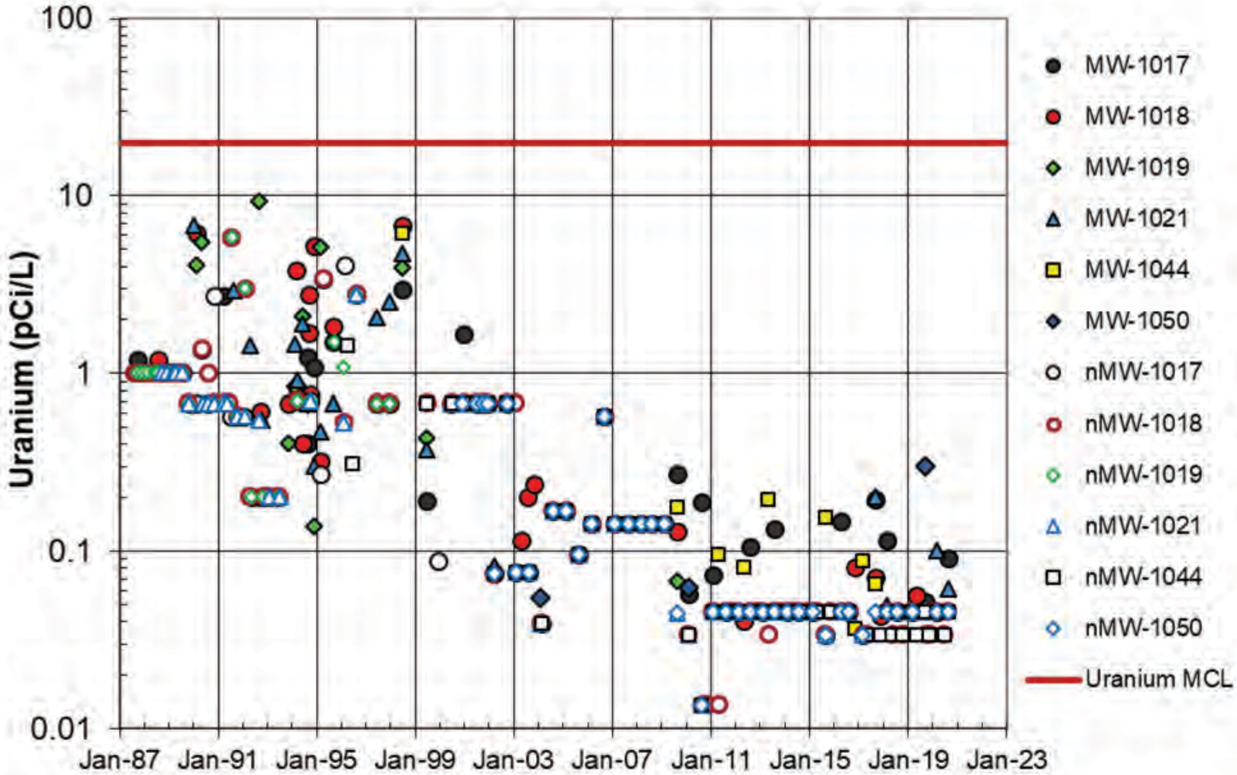


Figure 101. Uranium in Line 3 Monitoring Wells

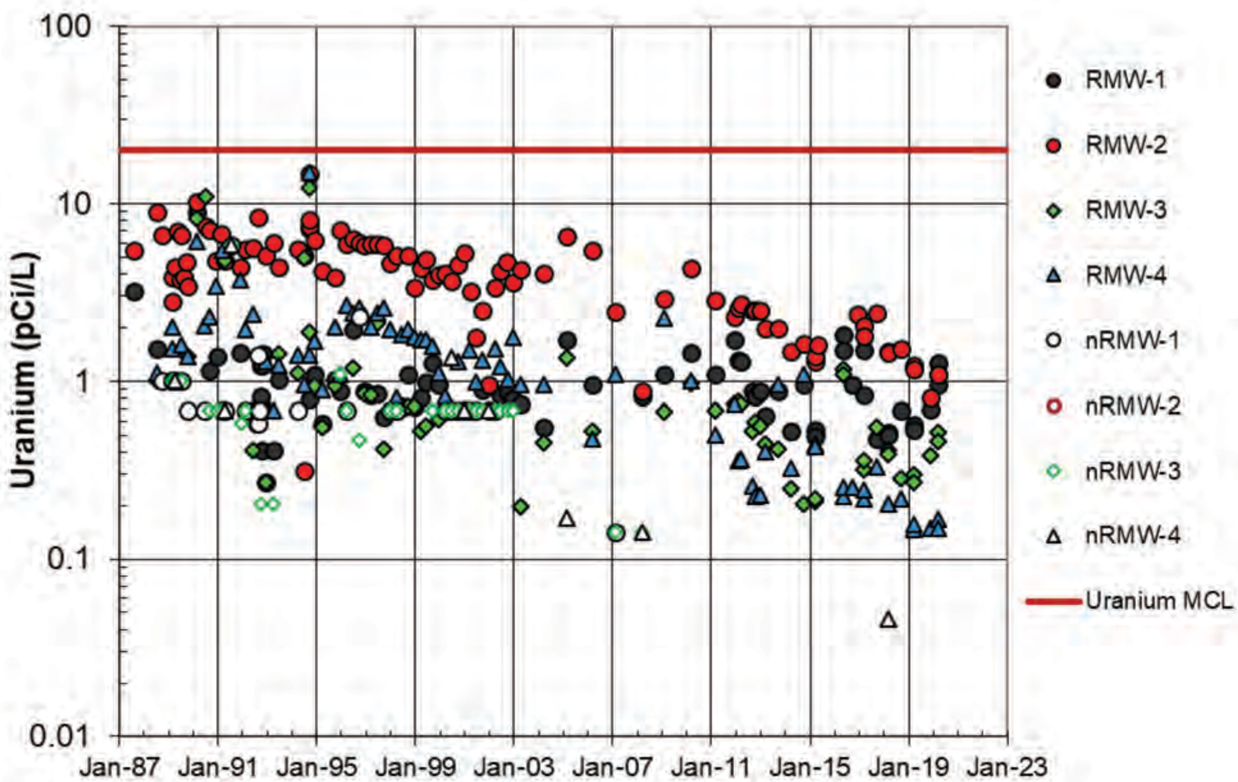


Figure 102. Uranium in Line 4 Monitoring Wells

Geochemical Parameters

The monitoring wells south of the slough were sampled for sulfate, dissolved iron, and ORP to assess oxidation-reduction conditions in the Missouri River alluvium downgradient of the area of uranium impact. The 2020 results are given in Table 39. Historical sulfate results are shown in Figure 103 (Line 3 wells) and Figure 104 (Line 4 wells). Dissolved iron results are shown in Figure 105 (Line 3 wells) and Figure 106 (Line 4 wells). Vertical scales are the same to facilitate comparison. ORP values for Line 3 and Line 4 wells are shown in Figure 107.

The data continue to indicate that a strongly reducing environment is prevalent in the groundwater immediately south of the slough, as shown by high dissolved iron concentrations, low sulfate concentrations, and low ORP values. This environment is not favorable for uranium migration if it were to pass beyond the reduction zone north of the slough. Data from the review period were consistent for all locations. The relatively high 2015 sulfate concentrations in MW-1044 decreased from 2016 through 2020, repeating the pattern of episodic increase followed by gradual decline seen from 2009 through 2014. High iron concentrations and low redox potential (*E*h) values indicate that a reducing environment is still prevalent in this area. Uranium levels remain low at this location and at the remainder of the locations along the southern edge of the Femme Osage Slough.

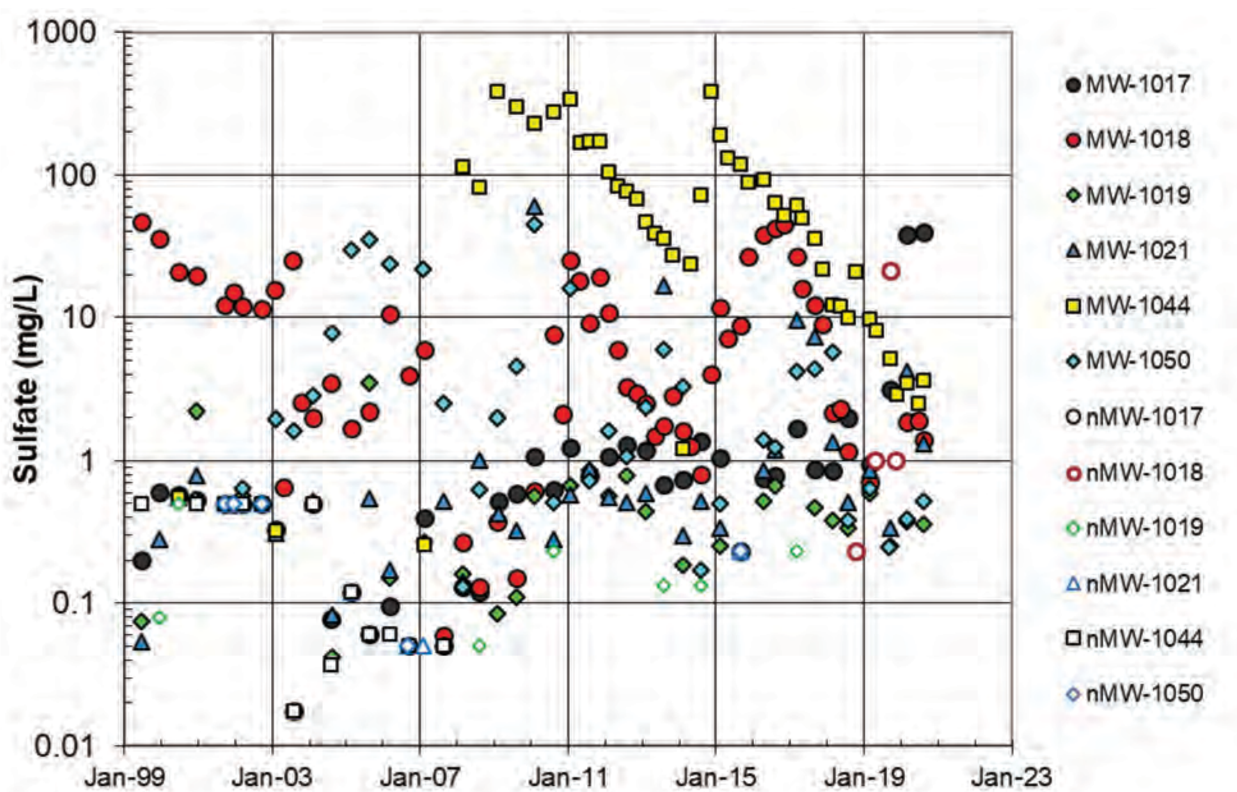


Figure 103. Sulfate in Line 3 Wells

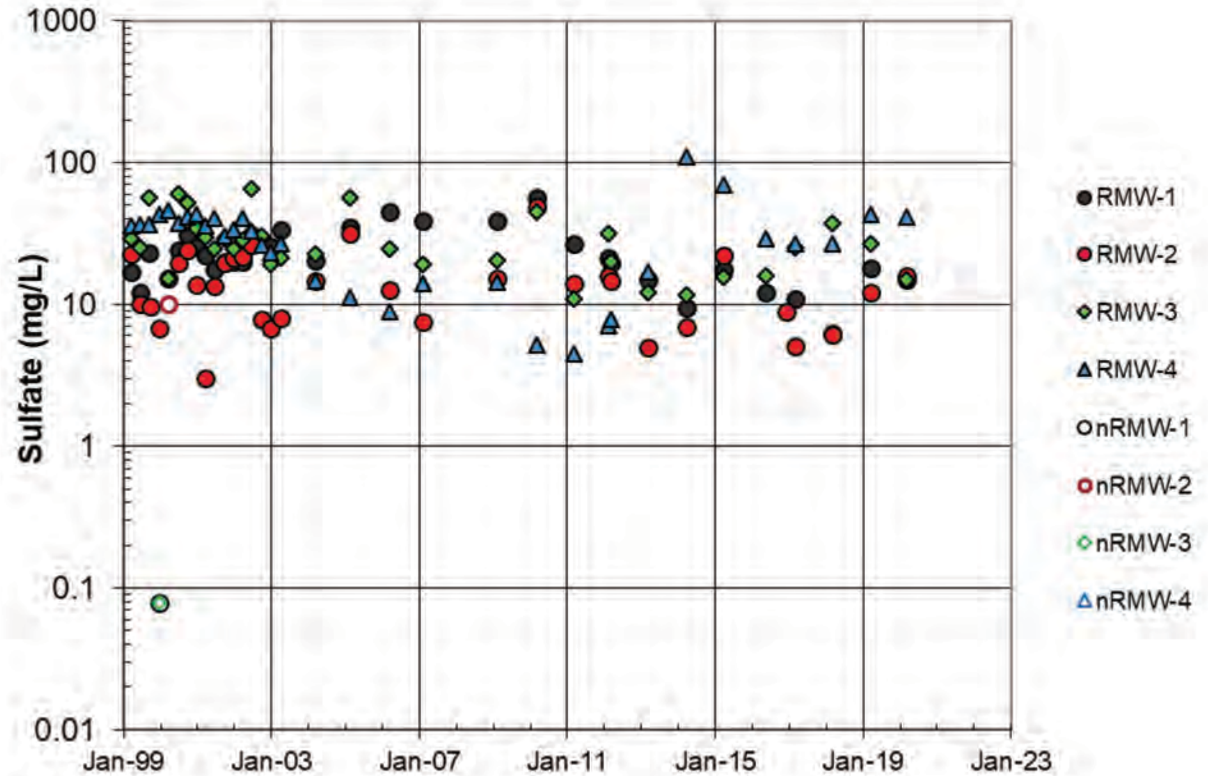


Figure 104. Sulfate in Line 4 Wells

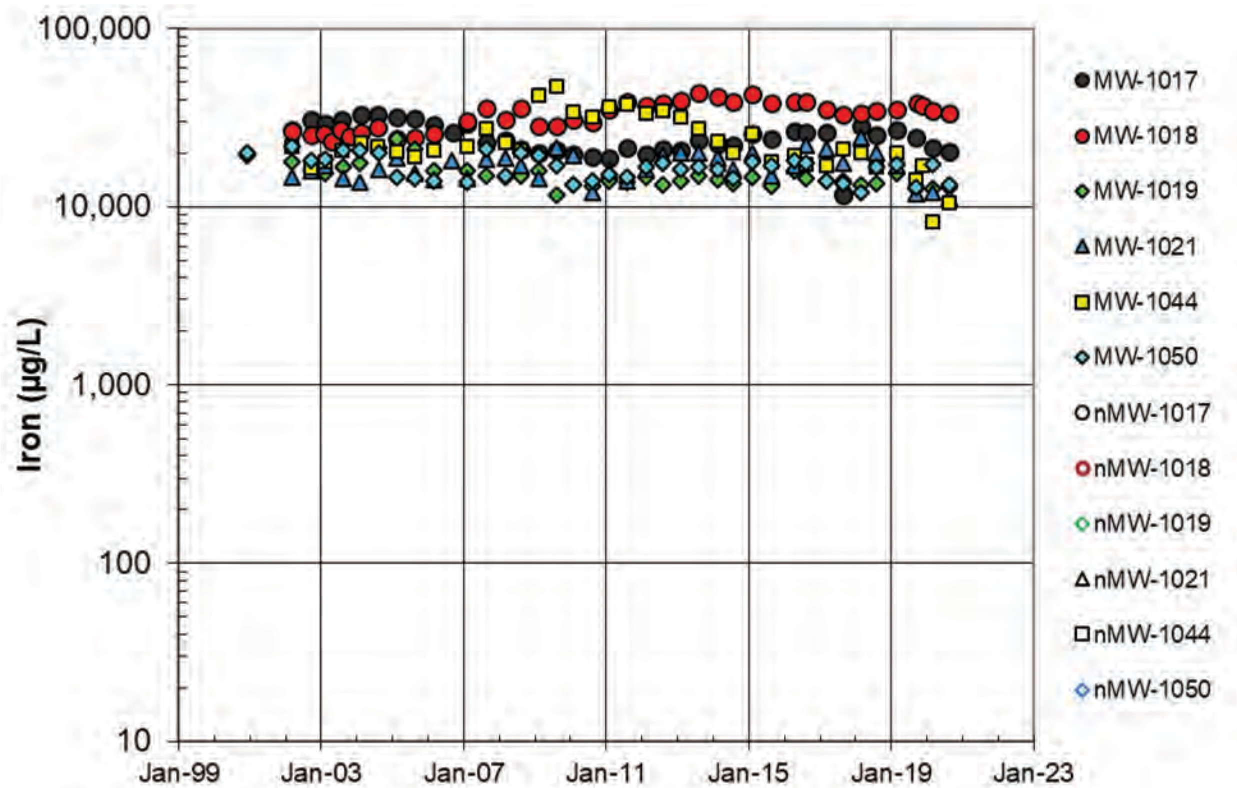


Figure 105. Dissolved Iron in Line 3 Wells

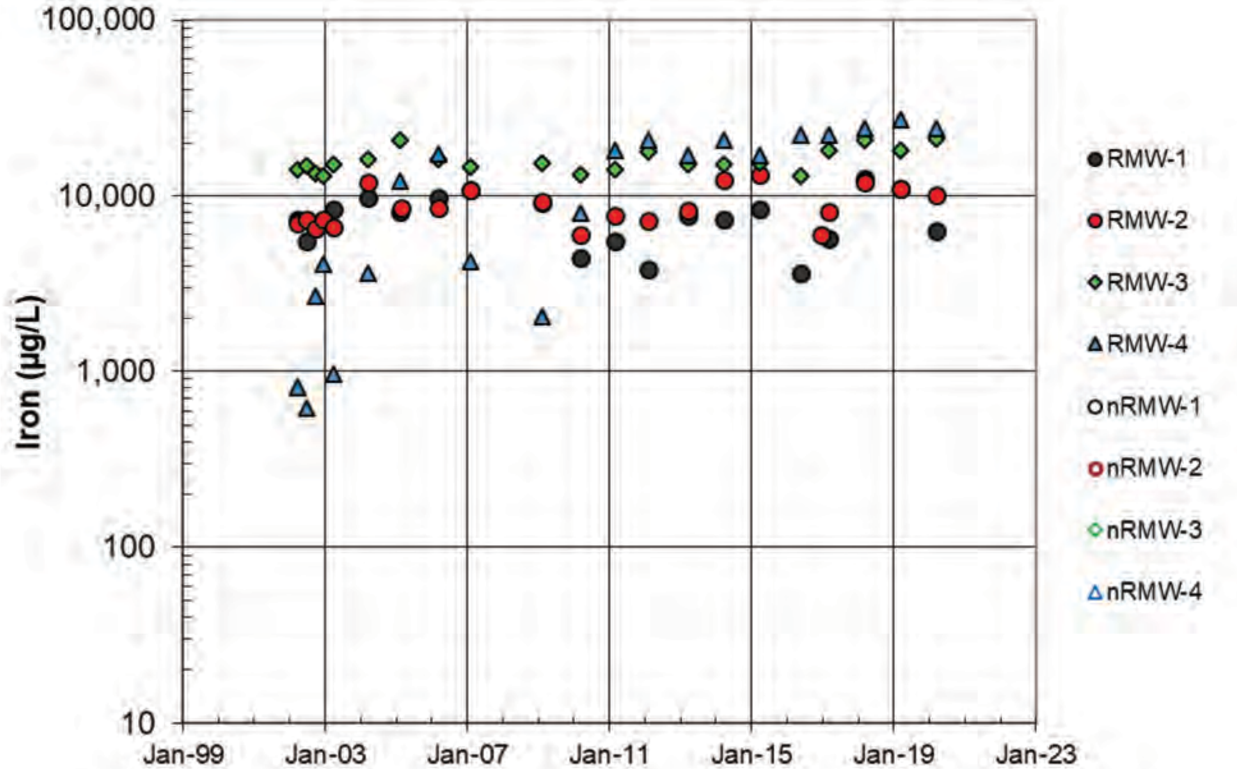


Figure 106. Dissolved Iron in Line 4 Wells

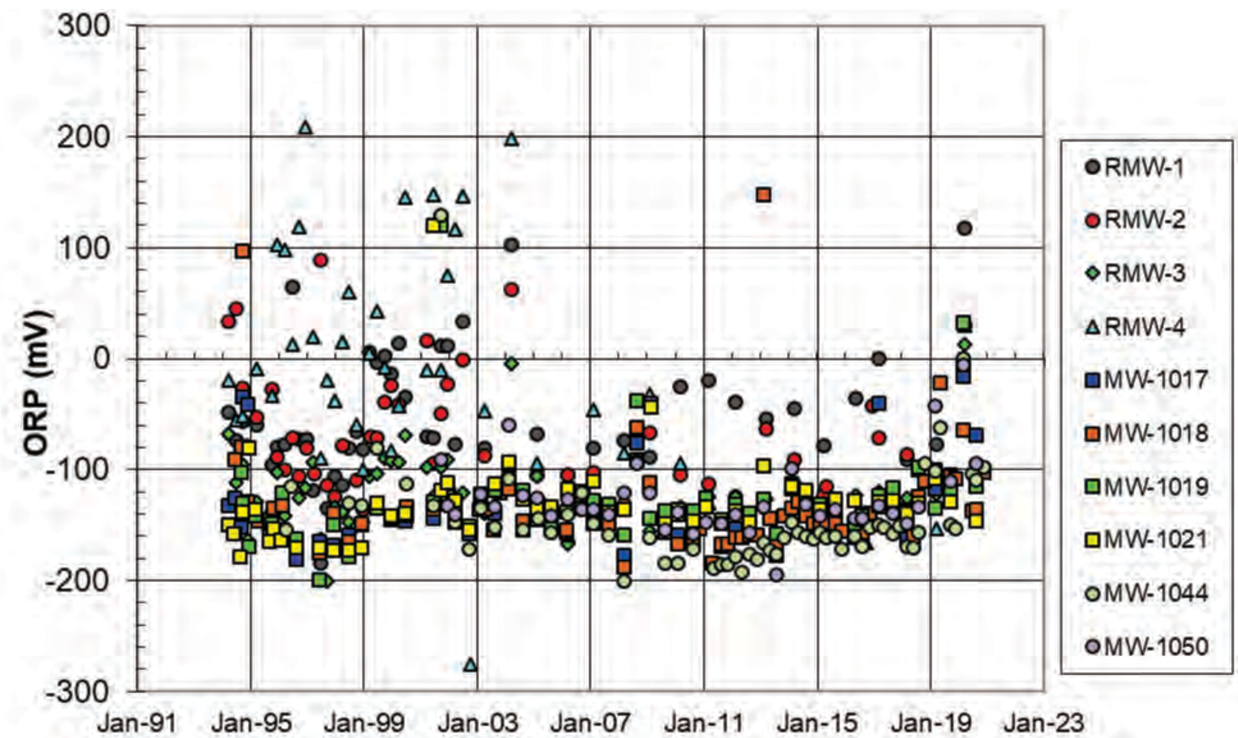


Figure 107. ORP in Line 3 and Line 4 Wells

4.2.5 Quarry Surface Water

Although surface water monitoring is not required as part of the remedy for the QROU, four locations within Femme Osage Slough (Figure 108) are sampled quarterly to assess the water quality in the slough and the potential impact from groundwater north of the slough (Table 40). These sampling sites are in the upper section of the slough, adjacent to the area of groundwater impact. Uranium concentrations in the slough are typically higher when water levels in the slough are lower and decrease when slough water levels are higher.

Table 40. 2020 Total Uranium in the Femme Osage Slough near the Quarry

Location	Uranium (pCi/L)			
	Q1 (Mar 9, 2020)	Q2 (Jun 17, 2020)	Q3 (Aug 13, 2020)	Q4 (Nov 10, 2020)
SW-1003	19	18	13	16
SW-1004	18	19	16	16
SW-1005	17	18	12	11
SW-1010	16	16	14	16

Abbreviations:
Q1, Q2, Q3, Q4 = quarterly sampling periods

Surface water samples collected after the slough refills following dry or very low periods when portions of the slough bottom are exposed typically have elevated uranium levels. Desorption from organics likely occurs when the areas are resaturated with surface water runoff and river water after the sediments have dried out. This accounts for the periods of elevated uranium in the early 1990s and again from 2007 through 2015 (Figure 109). Water levels in the slough have been relatively high for the last 5 years with periods of flooding in 2015, 2017, and 2019.

4.3 Site Inspection

The FYR inspection of the Site was conducted on December 1 and 2, 2020. In attendance were representatives from the Department of Energy, the LMS contractor, and MDNR. Annual inspections are conducted at the Weldon Spring Site and are documented along with this inspection in the site annual reports. The reports are as follows: *Weldon Spring, Missouri, Site Annual Report for Calendar Year 2016* (DOE 2017), *Weldon Spring, Missouri, Site Annual Report for Calendar Year 2017* (DOE 2018), *Weldon Spring, Missouri, Site Annual Report for Calendar Year 2018* (DOE 2019), *Weldon Spring Site Annual Report for Calendar Year 2019* (DOE 2020), and *Weldon Spring Site Annual Report for Calendar Year 2020* (DOE 2021). The purpose of the annual and FYR inspections is to confirm the integrity of the visible features (such as the disposal cell and monitoring wells) at the site, document site conditions subsequent to remediation and restoration, identify changes in conditions that may affect site integrity, determine if ICs are adequately implemented and restrictions are not being violated, determine the need, if any, for maintenance, and ensure the remedy remains protective.

No recommendations or findings were noted during the inspection.

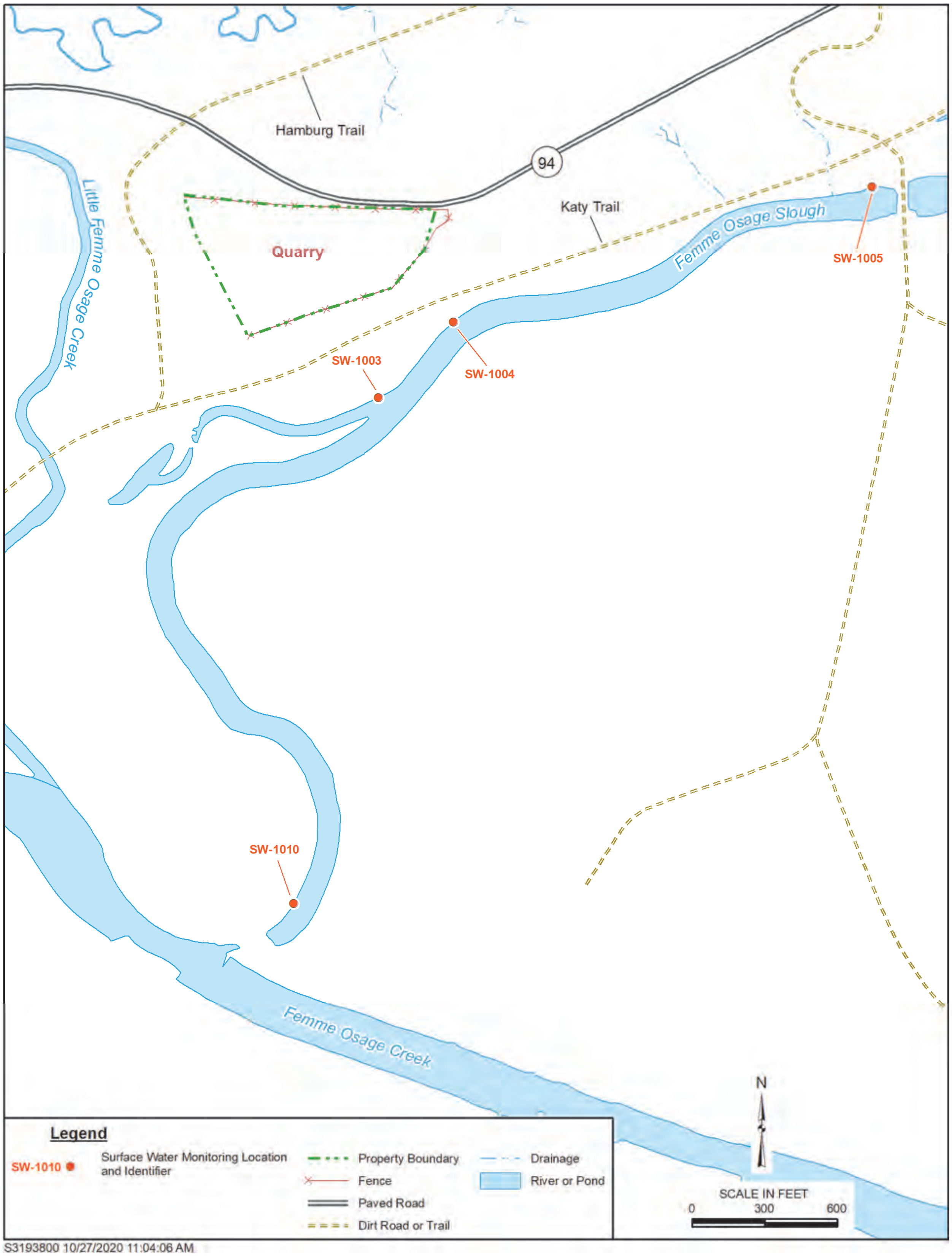


Figure 108. Surface Water Monitoring Locations at the Quarry Area

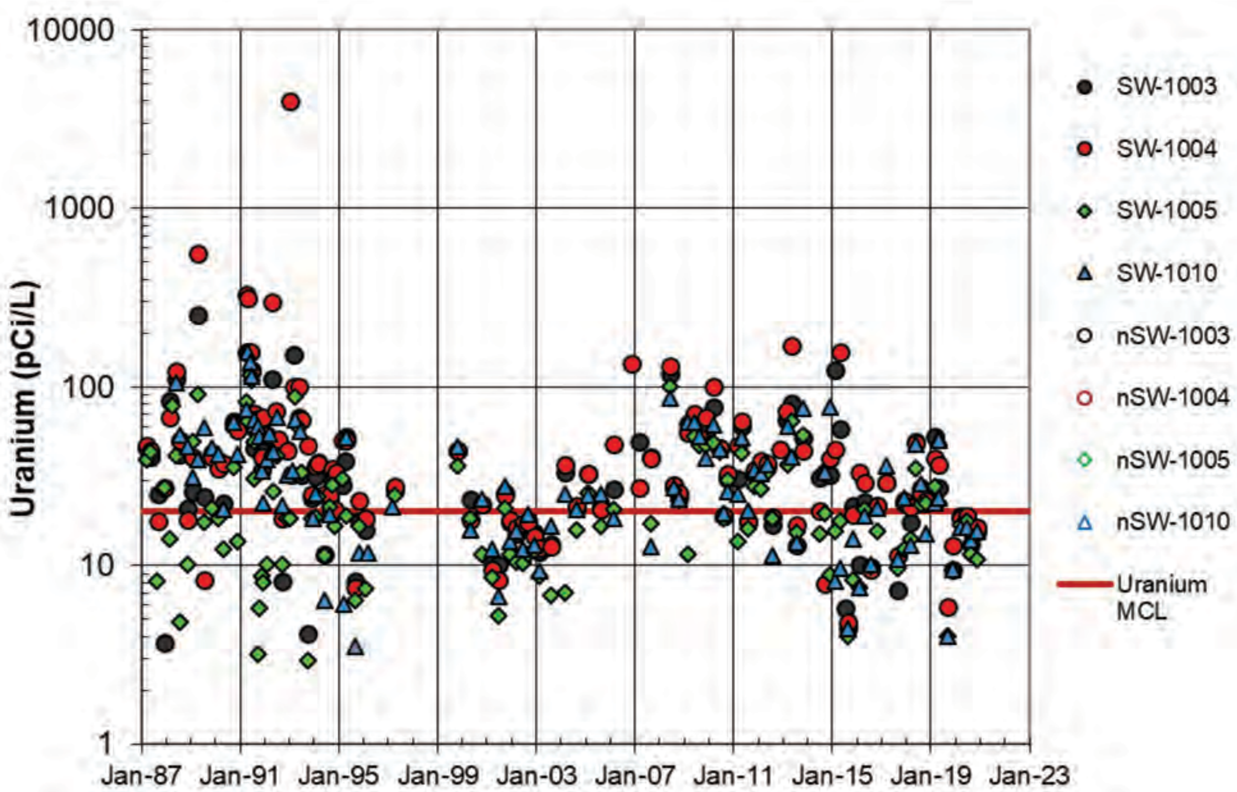


Figure 109. Uranium Levels in the Femme Osage Slough

Observations included:

- Half of a number was missing from the label on MW-4037. This item has been corrected.
- Historical Marker No. 8 was broken and on the ground. This item has been corrected.
- The “No Trespassing” signs on the LCRS were faded. This item has been corrected.
- The vault at the Quarry located on MDC property was open. This item has been corrected.

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5.0 Technical Assessment

5.1 Chemical Plant Operable Unit

5.1.1 Question A: Is the remedy functioning as intended by the decision documents?

Answer A: Yes, the remedy is functioning as intended by the decision documents.

5.1.1.1 Remedial Action Performance

The review of documents and environmental monitoring data and the results of the annual and FYR inspections indicate that the remedy for the CPOU, which consisted of controlling contaminant sources at the Chemical Plant and disposing of contaminated materials in an engineered onsite disposal facility, is functioning as intended. The disposal cell has remained stable; is in good condition; and, based on annual inspections, lidar surveys, and groundwater and leachate monitoring, is performing as intended. The disposal cell monitoring information is included in Section 4.2.3. The cleanup levels were previously achieved and documented.

The site reached construction completion under CERCLA on August 22, 2005.

5.1.1.2 System Operation and Maintenance

The LTS&M Plan includes system operation and operation-and-maintenance information for the site. DOE also performs annual inspections of site features, systems, and activities (e.g., the disposal cell, the LCRS, environmental monitoring, and ICs) and has found these areas to be functioning as intended.

5.1.1.3 Opportunities for Optimization

There have been no additional opportunities for optimization identified during the past FYR period.

5.1.1.4 Early Indicators of Potential Issues

There are no early indicators of potential issues that could affect the protectiveness of the remedy.

5.1.1.5 Implementation of ICs and Other Measures

The information in this section is extracted from Section 3.0 of the LTS&M Plan (DOE 2008a).

This section summarizes information pertinent to the implementation of ICs to meet objectives of the use restrictions described in the Explanation of Significant Differences (ESD) issued in February 2005 (DOE 2005b). The ESD clarified use restrictions necessary for the remedial actions specified in the CPOU, GWOU, and QROU RODs to remain protective over the long term. The areas requiring use restrictions are shown in Figure 110 and Figure 111.

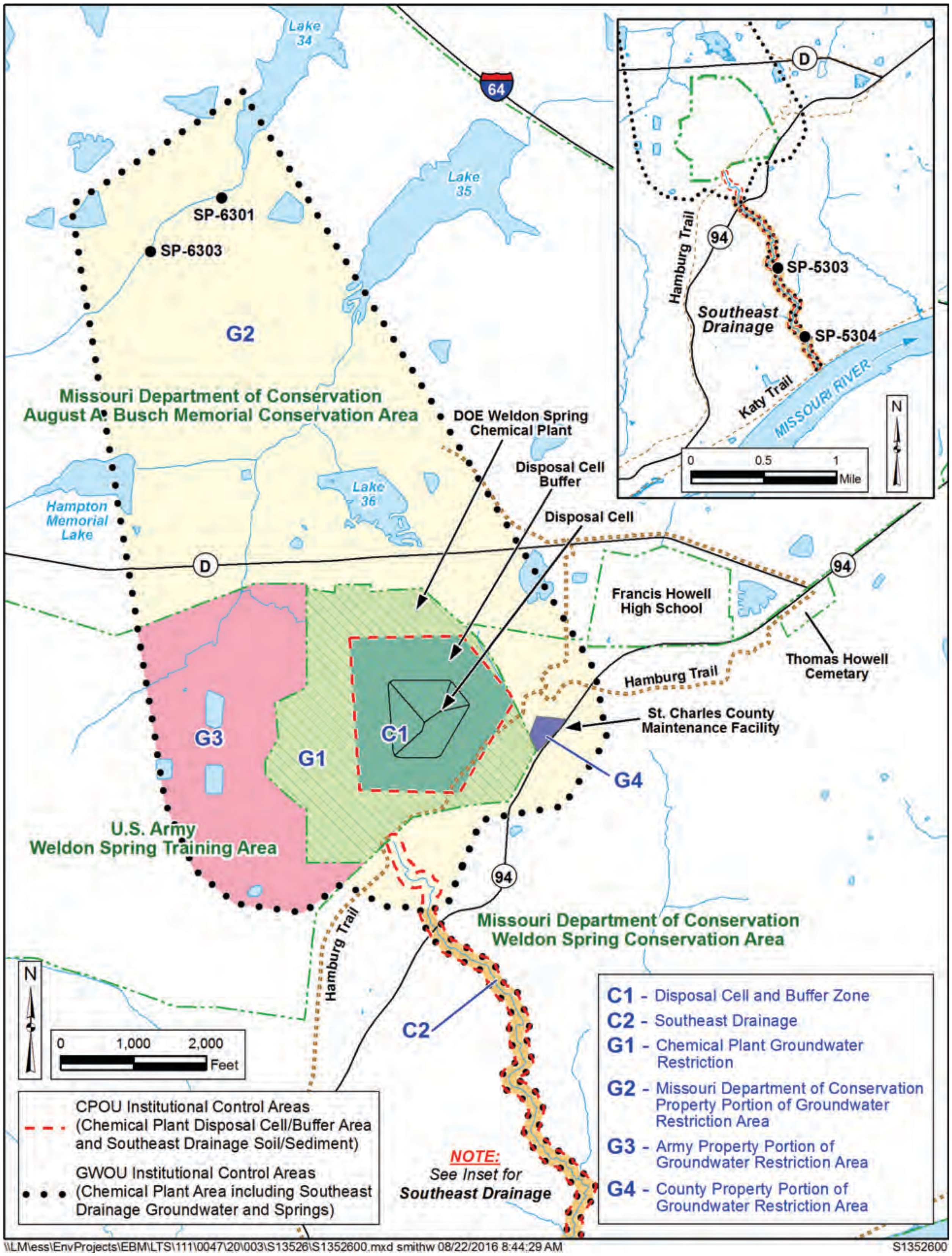

Figure 110. IC Areas for the Chemical Plant and GWOUs

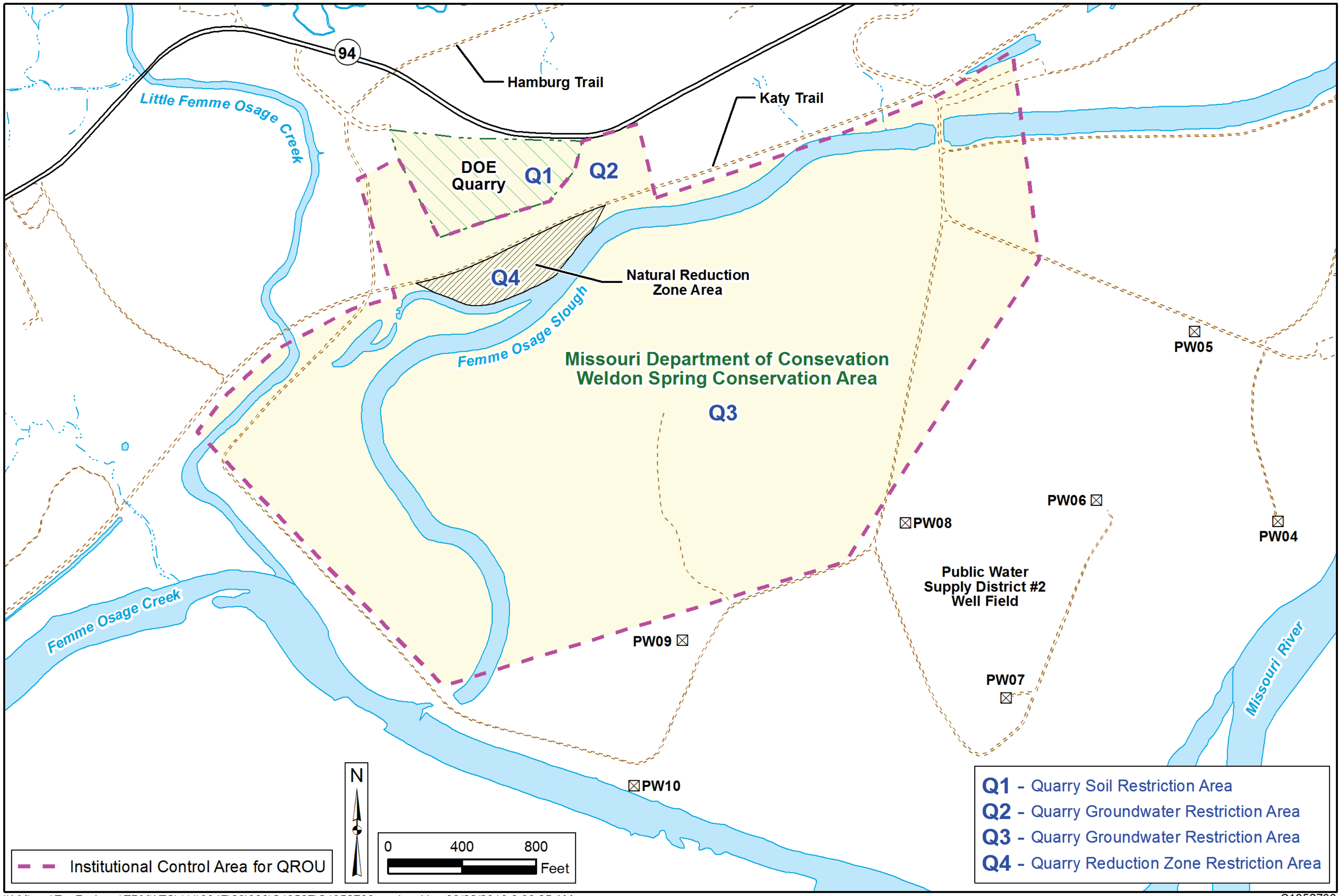

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Figure 111. IC Areas for the QROU

Use Restrictions

The ESD prepared for the Weldon Spring Site presents use restrictions for specific areas. The areas are on either federally owned or state-owned properties. No privately owned property is affected by the use restrictions. The use restrictions for the Chemical Plant property are described below.

Disposal Cell and Buffer Area

The use restrictions listed below must be met throughout the disposal cell area, including its surrounding 300 ft buffer zone. This area is under federal DOE jurisdictional control. The use restrictions listed here shall be maintained until the remaining hazardous substances are at levels allowing for UU/UE. Due to the extremely long-lived nature of the radioactive constituents in the disposal cell, these restrictions are expected to be necessary for perpetuity. The objectives of the controls or restrictions are to:

1. Prevent activities on the disposal cell, such as the use of recreational vehicles, that could compromise the integrity of the cell cover (e.g., result in the removal or disturbance of the riprap).
2. Prevent activities in the buffer zone, such as drilling, boring, or digging, that could disturb the vegetation, disrupt the grading pattern, or cause erosion.
3. Retain access to the buffer area for continued maintenance, monitoring, and routine inspections of the cell and buffer area.
4. Prevent construction of any type of residential dwelling or facility for human occupancy on the disposal cell and buffer area, other than facilities to be occupied for activities associated with performing environmental investigation or the restoration and expansion of the existing Interpretive Center.
5. Maintain the integrity of any current or future remedies or monitoring systems.

Southeast Drainage Soil or Sediment

The use restrictions listed below must be met at the approximately 37-acre area covering the 200 ft corridor along the length of the Southeast Drainage: The restricted area is located on property owned by state entities. The restriction will need to be maintained until the remaining hazardous substances are at levels allowing for UU/UE, which is anticipated to be a period of decades or longer. The objective of the use restriction is to:

- Prevent the development and use of the Southeast Drainage property for residential housing, schools, childcare facilities, and playgrounds.

Types of ICs

Specific IC mechanisms have been identified to implement the use restrictions presented for each area. The ICs generally fall into one of the four categories identified by EPA guidance (EPA 2000). Multiple mechanisms are being used to provide “layering” for additional durability.

The EPA IC categories are as follows:

1. **Proprietary controls:** Are based on real property law and generally create legal property interests; include easements and covenants.
2. **Governmental controls:** Are generally implemented and enforced by state or local governments; include zoning restrictions, well drilling regulations, building permits, ordinances, and similar mechanisms that restrict land or resource use.
3. **Enforcement and permit tools with IC components:** Can be used to enforce or restrict site activities; include CERCLA FFAs, CERCLA Unilateral Administrative Orders, and Administrative Orders on Consent.
4. **Informational devices:** Provide information that a site contains residual or capped contamination and include state registries, deed notices, information centers, markers, and advisories.

Summary of ICs Currently in Place

The following ICs are in place for the Weldon Spring Site, as listed in the LTS&M Plan (2008b):

1. DOE has exclusive jurisdictional control over the Chemical Plant and the Quarry. Federal ownership provides inherent authority for DOE to control land use based on its legislative jurisdiction and take action against unapproved uses but also entails statutory and regulatory obligations. Numerous requirements are placed on federal agencies that manage land to ensure the protection of human health and the environment. In accordance with DOE Order 430.1B, *Real Property Asset Management*, DOE is required to provide an inventory of the specific ICs implemented to restrict use of the property in DOE's Facilities Information Management System (FIMS). The maintenance of a real property asset inventory system is designed to communicate the presence of land use restrictions to current federal management personnel and to ensure that this information is readily available to possible future users of the land. As part of the protocol for maintaining this database, FIMS data must be (a) maintained as complete and current throughout the life cycle of real property assets, including real property-related ICs; and (b) archived after disposal of real property assets, with those necessary for long-term maintenance and surveillance identified, reviewed, and retained accordingly.

   CERCLA Section 120(h)(3) requires property transfers to be accompanied by a covenant warranting that "all remedial action necessary to protect human health and the environment with respect to any such substance remaining on the property has been taken before the date of transfer" and that "any additional remedial action found to be necessary after the date of transfer shall be conducted by the United States." Upon transfer, the deed or other agreement governing the transfer must contain clauses that indicate the following information: (a) necessary restrictions on the use of the property to ensure protection of human health and the environment (e.g., maintenance of ICs), and (b) restrictions on the use necessary to ensure that the required remedial investigations, response actions (e.g., monitoring, implementation of ICs), and oversight activities (e.g., LTS&M activities) will not be disrupted.

2. DOE has committed to perpetual care of the disposal cell and buffer zone as specified in the Chemical Plant ROD, which is enforceable under the FFA.

3. A notation has been entered on the ownership record filed at the St. Charles County Recorder's Office (deed notice). The notation explains the restrictions on groundwater use and residential development of the Chemical Plant and Quarry Areas. The notice acts as an informational device in the event ownership is transferred at some point in the future.

4. The Interpretive Center serves as a community information resource, which depicts the history of the area and details the progression of the cleanup process. Information is available on the construction of the engineered disposal cell and the residual groundwater contamination.

5. Historical markers have been placed along the Hamburg Trail, and informational plaques are accessible at the top of the engineered disposal cell. The historical markers depict significant events and locations along the trail related to the displacement of the population during the early 1940s to accommodate the federal government's war efforts. The markers also note significant events at their respective locations related to DOE cleanup efforts and encourage the reader to learn more by visiting the DOE Interpretive Center. Similarly, the plaques at the top of the disposal cell contain information regarding the surroundings and the history of St. Charles, as well as information regarding the cleanup and waste materials buried within the disposal cell.

6. Missouri regulates the construction of wells pursuant to 10 CSR Chapter 3, "Well Construction Code," Section 3.010(1)(A)4, which states that "a well shall be constructed so as to maintain existing natural protection against pollution of water-bearing formations and to exclude all known sources of contamination from the well including sources of contamination from adjacent property." 10 CSR 3.030(2) states, "Minimum Protective Depths of Well Casing. All wells shall be watertight to such depths as may be necessary to exclude contaminants. A well shall be constructed so as to seal off formations that are likely to pose a threat to the aquifer or human health." Well Construction Code 10 CSR 3.090(1)(A) says, "All persons engaged in drilling domestic wells in Area 1, a limestone or dolomite area shall set no less than 80 ft of casing, extending not less than 30 ft into bedrock. Example: if 60 ft of residual (weathered rock) material is encountered in drilling before bedrock, then 90 ft of casing must be set." These regulations combine to have the effect of preventing the construction of wells that would allow for consumption of contaminated groundwater by preventing the well from drawing water from groundwater from a depth less than 80 ft, which includes the surficial contaminated zone.

7. DOE has real estate licenses with MDC that allow access for the purpose of monitoring and maintaining groundwater wells, drilling and plugging wells, use of the effluent water pipeline, and entering through the north gate.

8. DOE has real estate licenses with MDNR that allow access along portions of the Katy Trail for the purpose of monitoring and maintaining groundwater wells, drilling and plugging wells, using the effluent water pipeline, and collecting samples along portions of the Katy Trail.

9. A Memorandum of Understanding (MOU) with the Army regarding cooperation with DOE's remedy implementation is in place. The MOU gives DOE permission to access Army property for the purpose of implementing remedial actions, which include monitoring and maintaining groundwater wells, drilling and plugging wells, and inspecting for consequential land or resource use changes. The revised MOU, signed in 2009 by both parties, is also specific with respect to the necessary groundwater use restrictions for property under Army control.

10. A “Special Use Area” Designation Under the State Well Drillers’ Act was finalized in the Missouri regulations and became effective in August 2007 (10 CSR 23-3.100[8]). This is a special regulation that DOE and the Army pursued. It designated DOE and Army’s groundwater restricted areas as special areas that require additional drilling protocols and construction specifications, imposed by MDNR, on any future domestic wells. This regulation has since been updated in January 2019, and the new citation is 10 CSR 23-3.090(13).
11. An easement with the MDNR Division of State Parks (finalized in September 2009) restricts the use of groundwater on areas of MDNR property along the Katy Trail and grants right of access to DOE for purposes of monitoring and characterization.
12. An easement with MDC (finalized in July 2011) restricting use of the contaminated groundwater and the hydraulic buffer zone on MDC property, and also to restrict land use in the Southeast Drainage and at the Quarry reduction zone.
13. An easement with MoDOT (finalized in May 2012) restricting the use of groundwater to investigative purposes and restricting the use of the property from being used in a way that could disturb or interfere with the integrity of any potential monitoring systems. This easement has since been transferred to St. Charles County, which purchased the property.
14. The use restrictions and the ICs identified in the LTS&M Plan are enforceable under the FFA.

The ICs required by the *Explanation of Significant Differences, Weldon Spring Site* (DOE 2005b) were all completed with the finalization of the easement with MoDOT in 2012.

In 2013, an issue regarding the easement with MDC was identified regarding the use of nonpotable water. An addendum to the easement that removed the allowance of nonpotable groundwater uses on MDC property and updated the special area. references to the new citation was signed by both the DOE and MDC and recorded with St. Charles County on June 30, 2021.

Easements and Environmental Covenants

DOE has finalized easements with three of the surrounding affected state-agency landowners for implementing the use restrictions required on state properties. An easement is a real property interest that conveys certain rights from the grantor (fee simple landowner) to the grantee. In the case of the Weldon Spring Site, DOE has finalized easements for the purpose of restricting use of the contaminated groundwater and the hydraulic buffer zone and also to restrict land use in the Southeast Drainage and at the Quarry reduction zone. The easements will also ensure DOE access to monitoring locations for sampling and maintenance and, where applicable, provide that DOE is notified of use inconsistent with the terms of the easements.

DOE has acquired the easements in accordance with DOE policy and procedures. The completed easements have been recorded with St. Charles County.

5.1.2 Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection still valid?

Answer: No. Changes in risk assessment methodology, exposure parameters, and toxicity values since the ROD was signed have resulted in some cleanup levels no longer being protective, assuming a residential land use scenario. However, implementation of the CPOU remedy resulted in achieving residual contaminant concentrations far below cleanup levels. Remaining concentrations are either reflective of background or do not pose unacceptable risk under reasonably anticipated future land use. In addition, ICs are in place to prevent residential land use.

5.1.2.1 Changes in Standards and To Be Considered (TBCs)

Section 1.5, *Current Regulatory Requirements*, of the LTS&M Plan discusses the applicable or relevant and appropriate requirement (ARARs) that apply to the postremediation aspect of the project, and states the following:

> The disposal cell contents are not regulated under the Resource Conservation and Recovery Act (RCRA), but RCRA postclosure disposal cell monitoring and maintenance requirements are ARARs. The RCRA groundwater protection standard (40 CFR 264 Subpart F) sets forth the general groundwater monitoring requirements for the disposal cell. Generally, the disposal cell groundwater monitoring program must provide representative samples of background water quality, as well as groundwater passing the point of compliance. For a more complete description, see the Disposal Cell Groundwater Monitoring Plan (Appendix K) which was developed to address these requirements. Additional postclosure requirements for the cell are identified in 40 CFR 264 Subpart N and include action leakage rate and leachate collection and removal requirements. These requirements are addressed in Sections 2.7.4, 2.9.2, and Appendixes I and J. Subpart N also includes requirements to maintain the integrity of the final cover, including making repairs as necessary, which is addressed in Section 2.6.

With respect to the excerpt from the LTS&M plan cited above, there have been no changes to standards or TBCs that could affect the remedy. Corresponding ARARs for the Chemical Plant are listed in Table 41.

Table 41. Chemical Plant ARARs

ARAR/Citation	Description	Status	Comments
RCRA Subtitle F and N; 40 CFR 264	Regulates groundwater monitoring and postclosure care	Relevant to postclosure care	Groundwater monitoring, leachate collection being conducted in accordance with these requirements

The soil cleanup criteria for radiological and chemical contaminants listed in Tables 9-3 and 9-4 of the ROD (DOE 1993) are also ARARs and TBCs. Table 42 and Table 43 compare the ROD cleanup criteria with EPA's Preliminary Remediation Goals (PRGs) and residential soil regional screening levels (RSLs) for radionuclides and chemicals, respectively. The PRGs and RSLs reflect the values that TBCs based on a hypothetical residential receptor would be, if calculated today. In some cases—for example, for radionuclides (Table 42), these levels are lower (more conservative) than corresponding criteria listed in the ROD. However, implementation of the CPOU remedy resulted in achieving residual contaminant concentrations that are either reflective of background or, for most chemicals (Table 43), below current EPA risk-based cleanup levels for residential receptors. Remaining concentrations do not pose unacceptable risk under reasonably anticipated future land use. In addition, ICs are in place to prevent residential land use.

5.1.2.2 Exposure Pathways, Toxicity and Risk Assessment

The contaminated soil and other wastes generated from the CPOU cleanup are now permanently disposed of at an engineered disposal cell constructed at the Chemical Plant. Wastes generated from cleanup of the Quarry Area have likewise been disposed of in the disposal cell. At the time of its closure, the cell contained approximately 1.48 million cubic yards of waste.

The following is excerpted from the ESD (DOE 2005b) and summarizes the remediation approach and residual risks:

> The 1993 CPOU ROD specifies that "perpetual care be taken of the committed land within the disposal cell footprint because waste would retain its toxicity for thousands of years." It stipulates that the cell cover be inspected and that the groundwater be monitored. This ROD also specified that "following completion of the site cleanup activities, an assessment of the residual risks based on actual site conditions will be performed to determine the need for any future land use restrictions. This assessment would consider the presence of the onsite disposal cell, the buffer zone, the adjacent Army site, and any other relevant factors necessary to ensure that appropriate measures are taken to protect human health and the environment for the long term."
>
> As part of the remedy selected for the CPOU, soil contamination was cleaned up by removing to depth and disposing of contaminated soils in the onsite disposal cell. Soil cleanup goals were established in the CPOU ROD that were intended to be as low as reasonably achievable given the design limitations pertaining to safe field excavation techniques and field survey capabilities. Recreational use was considered to be the reasonably anticipated future land use. A standard conservative recreational visitor scenario as defined in the CPOU Baseline Risk Assessment was considered to be representative of recreational use. The exposure assumptions used were consistent with those recommended for a recreational scenario in EPA Risk Assessment Guidance for Superfund (RAGS). Risk calculations based on the soil cleanup goals showed cumulative risk to the recreational visitor was within the acceptable risk range. Recognizing that the actual post cleanup condition might be different than what was anticipated by the cleanup goals, the ROD specified that a postremediation risk assessment would be performed following cleanup and that a final decision on the need for any future land use restrictions would be based on the actual residual condition.

Table 42. ROD Cleanup Criteria and Associated Risks for CPOU Radionuclides

Radionuclide/ Criterion	Soil Concentration (pCi/g)		Risk to Hypothetical Receptors at the Time of the ROD[a]			EPA PRG (pCi/g)[c]	Comment
	ROD Value[a]	Post-Cleanup[b]	Recreational Visitor	Ranger	Resident		
Ra-226						1.27	Residual (post-cleanup) soil concentration is reflective of background.
Cleanup criteria	6.2	1.04	5×10^{-5}	8×10^{-4}	2×10^{-2}		
ALARA goal	5		4×10^{-5}	6×10^{-4}	8×10^{-3}		
Background	1.2		9×10^{-6}	2×10^{-4}	2×10^{-3}		
Ra-228						0.99	Residual soil concentration is reflective of background.
Cleanup criteria	6.2	1.04	2×10^{-5}	2×10^{-4}	1×10^{-3}		
ALARA goal	5		1×10^{-5}	2×10^{-4}	8×10^{-4}		
Background	1.2		3×10^{-6}	5×10^{-5}	2×10^{-4}		
Th-230						1.26	Residual soil concentration slightly exceeds background.
Cleanup criteria	6.2	1.56	3×10^{-7}	4×10^{-6}	8×10^{-6}		
ALARA goal	5		2×10^{-7}	3×10^{-6}	6×10^{-6}		
Background	1.2		6×10^{-8}	8×10^{-7}	2×10^{-6}		
Th-232						0.99	Residual soil concentration is reflective of background.
Cleanup criteria	6.2	1.04	2×10^{-6}	2×10^{-5}	4×10^{-5}		
ALARA goal	5		1×10^{-6}	2×10^{-5}	3×10^{-5}		
Background	1.2		3×10^{-7}	4×10^{-6}	7×10^{-6}		
U-238						1.24	Residual soil concentration slightly exceeds background.
Cleanup criteria	120	2.91	2×10^{-5}	2×10^{-4}	5×10^{-4}		
ALARA goal	30		4×10^{-6}	5×10^{-5}	1×10^{-4}		
Background	1.2		2×10^{-7}	3×10^{-6}	8×10^{-6}		

Notes:

[a] Table adapted from Table 9-3 of the 1993 ROD (DOE 1993). Columns 1–2 (radionuclides and associated soil cleanup criteria) and 3–5 (corresponding hypothetical risks) duplicate entries in the original ROD table. As stated in the ROD (Note [a] of Table 9-3), the background soil concentration of 1.2 pCi/g represents the average concentration measured for each of the listed radionuclides at offsite locations that were not affected by site releases. Residual soil concentrations (column 2) and current EPA risk-based levels are provided for comparison purposes (refer to Notes b and c below).

[b] Average residual soil concentrations listed in Table A-4 of the December 2008 *Long-Term Surveillance and Maintenance Plan* (DOE 2008a).

[c] PRGs derived using EPA's RSL calculator for radionuclides for a residential exposure scenario:
https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search

The PRGs are based on ingestion, inhalation, and external gamma pathways (produce consumption excluded) assuming secular equilibrium; EPA defaults for a residential exposure scenario; and a target risk of 1×10^{-4} (cumulative risks are not reflected in these values). A target risk of 1×10^{-4} was used to facilitate direct comparison with post-cleanup residual soil concentrations. The updated PRGs are comparable to but lower than the ROD cleanup criteria and ALARA goals listed above and are not reflective of reasonably anticipated future land use at CPOU. ICs prohibiting residential land use are in place as documented in the 2004 *Notation on Ownership Record for Notification to Potential Owners of Contamination in Groundwater and Applied Restrictions, Chemical Plant and Quarry Areas.*

Abbreviations:

PRG = Preliminary Remediation Goal

RSL = Regional Screening Level

Table 43. ROD Cleanup Criteria and Associated Risks for CPOU Chemicals
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Chemical/ Criterion[a]	Soil Concentration (mg/kg)		Risks and HQs for Hypothetical Receptors at the Time of the ROD[c]			EPA RSL (mg/kg)[d]	Comment
	ROD Value[a]	Post-Cleanup[b]	Recreational Visitor	Ranger	Resident		
Arsenic						0.68	Although exceeding EPA's current RSL, the residual (post-cleanup) arsenic soil concentration is reflective of background.
Cleanup criterion	75	8.19	6×10^{-6} HQ = 0.02	7×10^{-5} HQ = 0.3	2×10^{-4} HQ = 0.9		
ALARA goal	45		3×10^{-6} HQ = 0.01	3×10^{-5} HQ = 0.2	1×10^{-4} HQ = 0.5		
Background	26		2×10^{-6} HQ = 0.008	2×10^{-5} HQ = 0.1	7×10^{-5} HQ = 0.3		
Chromium (total)[e]						120,000	Residual soil concentration is reflective of background and well below the total chromium RSL.
Cleanup criterion	110	17.4	HQ = 0.03	HQ = 0.6	HQ = 1.0		
ALARA goal	90		HQ = 0.02	HQ = 0.4	HQ = 0.8		
Background	36		HQ = 0.01	HQ = 0.1	HQ = 0.3		
Chromium (VI)[f]						0.3	Assuming Cr(VI) accounts for 10% of the total residual chromium (or 1.7 mg/kg) yields an excess cancer risk of 5.8×10^{-5}, well within EPA's target risk range.
Cleanup criterion	100	–	3×10^{-7} HQ = 0.03	6×10^{-6} HQ = 0.6	1×10^{-5} HQ = 1.0		
ALARA goal	90		3×10^{-7} HQ = 0.02	5×10^{-6} HQ = 0.4	9×10^{-6} HQ = 0.8		
Lead[g]						400[g]	Residual soil lead concentration is reflective of background and less than the residential RSL.
Cleanup criterion	450	18.2	–	–	–		
ALARA goal	240		–	–	–		
Background	34		–	–	–		
Thallium						0.78	Residual soil concentration is reflective of background.
Cleanup criterion	20	1.78	0.03	0.3	1		
ALARA goal	16		0.02	0.3	0.8		
Background	16		0.02	0.3	0.8		
PAHs[h]						Vary by individual PAH: 0.11–11 (mode= 1.1)	Average residual soil concentration is equal to the most conservative RSL.
Cleanup criterion	5.6	0.1	3×10^{-6} HQ = 2E-05	3×10^{-5} HQ = 2E-04	1×10^{-4} HQ = 7E-04		
ALARA goal	0.44		2×10^{-7} HQ = 1E-06	2×10^{-6} HQ = 2E-05	8×10^{-6} HQ = 5E-05		
PCBs						0.23 (for "high risk" PCBs)	Average residual soil concentration is less than the current RSL.
Cleanup criterion	8	0.04	2×10^{-6} HQ = 0.008	3×10^{-5} HQ = 0.09	1×10^{-4} HQ = 0.3		
ALARA goal	0.65		2×10^{-7} HQ = 0.0006	2×10^{-6} HQ = 0.008	8×10^{-6} HQ = 0.02		
TNT						21 (for 2,4,6-TNT)	Average residual soil concentration is well below the current RSL.
Cleanup criterion	140	0.17	2×10^{-7} HQ = 0.03	2×10^{-6} HQ = 0.3	7×10^{-6} HQ = 1		
ALARA goal	14		2×10^{-8} HQ = 0.003	2×10^{-7} HQ = 0.03	7×10^{-7} HQ = 0.1		

Table 43. ROD Cleanup Criteria and Associated Risks for CPOU Chemicals
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Notes:

[a] Table adapted from Table 9-4 of the 1993 ROD (DOE 1993). Columns 1–2 (chemicals/metals and associated soil cleanup criteria) and 3–5 (corresponding hypothetical risks and/or hazard quotients [HQs]) duplicate entries in the original ROD table. For metals, the soil background concentrations listed in the ROD were the mean plus two standard deviations measured at a nearby offsite area (from Note [b] of ROD Table 9-4). Soil background concentrations were not determined for chromium(VI) or for organic compounds (PAHs, PCBs, and TNT). Residual soil concentrations (column 2) and current EPA RSLs are provided for comparison purposes (refer to Notes b and d below).

[b] Average residual soil concentrations listed in Table A-4 of the December 2008 *Long-Term Surveillance and Maintenance Plan* (DOE 2008a).

[c] Includes both cancer risks and HQs from Table 9-4 of the ROD, where applicable. For example, for constituents for which only HQs are listed, the carcinogenic endpoint does not apply. The HQ shown for each contaminant represents the sum of the contributions from ingestion and inhalation (DOE 1993).

[d] Residential RSL from EPA's May 2021 Regional Screening Level (RSL) Summary Table, based on Target Risk (TR) of 1×10^{-6} and a target HQ of 1.0. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
The RSLs reflect the values that TBCs based on a hypothetical residential receptor would be, if calculated today. These values do not reflect reasonably anticipated future land use at CPOU. ICs prohibiting residential land use are in place as documented in the 2004 *Notation on Ownership Record for Notification to Potential Owners of Contamination in Groundwater and Applied Restrictions, Chemical Plant and Quarry Areas*.

[e] Cleanup goals and associated HQs for total chromium are based on Cr(III).

[f] Soil samples were analyzed for total chromium (only); hexavalent chromium was assumed to be 10% of total chromium. Although not directly relevant to an assessment of soil cleanup criteria, chromium(VI) levels in seven CPOU groundwater samples collected in October 1989 (0.006–0.05 mg/L) were below the 0.1 mg/L EPA MCL.

[g] Toxicity values are not available for lead; instead, the 450 mg/kg soil cleanup criterion in the ROD was developed using EPA's IEUBK model. This model has occasionally been updated over the years, most recently in May 2021. https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals
EPA's current residential soil RSL, 400 mg/kg, was derived based on this model. EPA issues the following caution regarding this screening level when both soil and water are assessed:

> When both water and soil are being assessed, if the average soil concentration is 400 mg/kg (the current residential screening level), an average tap water concentration above 5 µg/L would yield more than 5% of the population above a 10 µg/dL blood-lead level. (https://www.epa.gov/risk/regional-screening-levels-rsls-users-guide#special)

This consideration is not germane to CPOU because (1) the average residual soil lead concentration (18.2 mg/kg) is below background (34 mg/kg) and about 20 times less than the RSL; and (2) lead results for CPOU groundwater in 2019–2020 have all been nondetects (<0.0005 mg/L).

[h] According to the ROD, the carcinogenic PAHs detected at the Weldon Spring site are benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, and indeno(1,2,3-cd)pyrene. The range of RSLs in column 6 correspond only to these carcinogenic constituents.

Abbreviations:

– = Not Applicable or Not Available
Cr(III) = Trivalent chromium
Cr(VI) = Hexavalent chromium (no soil data available)
HQ = Hazard Quotient
IEUBK = Integrated Exposure-Uptake Biokinetic Model
PAHs = Polynuclear Aromatic Hydrocarbons
PCBs = Polychlorinated Biphenyls
RSL = Regional Screening Level

The soil excavations were conservatively designed to remove contamination to depth to achieve the established cleanup goals or better. The post-remediation risk assessment used post cleanup confirmation data to evaluate the cumulative risk posed by exposure to soil from all contaminants. The assessment is believed to overestimate risks because it did not take into consideration the backfilling and reworking of the soils following excavation. The assessment confirmed that the potential risks to recreational visitors are within the acceptable risk range.

The post-remediation risk assessment also evaluated the risk to a suburban resident. A standard conservative suburban residential scenario as defined in the CPOU Baseline Risk Assessment was used. Following recommendations in EPA guidance (RAGS, Exposure Factors Handbook), the exposure assumptions (e.g., contact rate, exposure frequency and duration variables) used as input to this estimate were based on statistical data representing the 95th or, if not available, the 90th percentile value for these variables. This approach provides risk estimates for reasonable maximum exposure (RME) to a resident receptor. The calculated risk to the suburban resident was generally greater than 1×10^{-4} but less than 1×10^{-3} and therefore slightly exceeds the acceptable risk range. However, the risk to the suburban resident from exposure to naturally occurring background concentrations of radionuclides in soils is 5.3×10^{-4} or essentially the same risk posed by residual concentrations in the remediated areas. In other words, there is no significant incremental increase in risk from exposure to the remediated areas for a suburban resident. For purposes of this site and this ESD, the standard conservative suburban residential scenario is considered representative of unlimited use and unrestricted exposure (UUUE), the EPA policy threshold for determining whether ICs are appropriate.

These calculated risks are cumulative of all contaminants; however, the risks are primarily due to the radionuclides associated with the uranium ores. The CPOU ROD considered the standards for residual Ra-226 found in 40 CFR 192, Subpart B to be relevant and appropriate (RAR) to the cleanup of these radionuclides. The ROD was issued in 1993 prior to the issuance of EPA Directive 9200.4-25, Use of Soil Cleanup Criteria *[in]* 40 CFR 192 as Remediation Goals for CERCLA Sites. A review of the expectations set forth by EPA in this guidance confirms 1) these standards would be considered RAR were the decision to be made today, i.e., the contamination and its distribution was consistent with the outlined expectations; and 2) the actual residual concentrations for radium and thorium combined are much less than the concentrations identified in the guidance as meeting the health-based standard.

The following explains relevant risk information.

To guide plans for managing contaminated sites, EPA established an acceptable risk range that represents the increased probability (above a background rate) of a hypothetical person developing cancer over his or her lifetime from assumed exposures to site contaminants. This acceptable range for an incremental lifetime cancer risk is between 1 in 1 million (1×10^{-6}, or 0.000001) and 1 in 10,000 (1×10^{-4}, or 0.0001).

Table 44 and Table 45 list the previous and 2021 toxicity values for CPOU radiological and chemical COCs, respectively. While not inclusive of all soil COCs listed in Table 1 (chemicals) and Table 2 (radionuclides), these are the constituents that were addressed in the postremediation risk assessment (DOE 2002b) and for which cleanup criteria were established in the ROD (DOE 1993). Risk calculations in the CPOU postremediation risk assessment showed that external exposure to radium-226 and radium-228 in CPOU soils accounted for the majority of carcinogenic site risks (higher than 1×10^{-4} but less than 1×10^{-3} for residential exposure) and were comparable to risks associated with background levels (5.3×10^{-4}).[1] External exposure to uranium-238 and ingestion of uranium and arsenic in site soils could also result in risks greater than 1×10^{-6} under a residential scenario. Other pathways and constituents resulted in much lower risks. Residual risks for all constituents and pathways under a visitor scenario were less than 1×10^{-5}.

Potential exposures to noncarcinogenic constituents were well below a hazard index of 1 for both residential and visitor exposures. A Hazard Index is the sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. A hazard quotient is the ratio of a single substance exposure level over a specified period to a reference dose for that substance derived from a similar exposure period. Based on EPA's risk guidelines, a maximum acceptable hazard index is 1.

For radionuclides, slope factors used in the risk assessment (Table 4.7 of DOE 2002b) were obtained from EPA's health effects assessment summary tables (HEAST) (EPA 2002). Current toxicity values listed in Table 44 are based on the risk coefficients used in EPA's PRG calculator for radionuclides (EPA 2019), an online tool used to estimate radiation risks for CERCLA sites.[2] These slope factors are based on calculations and coefficients reported by Oak Ridge National Laboratory (ORNL 2014).[3]

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[1] A discussion of the determination of background values is provided in Appendix A of the CPOU remedial investigation report (DOE 1992a). Two different studies including 10 different locations within 5 miles of the site were used for the determination of background. These locations were determined to have similar soils and vegetation native to the site. Radionuclides were characterized by performing gamma surveys and collecting surface soil samples. Metals were analyzed for a total of 50 samples.

[2] https://epa-prgs.ornl.gov/radionuclides; https://epa-prgs.ornl.gov/radionuclides/users_guide.html.

[3] Tables of slope factors are listed in: https://epa-prgs.ornl.gov/radionuclides/SlopesandDosesMasterTableFinal.pdf.

Table 44. CPOU Toxicity Value Summary for Radiological COCs

Constituent[a]	Pathway	Risk Coefficient Units	2002 Postremediation Slope Factors[b]	Current (2021) Slope Factors[c]	Change[d]
Radium-226+D	Ingestion	risk/pCi	7.50E-10	6.77E-10	Decrease
	External[e]	risk/yr per pCi/g	8.49E-06	8.38E-06	Decrease
	Inhalation	risk/pCi	1.16E-08	2.82E-08 (S)	Increase
Radium-228+D	Ingestion	risk/pCi	2.29E-09	1.98E-09	Decrease
	External[e]	risk/yr per pCi/g	4.53E-06	4.04E-06	Decrease
	Inhalation	risk/pCi	5.23E-09	4.37E-08 (S)	Increase
Thorium-230	Ingestion	risk/pCi	2.02E-10	1.66E-10	Decrease
	External[e]	risk/yr per pCi/g	8.19E-10	8.46E-10	Increase
	Inhalation	risk/pCi	2.85E-08	3.41E-08 (F)	Increase
Uranium-238+D	Ingestion	risk/pCi	2.10E-10	1.97E-10	Decrease
	External[e]	risk/yr per pCi/g	1.14E-07	1.19E-07	Increase
	Inhalation	risk/pCi	9.35E-09	2.36E-08 (S)	Increase

Notes:

[a] Only those radionuclides for which concentration data were available were addressed in the risk assessment (DOE 2002b). As such, some of the radiological COCs listed in Table 2 are not addressed.

[b] Toxicity values from postremediation risk assessment (Table 4.7 of DOE 2002b), based on EPA (2002).

[c] Current slope factors are from EPA's radionuclide PRG calculator: https://epa-prgs.ornl.gov/radionuclides/SlopesandDosesMasterTableFinal.pdf (last accessed July 2021). These values are generally the same as those reported in the last FYR (DOE 2016).

[d] Shaded rows denote radionuclide-pathway combinations for which current (2021) dose coefficients are higher than those applied in the postremediation risk assessment. As indicated above, these increases are nominal and apply mostly to the inhalation pathway, for which risks were approximately 3–4 orders of magnitude lower than risks associated with potential external exposures. Increases in external exposure dose coefficients for thorium-230 and uranium-238 would not affect risk estimates because associated risks are insignificant relative to those calculated for radium-226 and radium-228 (Table 5.1 of DOE 2002b).

[e] External risk coefficients apply to the entire soil volume, versus less conservative coefficients developed for the 1, 5, and 15 cm depth profiles.

Abbreviations:

+D = plus daughter isotopes
F = particulate aerosols that represent fast absorption to the blood
S = particulate aerosols that represent slow absorption to the blood

Table 45. CPOU Toxicity Value Summary for Chemical COCs

Constituent[a]	2002 Postremediation Toxicity Values[b]		Current (2021) Toxicity Values[c]		Comment
Carcinogenic Endpoints	Ingestion SF $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Ingestion SF $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	
Arsenic	1.5	0.0043	1.5	0.0043	No change.
Chromium(VI)[d]	–	0.012	0.5 (CalEPA)	0.012 (IRIS) 0.084 (RSL)	Postremediation inhalation risks were on the order of 1×10^{-9} to 1×10^{-8} (DOE 2002b). Previous assumptions are still valid.
PAHs[e]	7.3	–	1.0	6.0E-04	Decrease in SF.
PCBs[f]	2.0	–	2.0	5.7E-04	No change in SF.
2,4,6-TNT	0.03	–	0.03	–	No change.
Noncarcinogenic Endpoints	RfD (mg/kg-day)	RfC (mg/m^3)	RfD (mg/kg-day)	RfC (mg/m^3)	
Arsenic	3.0E-4	–	3.0E-04	1.5E-05 (CalEPA)	No change in RfD.
Chromium(III)	1.5	–	1.5	–	No change.
Chromium(VI)[d]	0.003	1.0E-04	0.003	1.0E-04	No change.
Lead	Residual soil risks assessed through IEUBK modeling.[g]				
PAHs[e]	–	–	3.0E-04	2.0E-06	EPA's RSLs for soil are based on cancer risk.
PCBs[f]	2E-05	–	2.0E-05	–	No change.
Thallium	8E-05	–	1.0E-05 (PPTRV)	–	Decrease in RfD (now more stringent).
2,4,6-TNT	5E-04	–	5E-04	–	No change.
Uranium	0.003	–	0.003 (IRIS) 2.0E-04 (ATSDR)	4.0E-05 (ATSDR)	Updated policy recommends use of a more stringent ATSDR RfD (EPA 2016).

Notes:

[a] Only those constituents for which concentration data were available and addressed in the risk assessment are listed here. As such, some of the initial soil COCs listed in Table 1 are not addressed.

[b] Toxicity values from postremediation risk assessment (Tables 4.8 and 4.9 of DOE 2002b). Based on results of the baseline risk assessment indicating insignificant contribution to total risks (DOE 1992d), dermal exposures were not assessed in the postremediation risk assessment (DOE 2002b).

[c] Current toxicity values are from EPA's Regional Screening Level (RSL) summary table (May 2021). Unless otherwise noted, values are based on IRIS, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables.

[d] Soil samples were analyzed for total chromium; hexavalent chromium was assumed to be 10% of total chromium (DOE 1993).

[e] Slope factor for benzo[*a*]pyrene used for all class B2 PAHs (Table 4.9 of DOE 2002b).

[f] Toxicity values based on Aroclor 1254.

[g] EPA's IEUBK model was last updated in May 2021 (https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals#overview). Refer to Table 43, Note "g", for additional information.

Abbreviations:

– = not addressed or not available
ATSDR = Agency for Toxic Substances and Disease Registry
CalEPA = California Environmental Protection Agency (basis cited in EPA's RSL summary table)
HQ = hazard quotient
IEUBK = Integrated Exposure Uptake Biokinetic (model)
IRIS = EPA's Integrated Risk Information System: https://www.epa.gov/iris (accessed July 2021)
mg/kg-day = milligrams per kilogram per day
mg/m^3 = milligrams per cubic meter
$\mu g/m^3$ = micrograms per cubic meter
PAHs = polycyclic aromatic hydrocarbons
PPRTV = provisional peer-reviewed toxicity value (https://www.epa.gov/pprtv)
RfC = reference concentration
RfD = reference dose
RSL = Regional Screening Level
SF = slope factor

For radionuclides, all slope factors currently in EPA's PRG calculator are slightly different than those used in the postremediation risk assessment (Table 44). Half of the values are slightly higher, and half are slightly lower. Most of the higher values are for the inhalation pathway, which is insignificant compared to the external exposure pathway. Most of the lower values are for external exposure and ingestion pathways and would result in slightly lower estimated risks. Using revised slope factors would probably result in an overall calculated lower residual risk than those reported in the postremediation risk assessment. Therefore, the slope factors used in the risk assessment remain valid. The fact that the cleanup achieved levels comparable to background for radionuclides means that they are ALARA, regardless of exposure assumptions and toxicity values. Unless currently unknown radiological contamination is discovered in the future, conditions are protective for current and anticipated future land use.

For chemicals listed in Table 45, EPA's RSL summary tables and website[4] were consulted for any changes in toxicological values since the last FYR. Only a few toxicity values are different from those used in the postremediation assessment; none of these changes would impact the conclusions previously drawn. For example, changes to ingestion and inhalation values for chromium(VI) (an oral slope factor was not previously available) would not affect postremediation risk estimates because chromium is not a primary site constituent. (Chromium(VI) was not analyzed in soil samples but was assumed to be 10% of the total chromium soil content.) The more stringent reference doses for thallium and uranium would also not affect noncancer risk estimates given their corresponding low hazard quotients (DOE 2002b).

Although there were no changes in most toxicological values for CPOU soil COCs since the last FYR, Table 45 does include a few new toxicity values for noncarcinogenic endpoints. For example, EPA's RSL summary tables currently list oral and inhalation toxicity values for polycyclic aromatic hydrocarbon (PAHs) (e.g., benzo[*a*]pyrene). As the carcinogenic endpoint would dominate for this class of compounds (e.g., as the basis for a remedial goal), this change is not expected to affect the overall risk assessment conclusions. In the postremediation assessment of chemical risks, inhalation risks were considered only for arsenic and chromium(VI). Although inhalation toxicity criteria are now also available for PAHs, PCBs, and uranium (Table 45), because of the relative insignificance of the inhalation pathway, these updates would not affect the overall risk assessment conclusions. Potential exposures to lead in soil were assessed differently given the lack of consensus on toxicity values.

A summary of related findings and updates is provided below.

The CPOU ROD established a cleanup criterion for lead of 450 milligrams per kilogram (mg/kg) with an ALARA goal of 240 mg/kg (DOE 1993). To determine human health impacts from residual lead concentrations in soil, the postremediation risk assessment evaluated the potential effect on blood lead levels (BLLs) in children using EPA's Integrated Exposure Uptake Biokinetic model (DOE 2002b). At the time it was EPA's policy that there should be no greater than a 5% probability that an individual child's BLL would exceed 10 micrograms per deciliter (µg/dL). The Centers for Disease Control and Prevention updated recommendations on children's BLL in January 2012 (CDC 2012), lowering its recommended screening level from 10 to 5 µg/dL for children ages 1 to 5. Modeling results included in the postremediation risk assessment indicated that children's BLLs would be $\leq$3.5 µg/dL (with less than a 1% probability of exceeding 10 µg/dL) for exposures to soil in all portions of the CPOU. Residual lead levels in

[4] http://www.epa.gov/risk/regional-screening-table.

soils are therefore still considered to be protective. Consistent with the last FYR, EPA continues to recommend a screening level of approximately 400 mg/kg for residential soils, a level that was developed using the IEUBK model.[5] As noted in Table 43, EPA issues a caution regarding the 400 mg/kg screening level when both soil and water are assessed. However, this consideration is not germane to the CPOU because (1) the average residual soil lead concentration (18.2 mg/kg) is below background (34 mg/kg) and about 20 times less than the RSL; and (2) lead results for CPOU groundwater in 2019–2020 have all been nondetects (<0.0005 mg/L).

In 2012, EPA issued a supplement (EPA 2012) to its FYR Guidance (EPA 2001) for assessing protectiveness at vapor intrusion sites. The vapor intrusion exposure pathway was not previously evaluated for the CPOU. EPA issued vapor intrusion guidance in June 2015 for assessing potential impacts to indoor air and made available a vapor intrusion screening level (VISL) calculator and user guide.[6,7] More than 100 constituents that had not previously been considered as volatile organic compounds (VOCs) were given that designation in EPA's RSL tables, including six constituents listed in Table 1 (acenaphthene, anthracene, fluorene, naphthalene, NB, and pyrene). Of these, only naphthalene and NB have inhalation toxicity data. None of these VOCs were specifically addressed in the CPOU ROD. From the baseline risk assessment for the CPOU (DOE 1992d) and data in Table 1, concentrations of the VOC constituents were all relatively low. None of the VOC constituents were identified as a groundwater COC. Although soil gas sampling was not conducted as part of site characterization, available data suggest that the vapor intrusion pathway is not of potential concern. Consistent with conclusions in the last FYR, residual VOCs in soil are not likely to pose a threat through the vapor intrusion pathway even if buildings were constructed in the CPOU area.

DOE concluded in the ESD that there is no need to restrict land use in the Chemical Plant Area for a potential soil exposure scenario. This conclusion still remains valid based on updated information. As demonstrated above, exposure assumptions are still considered valid, and site conditions remain protective. This assessment applies to land use only and does not apply to issues related to groundwater contamination or to soils and sediments in the Southeast Drainage, discussed below.

The Southeast Drainage is narrow and wooded with limited access. One of the objectives of the cleanup was to limit ecological damage to the drainage. It was determined that the soil cleanup goals developed for the CPOU, described above, were not appropriate for cleanup of this area. Risk-based cleanup goals were developed for the drainage that were designed to be protective for recreational use and for a modified residential scenario involving a child living near the drainage and using it periodically for play activities. Post-cleanup soil and sediment sampling was conducted, and a postcleanup risk assessment was performed to confirm that the drainage is protective for these uses and, therefore, protective for any reasonably anticipated land use. However, residual soil and sediment contamination remains in some locations within the drainage at levels exceeding those that would support UU/UE, as represented in this case by a standard conservative suburban residential exposure scenario described above. Therefore, land use restrictions are needed in the drainage to prevent residential use or other uses inconsistent with recreational use. As noted above, the Southeast Drainage is on property owned by state entities.

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[5] https://semspub.epa.gov/work/HQ/400750.pdf
[6] https://www.epa.gov/vaporintrusion/visl-users-guide.
[7] https://epa-visl.ornl.gov/cgi-bin/visl_search.

Risk-based cleanup criteria for the Southeast Drainage were based on achieving a risk level of 1×10^{-5} for recreational use of the area by a recreation visitor (child/hunter). Risk drivers were radionuclides, primarily radium-226, radium-228, thorium-230, and uranium-238. Pathways include soil ingestion and direct gamma exposure. The postremediation risk assessment (ANL 1999) did not provide calculations or toxicity values but referenced the methodology and assumptions used in a previous risk assessment documented in the EE/CA report (DOE 1996). Table 46 lists the risk coefficients used in the analysis along with the updated values.

Table 46. Southeast Drainage Toxicity Value Summary for Radiological COCs

Radionuclide[a]	**Risk Coefficients Used in 1996 Assessment**[b]		**Current (2021) Risk Coefficients**[c]	
	Ingestion (risk/pCi)[d]	**External (risk/yr per pCi/g)**[e]	**Ingestion (risk/pCi)**	**External (risk/yr per pCi/g)**
Radium-226	6.60E-10	6.83E-06	6.77E-10	8.38E-06
Radium-228	7.20E-10	3.57E-06	1.98E-09	4.04E-06
Thorium-230	3.18E-10	7.36E-10	1.66E-10	8.46E-10
Uranium-238[f]	1.50E-10 2.28E-11	8.41E-08	1.97E-10	1.19E-07

Notes:

[a] Radionuclides listed in Table 1 of ANL (1999) for hypothetical child and recreational hunter receptors.

[b] Risk coefficients from Table A.1 of DOE 1996.

[c] Current risk coefficients are from EPA's radionuclide PRG calculator: https://epa-prgs.ornl.gov/radionuclides/SlopesandDosesMasterTableFinal.pdf.

[d] Ingestion slope factors used in the 1996 assessment were originally listed in units of millirem per pCi and converted to units of risk/pCi using a factor of 6×10^{-7}/mrem (Section 2.3.1 of DOE 1996). This conversion factor aligns with that suggested in a 2002 DOE memorandum of 6×10^{-4} cancers per TEDE (rem) for mortality, or 6×10^{-7}/mrem. https://www.nrc.gov/docs/ML1127/ML112720579.pdf

[e] External slope factors were listed in units of mrem/hour/pCi/g, and were converted using the 6×10^{-7}/mrem factor noted above and correcting for the time frame (8760 hours per year).

[f] Two ingestion values were listed for uranium-238 in the 1996 assessment: the first assumes 5% of ingested uranium-238 reaches body fluids, the second 0.2%.

Abbreviation:
mrem = millirem

As indicated in Table 46, toxicity values applied in the Southeast Drainage risk assessment (DOE 1996; ANL 1999) are comparable to current values recommended by EPA. Risks estimated using EPA's PRG risk calculator using data and assumptions from the postremediation risk assessment in tandem with updated slope factors were also similar (Table 53 of DOE 2016) For the hunter scenario, it was assumed that exposure to the contaminated area would occur for 1 hour per event at a frequency of 20 events per year for 10 years. For the child scenario, it was assumed that exposure to the contaminated area would occur for 1 hour per event at a frequency of 90 events per year for 10 years. Soil ingestion and gamma exposure were included as indicated in Table 46. On the basis of these findings, the exposure assumptions and toxicity data used in the EE/CA report (DOE 1996) and Appendix A of the postremediation risk assessment (DOE 2002b) of the Southeast Drainage are still valid, as are the corresponding cleanup levels and remedial objectives. Because contaminant concentrations remain above levels that would permit UU/UE, ICs are needed to prevent residential land use. ICs for the Southeast Drainage have been implemented, as detailed in Section 5.1.1.1, and are monitored each year to ensure their continued effectiveness.

Although distinct from the direct exposure pathways addressed above, as a segue to the following section addressing ecological risks, results of earlier biouptake studies warrant mention. Sitewide biouptake studies were conducted to determine the potential effects of area fish and game consumption on an “avid sportsman” (DOE 1995a). Biouptake modeling was conducted using uptake factors and assumptions from the literature. In addition, fish, small mammals, and waterfowl were sampled to determine how modeled tissue concentrations (based on concentrations of contaminated media and literature uptake factors) compared to actual observations. Results revealed that modeled dose estimates were greater than measured dose estimates by factors from 3 to 10, indicating the conservatism of model assumptions. Risks to humans calculated using modeled values were within EPA’s acceptable risk range. It was determined that further biota monitoring was not needed to ensure protectiveness.

Ecological Risk

Numerous ecological investigations have been conducted at the Weldon Spring Site. A 1995 report (DOE 1995a) summarized studies that took place from 1987 until that time; a later letter report included a summary of more recent studies (ANL 2004). The investigations generally included sampling and analysis of various contaminated media and comparison against “safe” benchmark values. Quantitative and qualitative biological surveys were also conducted and included sampling and examination of plants, reptiles, birds, and small mammals to determine if any adverse effects could be observed. Mammals and fish were collected for tissue sampling, and toxicity testing was conducted to determine the potential for effects on aquatic life.

The baseline (preremediation) risk assessment for the CPOU (DOE 1992d) indicated that concentrations of some site-related constituents were present at levels that could potentially cause adverse effects in ecological receptors. However, no such adverse effects were actually observed in the fauna that were sampled, with the possible exception of the former raffinate ponds area (DOE 1992b). Those ponds were subsequently remediated, and exposures were eliminated.

Maximum surface water concentrations observed in the Southeast Drainage exceeded benchmarks and were further evaluated for ecological risks through toxicity testing (DOE 1996); limited toxicity was found at one location. Surveys of terrestrial wildlife indicated diverse communities and no adverse impacts. Although aquatic communities were more limited, this was attributed to the intermittent nature of the drainage as opposed to site-related contamination. Uranium concentrations as high as 1800 µg/L (about 1200 pCi/L based on a site-specific conversion factor) were reported in the past in the Southeast Drainage—exceeding levels at which toxic effects have been observed (DOE 1992b). However, since that time uranium concentrations have declined. Sampling results from 2020 indicate that concentrations are below 100 pCi/L (Figure 31), the Objective 2 trigger level for groundwater. This trigger level is not appropriate for application to aquatic life, and there are no state or federal aquatic standards for uranium in surface water.

Suter and Tsao (1996) cite 142 µg/L (212 pCi/L) as the lowest chronic threshold for aquatic life. Since the last FYR report (DOE 2016), uranium concentrations in southeast drainage samples SP-5303 and SP-5304 have been below this threshold, ranging from about 16 to 98 µg/L (11–66 pCi/L; Figure 31). In the last several years, most uranium concentrations have also been below Suter and Tsao’s Tier II secondary chronic value of 46 µg/L (or 31 pCi/L). As indicated in

Section 4.2.1.5, uranium levels at SP-5303 and SP-5304 have been decreasing over the long term (Figure 32).

In summary, consistent with the findings in the last FYR (DOE 2016) there have been no significant changes in exposure assumptions, toxicity, or ecological risk assessment methodology that would call into question the protectiveness of the CPOU remedy (including the Southeast Drainage) from an ecological risk perspective. Concentrations in relevant media have been reduced through the remediation that has taken place.

5.1.2.3 Progress Toward RAOs

Section 5.1.1.1 includes a status on progress toward RAOs. The CPOU did not include specific RAOs.

5.1.3 Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

Answer C: No other information has come to light that could call into question the protectiveness of the remedy.

5.2 Groundwater Operable Unit

5.2.1 Question A: Is the remedy functioning as intended by the decision documents?

Answer A: No, the remedy is not functioning as intended by the decision document. The remedy is short-term protective, however there are early indicators of potential issues.

5.2.1.1 Remedial Action Performance

The performance of the MNA remedy is assessed through the sampling of the Objective 2 monitoring wells. Objective 2 wells are within the areas of impact and monitor both the weathered and unweathered units of the Burlington-Keokuk Limestone. Objective 2 of the MNA strategy is to verify that contaminant concentrations are declining or remaining stable as expected and that cleanup standards will be met in a reasonable time frame.

Detection monitoring consists of sampling to fulfill Objectives 3, 4, and 5 of the MNA strategy. Wells along the fringes and downgradient (both laterally and vertically) of the areas of impact are monitored to ensure that lateral and vertical migration remains within the current area of impact and that expected lateral downgradient migration (due to dispersion) within the paleochannels is minimal or nonexistent. Springs and a surface water location on Dardenne Creek are also monitored as part of this program, as these are the closest groundwater discharge points for the shallow aquifer near the Chemical Plant. These locations are monitored to ensure that concentrations remain protective of human health and the environment and that water quality continues to improve in the springs.

Contaminant Trending Summary

Overall, groundwater impact is contained within the upper portion of the shallow aquifer (weathered and upper unweathered units of the Burlington-Keokuk Limestone). Decreases are attributed to source removal and attenuation mechanisms. Concentrations of uranium, nitrate, TCE, and nitroaromatic compounds are decreasing in most Objective 2 wells in the weathered unit. Statistically downward trends indicate that cleanup objectives will likely be attained in the weathered unit within the estimated time frames in the remedial design documents and the revised Baseline Concentrations Report (DOE 2008b). Unweathered unit locations that previously exhibited increasing concentrations have stabilized and are generally located along the leading edge of the area of impact.

Detection monitoring indicates that impacted groundwater is remaining within the paleochannels and is migrating along expected flow pathways. The levels of COCs in the springs are decreasing. The COC levels are below the cleanup objectives in all Chemical Plant springs except for Burgermeister Spring. It is the primary discharge point for groundwater from the Chemical Plant site, and while it continues to exceed the cleanup objective for uranium, levels are decreasing. It is expected that the average uranium levels in Burgermeister Spring will be below the cleanup objective before 2030. Since Burgermeister Spring is subject to dilution during wet periods and uranium concentrations regularly vary by an order of magnitude from quarter to quarter, it is more appropriate to focus on the decreasing higher concentrations. They have been steadily decreasing and should be consistently below the cleanup standard by around 2040 if the long-term trend over the last 25 years continues. Spring SP-6303 has been dry since 2013, except for one sample in February 2019. It is 1200 ft upstream from Burgermeister Spring and at a 22.7 ft higher elevation.

Uranium levels in the Southeast Drainage springs continue to exceed the cleanup objective. Contaminated groundwater from the Chemical Plant site is not the source of uranium in these springs; rather, surface water lost to the stream channel is flushing uranium from residually contaminated sediments within the bedrock fractures. Uranium concentrations in two Southeast Drainage springs are slightly higher than in Burgermeister Spring and are decreasing at a similar rate.

Uranium Levels in the Raffinate Pits Area

In the weathered unit, uranium in impacted area wells is decreasing, and uranium in detection monitoring wells remains at low levels. In the less permeable underlying unweathered unit, uranium concentrations are stable but at elevated levels (above the impacted area trigger value). When the Raffinate Pits were full, contamination was forced deeper, into the upper part of the unweathered unit by the high hydraulic head that resulted from the full pits. Remediation of the Raffinate Pits removed the primary source of contamination but also decreased the downward vertical gradient. This limits the flow of uncontaminated recharge water into the unweathered unit that could flush the poorly connected fractures and attenuate the remnant contamination. Recharge that does enter the system is more likely to move horizontally through the weathered unit than vertically into the low-permeability unweathered unit due to greater horizontal hydraulic conductivity and reduced downward vertical gradient.

The MNA trigger levels for the impacted area were established prematurely (in 2004), before data were collected from unweathered unit wells installed in 2004. Uranium concentrations in the new unweathered unit wells in the Raffinate Pits area were initially increasing but have been stable for the past 8 to 12 years.

Groundwater flow directions are unchanged in the Raffinate Pits area. Impacted groundwater is contained within the paleochannel in this area and is migrating along the expected pathways. Dilution and dispersion continue to reduce uranium levels in the weathered unit. In the unweathered unit, uranium levels are not yet trending downward in source area wells and the unweathered unit monitoring network is not as extensive as the weathered unit network. However, uranium levels in near downgradient unweathered unit well MW-4043 are steadily decreasing and are now below the Objective 3 (near) 50 pCi/L trigger level. Uranium levels in farther downgradient unweathered unit wells remain low. Uranium concentrations in Burgermeister Spring are steadily decreasing, with maximum concentrations expected to be below the drinking water standard within 20 years if the long-term trend continues.

DOE and regulators are currently working to resolve the ongoing issue regarding the long-term protectiveness of the MNA remedy with respect to the elevated uranium (relative to MNA progression trigger levels) in unweathered unit impacted area wells. The discussions will include the EPA Center for Environmental Solutions and Emergency Response Groundwater Characterization and Remediation Division memorandum, dated July 21, 2020.

5.2.1.2 System Operation and Maintenance

The operation and maintenance activities for the Weldon Spring Site are specified in the LTS&M Plan. Environmental monitoring and evaluation of data are performed in accordance with the procedures and methods outlined in the LTS&M Plan. DOE also performs annual inspections of LTS&M activities, environmental monitoring, and ICs and has found these activities to be functioning as intended.

5.2.1.3 Opportunities for Optimization

There were no additional opportunities for optimization identified during the past FYR period.

5.2.1.4 Early Indicators of Potential Issues

Uranium concentrations in the upper unweathered unit in the raffinate pits area are stable but remain elevated. Until the trend begins to decrease, it is not possible to project a cleanup time for this area.

5.2.1.5 Implementation of ICs and Other Measures

The following are the use restrictions listed in the LTS&M Plan for the GWOU. The ICs in place and planned for the Weldon Spring Site are discussed in the CPOU section (Section 5.1.1.5). The ICs that specifically apply to the GWOU are the Missouri Well Installation Special Area designation rulemaking; the easements with MDC, MoDOT, and the MDNR Division of State Parks; and the MOU with the Army.

In preparation for the FYR, the LTS&M Plan requires DOE to contact MDNR to determine if well registrations were issued for the groundwater restricted area. The MDNR responded in an email dated December 10, 2020, that no wells had been installed in Special Area 13 (the special area designed under the Missouri Well Installation Special Area designation for the Weldon Spring Site).

The use restrictions listed below must be met in the entire area of approximately 1140 acres shown in Figure 110 where groundwater use needs to be restricted until concentrations of the COCs meet drinking water or risk-based standards that allow for UU/UE. The period of time necessary for contaminants to attenuate to these levels has been estimated at approximately 100 years. The size of the restricted area includes a 1000 ft buffer area that accounts for the groundwater gradient and flow conditions at the site. The restricted area includes properties under federal jurisdictional control (DOE and the Army) as well as properties owned by state entities.

The objectives of the controls or restrictions are as follows:

1. Prevent the use of the contaminated shallow groundwater and spring water for drinking water purposes. The contaminated shallow groundwater occurs in the weathered and unweathered portions of the upper limestone unit (Burlington-Keokuk). The contaminated groundwater and spring water system occurs within the limits of the hydraulic buffer zone identified in Figure 110. The springs are identified in the figure as SP-6301, SP-6303, SP-5303, and SP-5304. This restriction will need to be maintained over a period of decades or longer.
2. Limit the use of all groundwater within the outlined restricted area to investigative monitoring only. The boundary of the restricted area extends beyond the area of contamination and is intended to provide a buffer against potential hydraulic influences on the area of contamination by preventing such things as pumping wells being located near the contaminated area. This restriction includes the shallow groundwater system and also extends vertically to all groundwater systems that underlie the contaminated groundwater. This restriction will need to be maintained over a period of decades or longer.
3. Retain access to the area for continued monitoring and maintenance of groundwater wells and springs.
4. Maintain the integrity of any current or future remedies or monitoring systems.

5.2.2 Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection still valid?

Answer B: Yes, the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection are still valid.

5.2.2.1 Changes in Standards and TBCs

Table 47 lists the cleanup standards for the Chemical Plant area GWOU established in the ROD, which are the contaminant-specific ARARs that apply to the GWOU. As stated in the ROD, these standards are considered protective of human health and the environment under UU/UE.

Table 47. Cleanup Standards for the Chemical Plant GWOU Established in the ROD

Constituent	ROD Cleanup Standard	ROD Basis	Alternate Standard[a]	Comment
Nitrate (nitrate as N)	10 mg/L	40 CFR 141.62	–	No change since ROD.
Total uranium	20 pCi/L[b]	40 CFR 141	–	No change since ROD.
1,3-DNB	1.0 µg/L	10 CSR 20-7[c]	2.0 µg/L[d]	No change since ROD in state standard. EPA RSL is 2 times higher.
2,4-DNT	0.11 µg/L	10 CSR 20-7[c]	–	No change since ROD for state drinking water supply standard. Current state guideline for groundwater is 0.04 µg/L.
NB	17 µg/L	10 CSR 20-7[c]	13 µg/L[d,e]	No change since ROD relative to the state water quality standard, the basis for the RG. Although the RG slightly exceeds the current RSL for residential uses for noncancer endpoints, this is not a concern with respect to the remedy given the very low prevalence and magnitude of NB in groundwater (<0.046 µg/L).[e]
TCE	5 µg/L	40 CFR 141.61	0.49 µg/L[d]	Both federal and state standards (also 5 µg/L) exceed EPA's 10^{-6} risk-based value.
2,6-DNT	1.3 µg/L	Risk-based[f]	0.049 µg/L[d]	10^{-5} risk-based equivalent for current EPA RSL for 2,4/2,6-DNT mixture, 1.1 µg/L, is comparable to ROD cleanup standard.
2,4,6-TNT	2.8 µg/L	Risk-based[g]	2.0 µg/L[c] 2.5 µg/L[d]	The state health advisory and the EPA RSL are slightly lower than the ROD standard.

Notes:

[a] Alternate standards are only listed in cases where the guidance value differs from the ROD cleanup standard.
[b] Based on site-specific conversion factor; equivalent to 30 µg/L standard.
[c] Missouri Water Quality Standard (last revision November 29, 2019; some tables dated March 31, 2018), https://s1.sos.mo.gov/cmsimages/adrules/csr/current/10csr/10c20-7a.pdf.
[d] Tap water RSL from EPA's May 2021 summary table: https://semspub.epa.gov/work/HQ/400770.pdf
The RSLs are generic screening values, not de facto or enforceable cleanup standards, reflecting (when applicable) ingestion, dermal contact, and inhalation pathways combined. For cancer risk endpoints, RSLs are based on a target risk of 10^{-6}. RSLs for noncancer endpoints are based on a target hazard quotient or hazard index of 1.0.
[e] The basis for the nitrobenzene RG of 17 µg/L cited in the ROD is the state groundwater and drinking water supply standard (refer to Note c above), a standard that is still current. The alternate standard (13 µg/L) is EPA's current RSL for tapwater, reflecting a hazard quotient of 1.0 for a child receptor. Although the current RSL is slightly lower than the 17 µg/L ROD cleanup standard, revision of the NB RG is not necessary given the very low detection frequency and NB levels in groundwater. Since the 2016 FYR report was issued (October 2016 to present), NB has been detected in only 3 of 268 CPOU groundwater samples: 0.035 µg/L (two detections) and 0.046 µg/L. Detection limits in the remaining 265 samples were ≤0.035 µg/L.
[f] Risk-based concentration equivalent to 10^{-5} for a resident scenario.
[g] Risk-based concentration equivalent to 10^{-6} for a resident scenario.

Abbreviation:
– = not applicable

Federal and state water quality standards specified in the ROD have not changed. In the absence of regulatory standards, risk-based levels corresponding to a residential scenario were derived for 2,6-DNT and 2,4,6-TNT (10^{-5} and 10^{-6} risk bases, respectively) (Table 8.1 of DOE 2004). Although current EPA or state guidelines are lower than these values, the ROD standards are still considered protective for the reasons stated in Table 47.

5.2.2.2 Exposure Pathways, Toxicity, and Risk Assessment

Human Health

A review of assumptions incorporated into the risk assessments documented in the *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri* (DOE 1997a) and *Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri* (DOE 1998c) was also performed. The review included the following risk assessment aspects: risk assessment methodology, exposure scenarios, exposure assessment input parameters, and toxicity values. The GWOU ROD states: "The shallow bedrock aquifer that is beneath the boundary of the Chemical Plant property and the adjacent DA and MDC properties is not currently used for drinking water or for irrigation. However, on the basis of EPA guidance for groundwater classification (EPA 1986), site groundwater could be classified as potentially usable from a water quality standpoint. That is, according to the EPA, a potential source of groundwater is one capable of yielding at least 150/gal/d to a well or spring, which is sufficient for the needs of a family, Also, a drinking water source must have a total dissolved solids concentration of less than 10,000 mg/L that can be supplied without treatment. Despite the unlikelihood of the impacted groundwater actually ever being used for household purposes, in accordance with EPA guidelines and for the purpose of making this remedial action determination, this shallow groundwater is categorized as a potentially usable resource."

As noted in Section 5.1.2, EPA has finalized guidance on the vapor intrusion pathway (EPA 2015a); this pathway was not previously evaluated for the GWOU. The only groundwater COC of potential concern for a vapor intrusion pathway is TCE. For a commercial exposure scenario, EPA's VISL calculator yields a screening level concentration for TCE in groundwater of 32.7 µg/L (using a site-specific upper end temperature of 16 C).[8] According to the most recent groundwater sampling results, detected TCE concentrations were above this screening level (Figure 44).

As noted in the last two FYR reports, there are no habitable structures near the TCE-contaminated groundwater, so the vapor intrusion pathway is currently incomplete and the remedy is protective. ICs for the CPOU prohibit the future construction of residences and allow only buildings that are mission-related. Therefore, while residences are prohibited, it is possible that a mission-related structure could be built over the TCE-contaminated groundwater. Comparison of site data to EPA's screening levels indicates that such a use might be unacceptable. Therefore, further characterization might be prudent if such use is considered in the future. The inhalation pathway is not considered further in this discussion of groundwater, as it is inconsequential for a recreational visitor. However, this pathway may require further analysis if changes in land or water use are contemplated.

[8] https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-level-calculator.

The toxicity values used to characterize risks for the GWOU COCs for the water ingestion pathway were reviewed. Table 48 compares the toxicity values included in the GWOU ROD and the last FYR with corresponding current values from EPA's RSL tables. Apart from some new inhalation toxicity values (pathway not considered in ROD or in the 2016 FYR) and an updated (more stringent) oral reference dose for uranium, toxicity values for most constituents have not changed since the last FYR (DOE 2016), when values were demonstrated to be protective. While the oral reference for NB has not changed since 2009 (the last IRIS update), the updated inhalation unit risk value resulted in a more stringent RSL. However, as noted in Table 47 (Note e), although the RG exceeds the current RSL for residential uses (based on the updated inhalation unit risk), this is not a concern with respect to the remedy given the very low prevalence and magnitude of NB in groundwater. Furthermore, as noted in the previous paragraph, the inhalation pathway would likely be inconsequential under anticipated land use scenarios.

Section 5.2.1.5 indicates that controls are intended to prevent the use of shallow groundwater and spring water for drinking water purposes. While groundwater use can be prevented by putting well drilling restrictions in place, it is much more difficult to prevent the use of surface water, particularly in areas that do not receive heavy use. Under current site conditions, the only potentially complete exposure pathway to groundwater is that of a recreational visitor to the Weldon Spring Conservation Area possibly coming into contact with spring water in the Southeast Drainage. No private residences are adjacent to the drainage, which is on land currently managed by MDC. The only site-related constituent that has been regularly detected in this area is uranium. The 2020 Annual Site Environmental Report (ASER) (DOE 2021) included an estimated total effective dose (TED) equivalent for a hypothetical recreational receptor assumed to access the drainage and occasionally drink from spring location SP-5304. Corresponding exposure assumptions are summarized below.

- The maximally exposed individual drinks 0.2 L (1 cup) of water from the spring 20 times per year.
- The maximum uranium concentration in water samples taken from spring locations during 2020 was at SP-5304 in the Southeast Drainage (58 pCi/L or 0.085 mg/L). This concentration was assumed to be present in all of the water ingested.

Using these assumptions, along with the activity ratios and dose conversion factors for uranium isotopes documented in Section 5.5.2 of the 2020 ASER, the estimated TED to the hypothetical maximally exposed individual was calculated to be 0.048 millirem (mrem), which is well below the 100 mrem guideline established by DOE for public exposure (DOE 2021). To equate these results to interpretations more aligned with risk assessment directives established in the National Contingency Plan (NCP), the assumptions outlined above were used to calculate a hazard quotients (HQ) for noncarcinogenic endpoints. [There is no cancer slope factor for uranium for chemical endpoints.] The following additional exposure assumptions recommended in EPA's RSL guidance were applied in the calculation (https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search):

- 80 kilogram (kg) body weight (applies to ages 6 to adult)
- 10-year exposure duration (EPA recommends an exposure duration of 20 years for adults but this was considered unlikely for this recreational exposure scenario)
- Oral reference dose for uranium of 0.0002 mg/kg-day (Table 48)

Table 48. Review of Toxicity Values Used in Risk Assessments for the GWOU and QROU

Parameter	Toxicity Value Basis	Units	Toxicity Values in GWOU ROD[a]	2016 Toxicity Values[b]	Current (2021) Toxicity Values[c,d]	Change Since 2016
Radiological Risk Endpoints						
Uranium ^{234}U ^{235}U+D ^{238}U+D	Ingestion slope factor	risk/pCi	4.4×10^{-11} 4.5×10^{-11} 6.2×10^{-11}	7.07×10^{-11} 7.18×10^{-11} 8.70×10^{-11}	7.07×10^{-11} 7.18×10^{-11} 8.70×10^{-11}	Unchanged Unchanged Unchanged
Cancer and Noncancer Risk Endpoints						
1,3-DNB	RfD_o	mg/kg-day	0.0001	0.0001	0.0001	Unchanged
2,4-DNT	SFO IUR RfD_o	$(mg/kg\text{-}day)^{-1}$ $(\mu g/m^3)^{-1}$ mg/kg-day	0.68 0.002	0.31 0.002	0.31 8.9E-05 0.002	Unchanged New[e] Unchanged
2,6-DNT	SFO RfD_o	$(mg/kg\text{-}day)^{-1}$ mg/kg-day	0.68 0.001	1.5 0.0003	1.5 0.0003	Unchanged Unchanged
2,4,6-TNT	SFO RfD_o	$(mg/kg\text{-}day)^{-1}$ mg/kg-day	0.03 0.0005	0.03 0.0005	0.03 0.0005	Unchanged Unchanged
Nitrate as N	RfD_o	mg/kg-day	1.6	1.6	1.6	Unchanged
Nitrobenzene	IUR RfD_o RfC_i	$(\mu g/m^3)^{-1}$ mg/kg-day mg/m^3	0.0005	0.002	4.0E-05 0.002 0.009	New[e] Unchanged New[e]
TCE	SFO IUR RfD_o RfC_i	$(mg/kg\text{-}day)^{-1}$ $(\mu g/m^3)^{-1}$ mg/kg-day mg/m^3	0.011	0.046[a] 0.0005	0.046 4.1E-06 0.0005 0.002	Unchanged New[e] Unchanged New[e]
Uranium	RfD_o RfC_i	mg/kg-day mg/m^3	0.003	0.003	0.0002[f] 4.0E-05	Revised New[e]

Notes:

[a] From Section 7.1.3 of the GWOU ROD (DOE 2004a). For radionuclides, only ingestion slope factors were used because inhalation and external radiation were not considered pathways of concern. Toxicity values for noncarcinogen and carcinogenic endpoints are listed in Tables 7.3 and 7.4 of the ROD, respectively.

[b] From Table 55 of DOE 2016; only ingestion pathways were considered because inhalation exposures were considered unlikely (refer to Note e below).

[c] Current (2021) toxicity values for radionuclides are the tap water ingestion coefficients from EPA's radionuclide PRG calculator: https://epa-prgs.ornl.gov/radionuclides/SlopesandDosesMasterTableFinal.pdf (last accessed July 2021).

[d] Current (2021) toxicity values for chemicals are from EPA's most recent (May 2021) RSL Summary Table https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables.

[e] Inhalation toxicity values are listed for chemical (cancer and noncancer endpoints) for purposes of completeness. However, as noted in the text, the inhalation pathway would likely be inconsequential for anticipated land use scenarios. For these reasons, these values were not listed in the 2016 FYR report.

[f] Previous oral reference doses for uranium have been based on IRIS; the 0.003 mg/kg-day value is still current today (https://www.epa.gov/iris). However, in deriving RSLs for oral and inhalation noncancer endpoints, EPA now uses toxicity values from ATSDR. Although more stringent, this reduction in the RfD is not likely to affect the protectiveness of the remedy given the controls that are in place preventing the use of shallow groundwater.

Abbreviations:

ATSDR = Agency for Toxic Substances and Disease Registry
D = daughters (short-lived decay products)
IRIS = EPA's Integrated Risk Information System
mg/m^3 = milligrams per cubic meter
mg/kg-day = milligrams per kilogram per day
$\mu g/m^3$ = micrograms per cubic meter
RfC_i = reference concentration (inhalation)
RfD_o = oral reference dose
SFO = oral cancer slope factor

The resulting HQ was 0.6, a value below EPA's target HQ (or hazard index) of 1.0. Exposures to small children (ages 0–6, 15 kg) were not considered given the terrain of the region.

As there is no slope factor for uranium for chemical endpoints, a dose conversion factor of 6×10^{-7}/mrem (refer to Table 46, Note d) was applied to the 0.048 mrem TED. This value was then multiplied by 10 (assumed exposure duration in years) to yield an estimated cancer risk of 2.9×10^{-7}. The aforementioned risk estimates are below the acceptable cancer risk range and noncancer hazard index established in the NCP.

5.2.2.3 Progress Toward RAOs

The RAO listed in the GWOU ROD is to restore contaminated groundwater in the shallow aquifer to its beneficial use by attaining the cleanup standards. The remedy is progressing as originally expected in the shallower weathered unit. However, persistent elevated uranium concentrations in the upper part of the unweathered unit near the former raffinate pits has shown limited progress. The initially increasing uranium concentrations have stabilized but have yet to begin decreasing. Until concentrations start declining, a cleanup time cannot be estimated.

Unweathered unit wells MW-3040 and MW-4040 were installed in May 2004, MW-3040 adjacent to MW-3024 due to suspect construction after raffinate pit remediation and MW-4040 to vertically delineate uranium impact. These wells were planned as objective 4 wells (monitor for vertical migration). The first sample results from the two new wells were not available until August 2004. The initial sample results from well MW-3040 were just below 100 pCi/L (objective 2 trigger level), and the initial results from well MW-4040 exceeded the prematurely set fixed trigger level. Subsequent sampling confirmed the elevated uranium concentrations in these unweathered unit wells were elevated and indicated an upward trend in wells MW-3024, MW-3040, and MW-4040. Due to the elevated concentrations, the wells were reclassified as objective 2. Uranium exceeded 100 pCi/L in all three unweathered unit wells within a few years (Figure 23). The objective 4 trigger level is 40 pCi/L.

A 2-year special study (February 2012–February 2014) was conducted in response to increasing uranium in the unweathered unit. At the time of the study, uranium levels in well MW-4040 appeared to have stabilized and the upward trend in MW-3024 and MW-3040 was slowing. The study recommended increasing the impacted area uranium fixed trigger to 500 pCi/L for the unweathered unit because it was set before sufficient data was available (Figure 23). The purpose of the fixed trigger is to address gradually increasing concentrations, so it should be set after sufficient data from all relevant wells have been acquired. To address the vertical extent of uranium (the original purpose of well MW-4040), MW 4042 was installed adjacent to MW-4040 and screened deeper in the unweathered unit. Well MW-4042 has had consistently low uranium concentrations. Uranium concentrations in the three impacted area wells are no longer trending upward. Well MW-4040 has been stable since 2008, and both MW-3024 and MW-3040 have been stable since 2013. This suggests that the uranium increase was a temporary remobilization of remnant uranium and not an expansion of the source area.

It has been concluded that the remediation objectives are still valid and that under the current exposure scenario the remedy remains short-term protective. ICs play a key role in maintaining protectiveness until final remedial objectives for groundwater can be met. Final remedy protectiveness cannot be assessed until groundwater remediation is completed.

As stated in the "Summary of the Rationale for the Selected Remedy" portion of the Chemical Plant ROD (DOE 2004a):

> Alternative 3, MNA with ICs to limit groundwater use, provides the best balance of tradeoffs among the alternatives when compared against the evaluation criteria. Alternative 3 would be more expensive than Alternative 2 [long-term monitoring with ICs], primarily because of the more rigorous monitoring requirements that would be applied, but the greater cost would be offset by greater long-term effectiveness.
>
> MNA is also considered appropriate on the basis of an examination of EPA policy and guidance. According to EPA's guidance for MNA (EPA 1999a…), "MNA is appropriate as a remedial approach where it can be demonstrated capable of achieving a site's remediation objectives within a timeframe that is reasonable compared to that offered by other methods and where it meets the applicable remedy selection criteria. EPA expects that MNA will be most appropriate when used in conjunction with other remediation measures (e.g., source control, groundwater extraction), or as a follow-up to active remediation measures that have already been implemented."
>
> Extensive field testing on active remediation technologies support the conclusion that pump-and-treat methods and in-situ treatment methods cannot be effectively deployed on a large scale and would not significantly reduce the timeframes needed to achieve the site's remediation objectives. In addition, the MNA remedy is selected as a follow-up to extensive source control remediation measures that have already been implemented. Therefore, there is no ongoing contamination of the groundwater from significant source areas. Residual contamination that has accumulated in subsurface cracks and fissures acts as a residual contaminant source to groundwater and surface water.
>
> The guidance presents an outline of factors that should be considered in determining whether MNA is appropriate for a particular site. The Weldon Spring groundwater condition compares favorably with all of these considerations as follows:
>
> - *Whether the contaminants present in soil or groundwater can be effectively remediated by natural attenuation processes*. — The soil medium was remediated through excavation and disposal as part of the Chemical Plant Operable Unit which resulted in the treatment and/or isolation of all source materials, including the principal threat wastes. Predictive modeling and long-term trend analysis support the conclusion that groundwater can be effectively remediated by natural attenuation processes.
> - *Whether or not the contaminant plume is stable and the potential for the environmental conditions that influence plume stability to change over time.* — Over 20 years of environmental monitoring indicate that the contaminant plumes are stable. In this case, the contaminant plumes will remain confined to the currently impacted groundwater system, in which the flow paths and discharge points are structurally controlled.

- *Whether human health, drinking water supplies, other groundwaters, surface waters, ecosystems, sediments, air, or other environmental resources could be adversely impacted as a consequence of selecting MNA as the remediation option.* — The endpoint for most of the contaminated groundwater is surface discharge to springs and seeps to the north. Contaminant concentrations in the springs and seeps are sufficiently low that they result in no adverse impacts to human health or ecosystems. No evidence of expansion to other uncontaminated groundwater systems has been observed, nor is it expected, given the hydrogeological constraints.
- *Current and projected demand for the affected resource over the time period that the remedy will remain in effect.* — There is no projected demand for the impacted resource. Residential use of the area is unlikely, and the impacted groundwater is shallow and low-yielding, making it an improbable choice as a drinking water source. Also, a municipal water supply is readily available.
- *Whether the contamination, either by itself or as an accumulation with, other nearby sources (on-site or off-site), will exert a long-term detrimental impact on available water supplies or other environmental resources.* — A municipal water supply is available for use. Contaminated groundwater at the Chemical Plant area and at the adjacent Army site is not expected to impact this municipal water supply. The ecological assessment indicates that contaminant concentrations in spring water and sediment pose little or no risk to ecological resources in the area.
- *Whether the estimated timeframe of remediation is reasonable compared to timeframes required for other more active methods (including the anticipated effectiveness of various remedial approaches on different portions of the contaminated soil and/or groundwater).* —Extensive field testing demonstrated that the available active restoration techniques could not be effectively deployed on a large stale. The hydrogeology is poorly suited for pump-and-treat or in-situ treatment methods. As a result, the use of active methods would not have a significant effect on the remediation timeframes estimated for MNA.
- *The nature and distribution of sources of contamination and whether these sources have been, or can be, adequately controlled.* — Sources of groundwater contamination have been removed via response actions implemented for the Chemical Plant Operable Unit and have been stabilized and permanently disposed of in the on-site disposal facility.
- *Whether the resulting transformation products present a greater risk, due to increased toxicity and/or mobility, than do the parent contaminants.* — Biodegradation of TCE and the nitroaromatics in the subsurface is expected to be a negligible component, so transformation to more mobile or toxic constituents is not anticipated to be a concern. Geochemical conditions do not exist in the aquifer to result in reduction of nitrate. Upon discharge to surface water, rapid and complete volatilization, photodegradation, and biodegradation of the TCE and nitroaromatics is expected. Biodegradation and uptake by plants, to a limited extent, are expected to decrease nitrate levels in surface water.

- *The impact of existing and proposed active, remediation measures upon the MNA component of the remedy, or the impact of remediation measures or other operations/activities (e.g., pumping wells) in close proximity to the site.* — Source control remediation under the Chemical Plant ROD involved significant disturbance of the subsurface and may have influenced contaminant concentrations in the groundwater. These influences could persist in the near term but are not expected to affect the long-term behavior of the attenuation processes.
- *Whether reliable site-specific mechanisms for implementing ICs (e.g., zoning ordinances) are available, and if an institution responsible for their monitoring and enforcement can be identified.* — The groundwater impacts are confined to federal and state land, and DOE has responsibility for implementation and enforcement of ICs. Therefore, ICs can be reliably used to limit groundwater use over the foreseeable future.

The information in the Groundwater ROD is presented in detail to fully document and display that MNA was the accepted remedy in accordance with the CERCLA process; it fully met each required consideration and continues to be protective today.

Ecological Risks

Numerous ecological studies have been conducted across the Weldon Spring site (DOE 1995a; ANL 2004). Specific to the GWOU, sediment and surface water at Burgermeister Spring exhibited some elevated concentrations, prompting toxicity testing with those media (DOE1997c). Toxicity was indicated for some samples on the basis of reduced survival of test organisms; however, no spatial relationship was observed between toxicity gradients and the spring. It was concluded that the toxicity could be due to some other source. Biotic surveys indicated no ill effects on invertebrate, fish, and amphibian communities, and it was suggested that the communities have adapted and are tolerant of any contamination in the area. Uptake modeling indicated no risks to terrestrial receptors. The ecological risk assessment conducted as part of the GWOU baseline risk assessment concluded that groundwater associated with the Chemical Plant does not pose an unacceptable risk to aquatic or terrestrial biota, particularly due to the small and intermittent nature of most of the springs.

Consistent with the last FYR, there have been no changes in exposure assumptions, toxicity, or risk assessment methodology that would call into question the protectiveness of the remedy from an ecological risk perspective. Concentrations in relevant media have been reduced through the remediation that has taken place. Although uranium concentrations remain elevated, observations at the site suggest this is not having an adverse impact on the ecological communities at the site.

5.2.3 Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

Answer C: No other information has come to light that could call into question the protectiveness of the remedy.

5.3 Quarry Remedies and Operable Units

The QBWOU acted as an interim remedial action and the QROU as the final remedial action for the Quarry. The following technical evaluation was used to derive protectiveness statements for both of the operable units.

5.3.1 Question A: Is the remedy functioning as intended by the decision documents?

Answer A: Yes, the remedy is functioning as intended by the decision documents.

5.3.1.1 Remedial Action Performance

Long-term monitoring at the Quarry is designed to (1) monitor uranium levels south of the Femme Osage Slough to ensure that they remain protective of human health and the environment and (2) monitor uranium and 2,4-DNT levels within the area of groundwater impact north of the slough until they attain target levels that have been identified as having a negligible impact on the groundwater south of the slough (DOE 2000a). Groundwater north of the Femme Osage Slough will be monitored until a target level of 300 pCi/L for uranium is attained. In addition, groundwater south of the slough will be monitored to ensure protection of human health and the environment.

Missouri River Alluvium

Monitoring results from the Missouri River alluvial groundwater indicate that the average uranium levels were under the statistical background value in the alluvium. The geochemical data continue to indicate that a strongly reducing environment is prevalent in the groundwater immediately south of the slough, as shown by high dissolved iron concentrations, low sulfate concentrations, and low ORP values. This environment is not favorable for the migration of uranium if it were to pass beyond the reduction zone north of the slough.

Area of Uranium and 2,4-DNT Impact

Uranium levels within the area of impact are decreasing in the bedrock wells along the Quarry rim and in some wells north of the Femme Osage Slough (though at a slowing rate over the past 5 years). These decreases are the result of bulk waste removal and restoration activities in the Quarry proper that reduced and possibly prevented infiltration of precipitation and storm water into the residually contaminated fracture system in the Quarry proper. The distribution of uranium in groundwater is still predominantly controlled by the precipitation of uranium along the oxidizing–reducing front north of the Femme Osage Slough. Uranium levels in some alluvial wells north of the slough were previously reported as increasing, but when viewed over the long term, they have been stable. Trends interpreted from short-term datasets are artifacts of their significant variability in uranium results (typically an order of magnitude). Uranium levels continue to remain low in monitoring wells screened in the reducing portion of the area north of the slough.

The attainment objective for uranium in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 300 pCi/L and that data from each well will also be trended to establish that uranium concentrations north of the slough are decreasing (DOE 2000b). The 90th percentile associated with data from the Line 1 and 2 wells was 1051 pCi/L for 2020, a significant decrease from 2015 when it was at 1470 pCi/L. This metric is strongly influenced by the uranium levels in the Line 2 alluvial wells. Increases in the uranium levels appear to be loosely correlated to wet years following dry periods, though for only a few wells. Uranium impact in this area still poses a potential impact to the groundwater quality in the Missouri River alluvium south of the Femme Osage Slough.

Only two discrete areas in the Quarry Area exhibit 2,4-DNT impact in groundwater, the exit from the Quarry and one Line 2 alluvial well. Nitroaromatic concentrations have been highly variable but are generally decreasing since the removal of the bulk wastes in the Quarry. The average 2020 concentrations in groundwater are below the cleanup standards and pose little potential impact on the groundwater in the Missouri River alluvium. The attainment objective for the long-term monitoring of 2,4-DNT in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 0.11 µg/L and that data from each well will also be trended to establish that 2,4-DNT concentrations north of the slough are decreasing (DOE 2000b). The 90th percentile associated with the data from the 2,4-DNT monitoring network was 0.024 µg/L in 2020, which is below the attainment objective. Nondetect values are assigned the detection limit value (typically about 0.020 µg/L) for calculations. Due to the decrease in nitroaromatic concentrations in six of the eight wells at the Quarry (almost all results have been nondetect for the past 5 years in these wells), a decrease in sampling frequency from semiannual or quarterly to annual is recommended.

A review of the geochemical data north of the slough indicates that although the area of highest uranium impact has an oxidizing environment (that’s what keeps the uranium in solution in the samples), reducing conditions are prevalent immediately downgradient along the northern edge of the slough, preventing uranium migration. This is consistent with the uranium data where low levels are detected, especially along the edge of the slough where very low sulfate and high dissolved iron concentrations are also observed. The location of this reduction area was consistent during the review period, and the attenuation of uranium in this area continues.

5.3.1.2 System Operation and Maintenance

The LTS&M Plan includes system operation and operation and maintenance information for LTS&M. DOE also performs annual inspections of LTS&M activities, environmental monitoring, and ICs and found these activities to be functioning as intended.

5.3.1.3 Opportunities for Optimization

There have been no additional opportunities for optimization identified during the past FYR period.

5.3.1.4 Early Indicators of Potential Issues

There are no early indicators of potential issues.

5.3.1.5 Implementation of ICs and Other Measures

The following are the use restrictions listed in the LTS&M Plan (DOE 2008a) for the QROU. The ICs in place and planned for the Weldon Spring Site are discussed in the CPOU section (Section 5.1.1.5). The ICs that specifically apply to the QROU are the Missouri Well Installation Special Area designation rulemaking and the easements with MDC and the MDNR Division of State Parks.

The use restrictions listed below must be met at the specific areas shown in Figure 111 and must be maintained until the remaining hazardous substances are at levels allowing for UU/UE.

1. Prevent the development and use of the Quarry for residential housing, schools, childcare facilities, and playgrounds. Prevent drilling, boring, digging, or other activities in the Quarry proper that disturb the vegetation, disrupt the grade, expose the Quarry walls, or cause erosion of the clean fill that was used to restore the Quarry. This restriction should be maintained for the long term. The 9-acre Quarry is under DOE jurisdictional control.
2. Prevent the use of the contaminated shallow groundwater for drinking water purposes. The contaminated shallow groundwater underlies the Quarry and extends to the marginal alluvium north of the slough, as indicated in Figure 111. This restriction will need to be maintained over a period of decades or longer.
3. Limit the use of all groundwater within the outlined restricted area shown in Figure 111 to investigative monitoring only. The boundary of the restricted area extends beyond the area of contamination and is intended to provide a buffer against potential hydraulic influences on the area of contamination by preventing such things as pumping wells being located near the contaminated area. This restriction includes the shallow groundwater system and also extends vertically to all groundwater systems that underlie the contaminated groundwater. This restriction will need to be maintained over a period of decades or longer, until uranium concentrations in Quarry groundwater north of the slough are at 300 pCi/L or lower. With the exception of the 9-acre Quarry, this restricted area is owned by state entities. This area covers approximately 202 acres.
4. Prevent drilling, boring, digging, construction, earth moving, or other activities in the location identified as the Quarry natural reduction zone area that could result in disturbing the soils at this location or exposing subsurface soils (i.e., soils deeper than about 5 ft below the surface). The soil in this area at a depth of 5 ft or greater contains geochemical properties that allow reduction processes to naturally occur, resulting in the precipitation of uranium from Quarry groundwater north of the Femme Osage Slough and thereby minimizing uranium migration to the well field. The restrictions must be maintained over a period of decades or longer, until uranium concentrations in Quarry groundwater north of the slough are 300 pCi/L or lower. This area is located on property owned by a state entity and is approximately 4.7 acres in size.
5. Retain access to the area for continued monitoring and maintenance of groundwater wells.
6. Maintain the integrity of any current or future remedies or monitoring systems.

5.3.2 Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection still valid?

Answer B: Yes, the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection are still valid.

5.3.2.1 Changes in Standards and TBCs

Section 1.5, "Current Regulatory Requirements," in the LTS&M Plan discusses the ARARs that apply to the postremediation aspect of the project, and it states the following:

> The 30 µg/L standard for uranium in groundwater outlined in 40 CFR 192.02 was considered as a potential ARAR for the quarry groundwater during development of the Feasibility Study (DOE 1998a) and Proposed Plan (DOE 1998b). The groundwater north of the slough is impacted; however, it is not considered to be a usable groundwater source. Conversely, the Missouri River alluvium south of the slough is currently not impacted and is presently being used as a potable water source. Because groundwater north of the slough is not a useable source, 40 CFR 192.02 is not considered an ARAR for that groundwater. However, 40 CFR 192.02 would likely be an ARAR for any remedial action considered for the useable groundwater source south of the slough in the unlikely event of contaminant migration from north of the slough. The Missouri Water Quality Standard for 2,4-DNT (0.11 µg/L) is also a chemical-specific ARAR for quarry groundwater.

There are no changes in standards or TBCs that affect the protectiveness of the remedy.

5.3.2.2 Exposure Pathways, Toxicity and Risk Assessments

Human Health

A review of assumptions incorporated into the risk assessments documented in the *Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998b) and the *Feasibility Study for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri* (1998d) was also performed. The review included the following risk assessment aspects: risk assessment methodology, exposure scenarios, exposure assessment input parameters, and toxicity values. The remediation and ICs have resulted in the severing of all exposure pathways.

A postremediation risk assessment was conducted for the QROU (ANL 2003) to estimate risks associated with residual contamination at the site and compare it to pre-remediation risks estimated in the baseline risk assessment. Risks were calculated for exposures at Femme Osage Slough, the Quarry proper, and soils outside the Quarry for both a recreational visitor and a resident using assumptions from the original baseline risk assessment (DOE 1997b). Toxicity data were not provided in the postremediation risk assessment, but it is assumed that data were the same as those used in the CPOU postremediation risk assessment (DOE 2002b) and that data and calculations remain valid (refer to discussion in Section 5.1. 2 and the toxicity value comparison summaries provided in Table 44 and Table 45). The calculations indicated that risks to recreational visitors and residents are acceptable (resident risks were comparable to background; recreational visitor risks were lower). Risks were dominated by external exposure to radium-226 and radium-228.

As discussed for the CPOU, current EPA guidance recommends the use of PRG calculator toxicity values in evaluating radiological risks. Assuming that the QROU postremediation risk assessment used the same toxicity values as the CPOU postremediation risk assessment, the slope factors for external exposure to radium-226 and radium-228 currently in EPA's PRG calculator are slightly lower, therefore slightly lowering corresponding risks. No other changes to the risk assessment methodology recommended by EPA for CERCLA sites have occurred since the publication of the QROU documentation that would significantly affect the conclusions of the postremediation risk assessment. Exposure scenarios and exposure assessment input parameters are also still valid, as they remain representative of current and expected future land use (i.e., a recreational visitor scenario). In addition, as for the GWOU, ICs are also being implemented to ensure that current land uses remain unchanged.

In 2019, EPA conducted a reevaluation of potential human health risks at the slough. The report *Final Human Health Risk Assessment Re-Evaluation Femme Osage Slough, Quarry Residuals Operable Unit Weldon Spring Quarry/Plant/Pits Site*, March 2019 (EPA 2019a), was transmitted to DOE with a letter that summarized the results. The letter stated:

The purpose of this risk assessment re-evaluation was to update estimates of potential health risks posed by the Slough using the EPA's current Superfund risk assessment methodology and guidance, including updated toxicity values and exposure factors. In this re-evaluation, the EPA found no unacceptable human health risks at the Slough.

40 CFR 300.430(e)(2)(i)(A)(l) of the National Oil and Hazardous Substances Pollution Contingency Plan, "for systemic toxicants [noncancer risk], acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety." A hazard index greater than one [1] represents the threshold for unacceptable noncancer risk. Per 40 CFR 300.430(e)(2)(i)(A) "for known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}." Per the April 1991 EPA guidance titled Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (OSWER Directive 9355.0-30), "[w]here the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10 ($^{-4}$) and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted." In this re-evaluation, the estimates of total excess lifetime cancer risks posed by exposure to all media at the Slough fall within the EPA's acceptable cancer risk range, and the total noncancer hazard indices are less than 1, for both adolescent and adult recreational visitors.

In summary, this re-evaluation, conducted according to current risk assessment methodology, found no unacceptable risks of cancer or noncancer health effects to adult or adolescent recreational visitors at the Slough.

Ecological Risk

The baseline risk assessment for the Quarry Residuals OU (DOE 1997b) included an ecological risk assessment of the quarry proper, Femme Osage Slough, Femme Osage Creek, and Little Femme Osage Creek. Media concentrations were screened against benchmark values that included federal ambient water quality criteria, state water quality standards, federal (EPA and U.S. Fish and Wildlife Service) ecotoxicity threshold values, and other relevant values. Complete exposure pathways were identified for representative ecological receptors, and conservative exposure scenarios were modeled to estimate contaminant doses to receptors. These results were then used to determine whether site conditions posed a potentially unacceptable ecological risk. Quantitative and qualitative biological surveys were conducted at the site and reference locations to evaluate whether past conditions at the quarry (associated with both the quarry residuals and bulk wastes) may have adversely affected local ecological resources.

Although the baseline (preremediation) risk assessment indicated that some contaminants were present at levels above “safe” values for ecological receptors (DOE 1997b), no such adverse effects were actually observed in the fauna sampled. Furthermore, most of the QROU was determined to not provide good habitat for ecological receptors based on its physical characteristics. The exceptions are Femme Osage Slough and Little Femme Osage Creek.

Radionuclides in tissues of small mammals collected from the Quarry were comparable to those from the reference areas. Internal and external examinations of small mammals did not show any sign of abnormalities that could be attributed to site contamination. Fish sampling was conducted every 2 years in Femme Osage Slough and area lakes for a number of years in the 1990s and did not detect any abnormal results. Sampling was discontinued in the late 1990s. The baseline risk assessment concluded that the levels of contamination in surface water and sediments in Femme Osage Slough and Little Femme Osage Creek do not appear to have impacted ecological resources and would not pose a future risk to biota at the site (DOE 1997b). These findings were confirmed in Argonne National Lab’s subsequent analysis of collective results of the ecological and related environmental assessments performed for the Weldon Spring Site (ANL 2004).

Remediation has addressed most of the potential ecological risks associated with the QROU. There have been no changes in exposure assumptions, toxicity, or risk assessment methodology that would call into question the protectiveness of the remedy from an ecological risk perspective. Concentrations in relevant media, a critical element of the exposure assumptions, have been reduced through the remediation that has taken place.

5.3.2.3 Progress Toward RAOs

Section 5.3.1.1 documents the current status of progress toward RAOs.

5.3.3 Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

Answer C: No other information has come to light that could call into question the protectiveness of the remedy.

6.0 Issues/Recommendations

The below table summarizes remedy protectiveness issues identified during this FYR and provides recommendations for their resolution.

Issues/Recommendations				
OU(s) without Issues/Recommendations Identified in the Five-Year Review:				
Chemical Plant, Quarry Bulk Waste, and Quarry Residuals				
Issues and Recommendations Identified in the Five-Year Review:				
OU (s): Groundwater, Sitewide	**Issue Category: Monitoring**			
	Issue: The current monitoring well network may not be adequate to meet the MNA remedy objectives.			
	Recommendation: LM will initiate a working group in collaboration with the DOE National Lab Network to evaluate the need and location(s) for additional monitoring wells to further delineate the uranium plume in the unweathered unit. The recommendations identified in the July 2020 EPA Office of Research and Development Memorandum will be evaluated during this working group. The results of this evaluation will be presented as a written summary and an implementation strategy will be discussed with EPA.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	**Yes**	**Federal Facility**	**EPA**	**9/31/2022**
OU (s): Groundwater	**Issue Category: Remedy Performance**			
	Issue: The remedy is not projected to return groundwater to its beneficial use within a reasonable timeframe.			
	Recommendation LM will evaluate alternative solutions for removing residual uranium sources and restoring groundwater. If this evaluation finds no viable alternative remedies, and after Issue 1 has been resolved, evaluate justification for a Technical Impracticability waiver. The results of this evaluation will be presented as a written summary.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	**Yes**	**Federal Facility**	**EPA**	**09/30/2026**

6.1 Other Findings and Recommendations

The following are recommendations from the FYR:

Barium no longer meets the criteria as a BTL signature parameter. Barium concentrations in leachate have decreased to levels similar to those in the disposal cell monitoring wells (Section 4.2.3.1). It is recommended that barium be discontinued as a signature parameter.

Concentrations in six of the eight Quarry wells sampled for nitroaromatics have been nondetect for the last 5 years. It is recommended that the sampling frequency in these six wells be reduced to annual beginning in 2022 and reviewed for discontinued nitroaromatic sampling during the 2026 FYR. A semiannual sampling frequency is recommended for the two wells (MW-1027 and MW-1006) that have had nitroaromatic detects during the last 5 years.

7.0 Protectiveness Statements

Protectiveness Statement(s)		
Operable Unit: Chemical Plant	*Protectiveness Determination:* Protective	*Planned Addendum Completion Date:* NA
Protectiveness Statement: The remedy that has been implemented at the CPOU is protective of human health and the environment. Contaminant sources are contained in an onsite disposal facility at the Chemical Plant. The environmental monitoring data and annual inspections continue to verify that the disposal cell is functioning as intended.		

Protectiveness Statement(s)		
Operable Unit: Groundwater	*Protectiveness Determination:* Short-term Protective	*Planned Addendum Completion Date:* NA
Protectiveness Statement: The GWOU remedy currently protects human health and the environment because exposure pathways that could result in unacceptable risks are being controlled, and ICs are in place and are effective. However, for the GWOU remedy to be protective in the long-term, an evaluation of the unweathered unit must be performed to determine the need for additional monitoring wells and to assess alternative remedies in order to return groundwater to its beneficial use within a reasonable timeframe.		

Protectiveness Statement(s)		
Operable Unit: Quarry Bulk Waste	*Protectiveness Determination:* Protective	*Planned Addendum Completion Date:* NA
Protectiveness Statement: The remedy for the QBWOU is protective of human health and the environment. The action consisted of excavating the bulk wastes from the Quarry and placing them in controlled temporary storage pending final placement in the onsite disposal cell at the Chemical Plant. Excavating the wastes from the Quarry eliminated the potential for direct contact with the waste material and removed the source of ongoing contaminant migration to groundwater.		

Protectiveness Statement(s)		
Operable Unit: Quarry Residuals	*Protectiveness Determination:* Protective	*Planned Addendum Completion Date:* NA
Protectiveness Statement: The remedy for the QROU is protective of human health and the environment through long-term monitoring with ICs. The remedy consists of long-term groundwater monitoring and ICs to maintain appropriate land and resource use and ensure that the remedy remains protective over the long term.		

Sitewide Protectiveness Statement	
Protectiveness Determination: Short-term Protective	*Planned Addendum Completion Date:* NA
Protectiveness Statement: The Weldon Spring Chemical Plant, Quarry Bulk Waste, and Quarry Residuals remedies are protective of human health and the environment. The GWOU remedy currently protects human health and the environment because exposure pathways that could result in unacceptable risks are being controlled, and ICs are in place and are effective. However, for the GWOU remedy to be protective in the long-term, an evaluation of the unweathered unit must be performed to determine the need for additional monitoring wells and to assess alternative remedies in order to return groundwater to its beneficial use within a reasonable timeframe.	

8.0 Next Review

This is the sixth statutory FYR for this site. The next FYR for the Weldon Spring Quarry/Plant/Pits site is due September 30, 2026

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9.0 References

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Appendix A

2016 Five-Year Review Issue Correspondence

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
11201 Renner Boulevard
Lenexa, Kansas 66219

NOV 2 3 2016

RECEIVED
NOV 3 0 2016
BY:

Ken Starr
US Department of Energy
Office of Legacy Management
11025 Dover Street, Suite 1000
Westminster, Colorado 80021

RE: Weldon Spring Site - Fifth Five-Year Review/Additional Work or Modification to Work

Dear Mr. Starr:

The U.S. Environmental Protection Agency has reviewed the Fifth Five-Year Review Report dated September 2016. The report was submitted by the Department of Energy (DOE) for the Weldon Spring Site (Site) in Weldon Spring, Missouri. The review of the report was in accordance with the 2006 Federal Facilities Agreement (FFA) for the Site between the EPA, the Missouri Department of Natural Resources (MDNR) and DOE.

Fifth Five-Year Review

The EPA generally concurs that the remedy is protective in the short term, but an issue remains with the monitored natural attenuation (MNA) remedy at the Groundwater Operable Unit (GWOU) that affects long-term protectiveness. Consequently, the agency issued an independent protectiveness statement for the GWOU and the overall Site. The agency's protectiveness statements are detailed in a memorandum to file. A copy of the memorandum is enclosed with this letter.

The issue that affects the long-term protectiveness for the GWOU and overall site remedy is provided as follows:

Issues and Recommendations Identified in the Five-Year Review:				
OU(s): GWOU	**Issue Category: Monitoring**			
	Issue: The MNA remedy for the GWOU is not meeting the objectives as specified in the 2004 Remedial Design/Remedial Action Work Plan for the GWOU and the 2008 Long-term Surveillance and Maintenance Plan for the site.			
	Recommendation: Additional sampling locations should be added to the sampling and monitoring program to meet the objectives of the MNA remedy. Additional monitoring and characterization of the uranium impact in the unweathered unit are required to meet the objectives of the MNA remedy.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Party Responsible**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	9/30/2019

Additional Work or Modification to Work

On August 4, 2016, EPA, MDNR and DOE met at the Site to discuss issues with the MNA remedy. During the meeting, DOE informally proposed changes to the MNA sampling plan within the Long-Term Surveillance and Monitoring Plan (the "proposed changes").

After consultation with MDNR, and in accordance with *Section XII. Additional Work or Modification to Work* of the FFA, the Agency has determined that Additional Work or Modification to Work, as outlined in the informal proposed changes, is necessary to meet the objectives of the FFA.

The Agency is sending this letter to serve as written notice to DOE, subject to the dispute resolution procedures in the FFA, that DOE indicate no later than 30 days from receipt of this letter its commitment to implementing the proposed changes, and within 30 days after such commitment to formally submit the proposed changes to EPA and MDNR for regulatory review and approval.

The Agency looks forward to resolving this remaining issue. If you have any questions, you can contact me at (913) 551-7330 or tran.hoai@epa.gov.

Sincerely,

Hoai Tran
Remedial Project Manager
Federal Facilities and Post Construction Section
Superfund Division

Enclosure

cc: Patrick Anderson, Missouri Department of Natural Resources

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
11201 Renner Boulevard
Lenexa, Kansas 66219
SEP 30 2016

RECEIVED
NOV 30 2016
BY:

MEMORANDUM:

SUBJECT: Fifth Five-Year Review
Weldon Spring Quarry/Plan/Pits
Weldon Spring, Missouri

FROM: Hoai Tran, Remedial Project Manager
Federal Facility & Post Construction Section

THRU: Lynn M. Juett, Branch Chief
Site Remediation Branch

TO: Mary P. Peterson, Director
Superfund Division

Attached for your approval is the Fifth Five-Year Review Report dated September 2016 that was submitted by the Department of Energy for the Weldon Spring Quarry/Plant/Pits site in Weldon Spring, St. Charles County, Missouri. The site consists of four operable units (OUs): the Chemical Plant Operable Unit (CPOU), the Quarry Bulk Waste Operable Unit (QBWOU), the Quarry Residual Operable Unit (QROU) and the Groundwater Operable Unit (GWOU).

The Department of Energy provides the following protectiveness statements in the report:

Chemical Plant Operable Unit
The remedy that has been implemented at the CPOU is protective of human health and the environment. Contaminant sources are contained in an onsite disposal facility at the chemical plant. The environmental monitoring data and annual inspections continue to verify that the disposal cell is functioning as intended. The remedy that has been implemented at the southeast drainage is protective of human health and the environment. The remedy consisted of removing contaminated soils and sediment to levels that are protective under the current land use. The drainage has recovered from the removal activities and is stable. Institutional controls are used to maintain appropriate land and resource use, and ensure that the remedy remains protective over the long term.

Quarry Bulk Waste Operable Unit
The remedy for the QBWOU is protective of human health and the environment. The action consisted of excavating the bulk wastes from the quarry, and placing them in controlled temporary storage pending final placement in the on-site disposal cell at the chemical plant. Excavating the wastes from the quarry eliminated the potential for direct contact with the waste material, and removed the source of ongoing contaminant migration to groundwater.

Quarry Residual Operable Unit
The remedy for the QROU is protective of human health and the environment through long-term monitoring with institutional controls. The remedy consists of long-term groundwater monitoring and institutional controls to maintain appropriate land and resource use, and ensure that the remedy remains protective over the long-term.

Groundwater Operable Unit
The remedy for the GWOU will be protective of human health and the environment upon attainment of groundwater cleanup goals, through monitored natural attenuation (MNA), which is expected to require approximately 100 years to achieve. The clean-up time for Burgermeister Spring is predicted to be much shorter than the 100 year time frame. In the interim, exposure pathways that could result in unacceptable risks are being controlled, and institutional controls are in place to prevent the groundwater from being used in the restricted area.

Site-Wide
This five-year review found the remedy for the entire site to be protective of human health and the environment for all OUs.

The EPA provides the following independent protectiveness statements:

The EPA concurs with the protectiveness statements for three of the four OUs. The remedies at the CPOU, the QBWOU, and the QROU are protective of human health and environment, and no issues were found during the five-year review.

Groundwater Operable Unit
For the GWOU, the EPA concurs that the remedy is currently protective of human health and environment, but the agency identified an issue that may potentially affect the long-term protectiveness. The issue, along with the recommendations to address it, is given in the following table:

Issues and Recommendations Identified in the Five-Year Review:				
OU(s): GWOU	**Issue Category: Monitoring**			
	Issue: The MNA remedy for the GWOU is not meeting the objectives, as specified in the 2004 Remedial Design/Remedial Action Work Plan for the GWOU, and the 2008 Long-term Surveillance and Maintenance Plan for the site.			
	Recommendation: Additional sampling locations should be added to the sampling and monitoring program to meet the objectives of the MNA remedy. Additional monitoring and characterization of the uranium impact in the unweathered unit are required to meet the objectives of the MNA remedy.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Party Responsible**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	9/30/2019

The remedy for the GWOU is currently protective of human health and the environment because exposure pathways that could result in unacceptable risks are being controlled, and institutional controls are in place to prevent the groundwater from being used in the restricted area. However, in order for the remedy to be protective in the long-term, additional sampling locations and characterization are needed to demonstrate that the objectives of the MNA remedy can be met.

Site-Wide
The change in the protectiveness statement for the GWOU results in a change for the entire site. Therefore, the agency is issuing the following independent protectiveness statement for the entire site:

This five-year review found the remedy for the entire site to be currently protective of human health and the environment. However, in order for the remedy to be protective in the long-term, issues will need to be addressed at the GWOU.

The next FYR is due on September 30, 2021.

Approval:

Mary P. Peterson
Mary P. Peterson, Director
Superfund Division

9/30/2016
Date

Attachment

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Department of Energy
Washington, DC 20585

January 30, 2017

Mr. Hoai Tran
Remedial Project Manager
Superfund Division
U.S. Environmental Protection Agency – Region 7
11201 Renner Blvd.
Lenexa, KS 66219

Subject: Formal Submittal in Response to Correspondence from the U.S. Environmental Protection Agency "Response to Weldon Spring Site Fifth Five-Year Review/Additional Work or Modification to Work"

Dear Mr. Tran:

As requested by the U.S Environmental Protection Agency (EPA) in the letter dated November 30, 2016, the U.S. Department of Energy (DOE) is formally submitting the proposed changes to the monitored natural attenuation (MNA) monitoring network as discussed in the August 4 and December 7 meetings with EPA and the Missouri Department of Natural Resources. DOE informed the agencies in the August 4 meeting that additional unweathered wells had been sampled to support the MNA remedy. The EPA is requesting that these additional sampling locations be added formally to the sampling and monitoring program to meet the objectives of the MNA remedy. The revised MNA network is detailed in the attached table and figure with the additional sampling locations noted. Once the proposed changes are approved, DOE will modify the Long-Term Surveillance and Maintenance Plan to reflect the changes.

If you have any questions, contact me at (303) 410-4801 or ken.starr@lm.doe.gov or Yvonne Deyo at (636) 300-2612 or yvonne.deyo@lm.doe.gov. Please send any correspondence to:

U.S. Department of Energy
Office of Legacy Management
11025 Dover Street, Suite 1000
Westminster, CO 80021-5573

Sincerely,

Kenneth Starr

Kenneth I. Starr, PE
DOE Weldon Spring
Site Manager

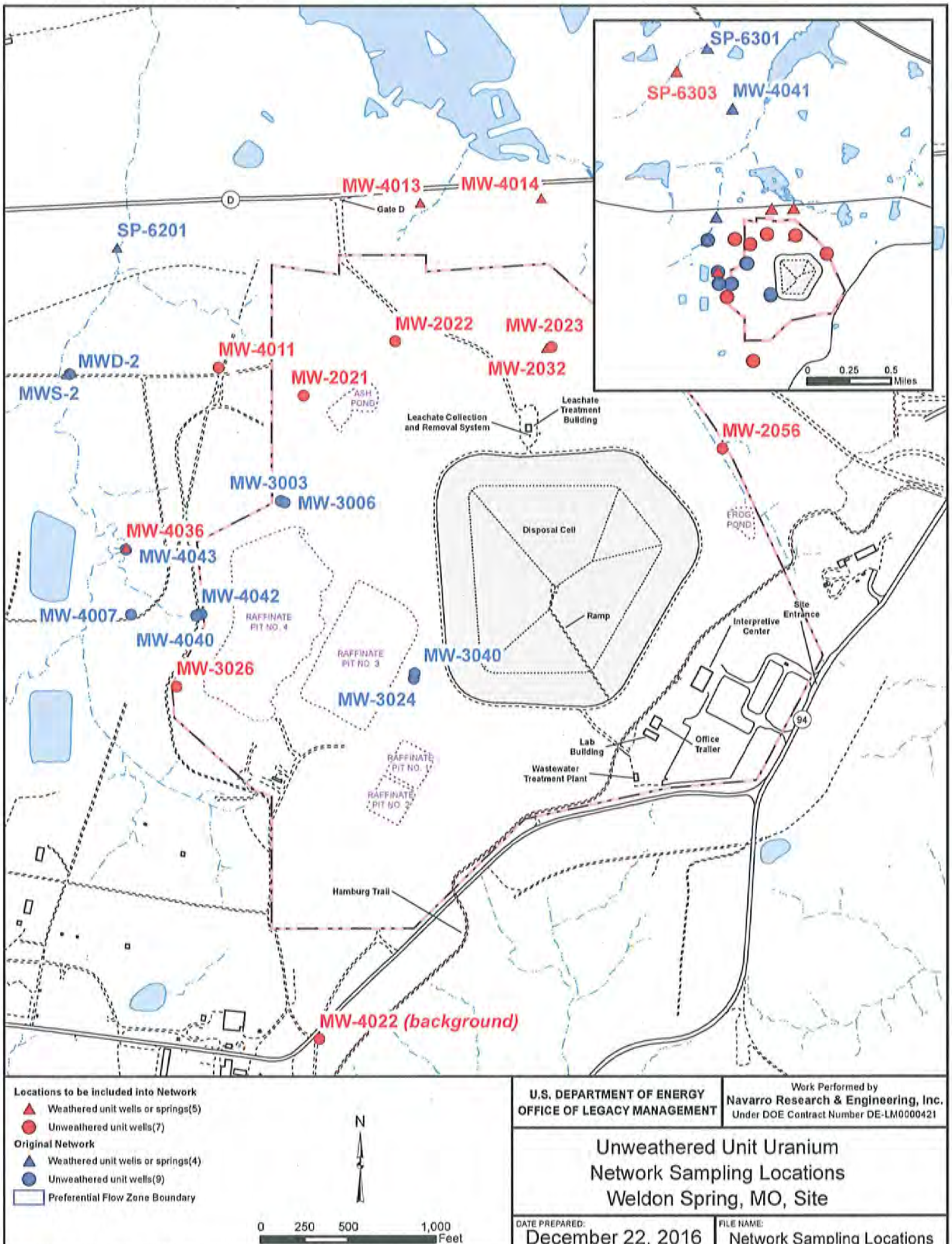
Enclosure

cc:
G. Hooten, DOE
S. Lipstein, DOE
R. Hodges, Navarro
Y. Deyo, Navarro
T. Uhlmeyer, Navarro
File: WEL 0510.20

Unweathered Unit Monitoring Network

Location	Objective	Unit	Yearly Frequency
MW-4040	2	Unweathered	4
MW-3026[a]	2	Unweathered	4
MW-3040	2	Unweathered	4
MW-3024	2	Unweathered	4
MW-3003	2	Weathered	4
MW-3006	2	Unweathered	4
MW-4042	4	Unweathered	4
MW-4043	3	Unweathered	4
MW-4036[a]	3	Weathered	4
MWS-2	3	Weathered	4
MWD-2	3	Unweathered	4
MW-4007	3	Unweathered	4
MW-4011[a]	3	Unweathered	2
MW-4041	3	Weathered	4
MW-2021[a]	3	Unweathered	2
MW-2022[a]	3	Unweathered	2
MW-2023[a]	3	Unweathered	2
MW-2032[a]	3	Weathered	2
MW-2056[a]	3	Unweathered	2
MW-4022[a]	1	Unweathered	1
MW-4013[a]	3	Weathered	2
MW-4014[a]	3	Weathered	2
SP-6201	5	Spring	4
SP-6301	5	Spring	4
SP-6303[a]	5	Spring	4

[a] Added to the network



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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
11201 Renner Boulevard
Lenexa, Kansas 66219

APR 0 5 2017

RECEIVED
APR 18 2017
BY:

Mr. Ken Starr
U.S. Department of Energy
Office of Legacy Management
11025 Dover Street, Suite 1000
Westminster, Colorado 80021

Re: Weldon Spring Site
Response Comments to Department of Energy (DOE) Letter dated January 30, 2017

Dear Mr. Starr,

The U.S. Environmental Protection Agency has reviewed the letter from the DOE Office of Legacy Management dated January 30, 2017, regarding the Weldon Spring Site (site) in Weldon Spring, Missouri. The EPA's review was in accordance with the Federal Facilities Agreement (FFA) between the EPA, the DOE and the Missouri Department of Natural Resources for the site dated March 2006. The subject of the letter was a Formal Submittal in Response to Correspondence from the U.S. Environmental Protection Agency "Response to Weldon Spring Site Fifth Five-Year Review/Additional Work or Modification to Work." In the letter, the DOE proposed changes to the monitored natural attenuation (MNA) monitoring network at the site.

The agency is sending this letter to provide comments to the proposed changes for the MNA monitoring network. The agency agrees that additional sampling points are needed to meet the objectives of the MNA remedy and appreciates the DOE's willingness to expand the existing sampling program. The enclosed comments generally address areas where the proposed expanded well network does not meet the MNA remedy objectives, as specified in the Long-Term Surveillance and Maintenance Plan (LTS&M Plan) for the site dated December 2008. These areas should be sampled to monitor and to evaluate the performance of the MNA remedy.

As stated in the FFA, the DOE shall respond to the agency's enclosed comments within 60 days of receipt of this letter. If you have any questions, you can contact me via phone at (913) 551-7330 or via e-mail at tran.hoai@epa.gov.

Sincerely,

Hoai Tran
Remedial Project Manager
Federal Facilities and Post Construction Section
Site Remediation Branch
Superfund Division

Comments to the Department of Energy (DOE) Letter
Weldon Spring Site, Weldon Spring, Missouir
January 30, 2017

1. There are no upgradient wells to monitor un-impacted water quality in the unweathered zone. Groundwater samples should be collected from the unweathered zone near MW-2055 to evaluate baseline conditions (Objective 1).

2. The lateral extent of the contaminant plume cannot be verified in the unweathered zone between MW-3024/3040 and MW-4040. Groundwater samples should be collected to verify that the contaminant concentrations are declining (Objective 2) in the unweathered zone near MW-3031 or MW-3030.

3. The lateral extent of the contaminant plume in the unweathered zone is not delineated near MW-2038 or MW-3039. Groundwater samples should be collected at similar elevations in the unweathered zone near either MW-2038 or MW-3039 and north of Raffinate Pit #3 to ensure that lateral migration remains confined to the know areas of impact (Objective 3).

4. The lateral extent of the contaminant plume within the preferential flow path has not been delineated. Groundwater samples should be collected within the preferential flow path from the areas downgradient of MW-4036 or MW-4043 to ensure that lateral migration within the preferential flow path remains confined the known areas of impacts (Objective 3).

5. The levels of uranium near MW-3024 or MW-3040 exceed trigger levels. This indicates that the vertical extent of the contaminant plume has not been delineated in this area. Groundwater samples should be collected near MW-3024 or MW-3040 to ensure there is no significant vertical migration of contaminants (Objective 4).

Department of Energy

Washington, DC 20585

July 12, 2017

Mr. Hoai Tran
Remedial Project Manager
Superfund Division
U.S. Environmental Protection Agency – Region 7
11201 Renner Blvd.
Lenexa, Kansas 66219

Subject: Response to U.S. Environmental Protection Agency letter, dated April 5, 2017, Weldon Spring Site – Fifth Five-Year Review/Additional Work or Modification to Work

Dear Mr. Tran:

The U.S. Department of Energy (DOE) is responding to correspondence from the U.S. Environmental Protection Agency (EPA) that was dated April 5, 2017, and received April 18, 2017, concerning the Weldon Spring, Missouri, Site. This April 5 EPA letter was in response to the DOE's response (dated January 30, 2017) to EPA's letter with the subject *Weldon Spring Site – Fifth Five-Year Review/Additional Work or Modification to Work,* dated November 23, 2016. In that November 2016 letter, EPA stated:

> On August 4, 2016, EPA, MDNR [Missouri Department of Natural Resources] and DOE met at the Site to discuss issues with the monitored natural attenuation (MNA) remedy. During the meeting, DOE informally proposed changes to the MNA sampling plan within the Long-Term Surveillance and Monitoring Plan (the "proposed changes").
>
> After consultation with MDNR, and in accordance with Section VII. Additional Work or Modification to Work of the FFA [Federal Facility Agreement], the Agency has determined that Additional Work or Modification to Work, as outlined in the informal proposed changes, is necessary to meet the objectives of the FFA.
>
> The Agency is sending this letter to serve as written notice to DOE, subject to the dispute resolution procedures in the FFA, that DOE indicate no later than 30 days from receipt of this letter its commitment to implementing the proposed changes, and within 30 days after such commitment to formally submit the proposed changes to EPA and MDNR for regulatory review and approval.

DOE submitted the proposed changes that were requested by EPA and that were discussed in the August 4, 2016, meeting. Our understanding was EPA was requesting these changes to move this issue forward.

In the April 5 letter, EPA approved the scope of work associated with DOE's January letter; however, EPA added five additional monitoring wells based upon the assertion that the unweathered bedrock needs to be further characterized in order to address the long-term protectiveness of the remedy. DOE disagrees with this assertion, and provides the following response.

General Response:

The MNA remedy for the Groundwater Operable Unit (GWOU) at the Weldon Spring site was selected through a long and detailed Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process with both regulatory agencies heavily involved. The MNA remedy was approved for the GWOU in the January 2004 Record of Decision (ROD). DOE agrees with EPA's concurrence that the Groundwater Operable Unit (GWOU) is currently protective of human health and the environment, but adamantly disagrees with the EPA statement regarding the long-term protectiveness of the current remedy including controls. Current data from existing downgradient wells indicate that uranium has not migrated far from source areas in the unweathered unit. The low concentrations in the downgradient wells and the continuing long-term decline in uranium concentrations at Burgermeister Spring prove the successful implementation of the current MNA remedy and its long term protectiveness for the site.

Downgradient wells MW-4011, MW-2021, and MW 2022 (Ash Pond and Frog Pond monitoring wells) are screened in the unweathered unit and have provided confirmation that uranium has not migrated to the northern part of the former Chemical Plant. Well MW-3026 is about the same distance west of former Raffinate Pit No. 4 as high-concentration well MW-4040 and provides an additional unweathered unit monitoring location in the impacted area. The enhanced monitoring network for the unweathered unit supports the MNA remedy overall and the continued protectiveness of human health and the environment. All unweathered-unit wells are now part of the unweathered-unit uranium monitoring network.

The issue of exceeding the trigger level for uranium in higher-impact areas has been known since 6 months after the ROD was signed. The issue was well documented in the March 2005 *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site* (DOE/GJ/79491-952), which stated:

> Based on the new data, new wells MW-3040 and MW-4040 could be reassigned to more appropriate objectives than those for which they were originally installed. Both could be categorized as Objective 2 wells that monitor the areas of higher impact, but are within the unweathered zone. The Objective 2 trigger for uranium

is presently set at 100 pCi/L [picocuries per liter]. This trigger would be re-evaluated and a more appropriate trigger level would be established after the 2-year baseline monitoring period.

Several special studies and discussions have occurred since 2005, which provided additional data in order to evaluate the trigger levels and monitoring locations as stated in the March 2005 Remedial Action Report.

Two of those wells (MW-3040 and MW-4040) were installed the month before the trigger levels were set, with the results from the first sampling event available just after the triggers were set in the July 2004 Remedial Design/Remedial Action Work Plan. The issue was further discussed and addressed in the 2011 *Weldon Spring Site Fourth Five-Year Review* (LMS/WEL/S07406), and the protectiveness of the long-term remedy was not questioned.

The protectiveness of the remedy is further supported by the fact that the EPA issued the Superfund Sitewide Ready for Anticipated Use (SWRAU) designation in a letter dated March 20, 2013, which stipulated that for the entire construction complete National Priority List (NPL) site:

- All cleanup goals in the RODS or other remedy decision documents have been achieved for media that may affect current and reasonably anticipated future land uses of the site, so that there are no unacceptable risks; and

- All institutional or other controls required in the Records of Decision or other remedy decision document(s) have been put in place.

For more than 10 years, DOE has actively cooperated with both EPA and MDNR, including installing additional wells, conducting several special groundwater studies, preparing several reports, and coordinating and discussing the issue with EPA and MDNR. In a June 15, 2015, letter from DOE to EPA and MDNR, DOE requested a meeting with the management from the EPA and MDNR at a Division Director or above level so that resolution of the issues could be attained.

EPA's response to this request, dated February 10, 2016, requested a meeting at the technical level and stated that EPA believed that "this meeting can be the catalyst to move the project forward." DOE coordinated a meeting for August 4, 2016, with EPA and MDNR, in anticipation of a technical, data-driven discussion of these issues. Unfortunately, the technical aspects of the DOE's presentation were not addressed by EPA and MDNR at that August 2016 meeting; instead, discussion focused primarily on EPA's suggestion that the DOE apply for a Technical Impracticability waiver.

SPECIFIC RESPONSES TO EPA's REQUESTS:

EPA Comment 1: There are no upgradient wells to monitor unimpacted water quality in the unweathered zone. Groundwater samples should be collected from the unweathered zone near MW-2055 to evaluate baseline conditions (Objective 1).

DOE Response 1: This location is almost 1000 feet (ft) east of the raffinate pits and side gradient (Figure 1). Well MW-4022 (1000 to 1500 ft south of the raffinate pits) is already the designated unweathered unit background well.

EPA Comment 2: The lateral extent of the contaminant plume cannot be verified in the unweathered zone between MW-3024/3040 and MW-4040. Groundwater samples should be collected to verify that the contaminant concentrations are declining (Objective 2) in the unweathered zone near MW-3031 or MW-3030.

DOE Response 2: This area is within the footprint of Raffinate Pit No. 3 and Raffinate Pit No. 4. While the unweathered unit concentrations in this area are elevated, the current data indicates that the current wells located adjacent to the pits are beginning to stabilize (MW-4040 to the west and MW-3024/3040 to the east). In addition, the risk of drilling through areas of known impact could provide a pathway for deeper migration of the contamination into less permeable material, which could slow attenuation in the impacted area and actually create a new condition that does not exist today.

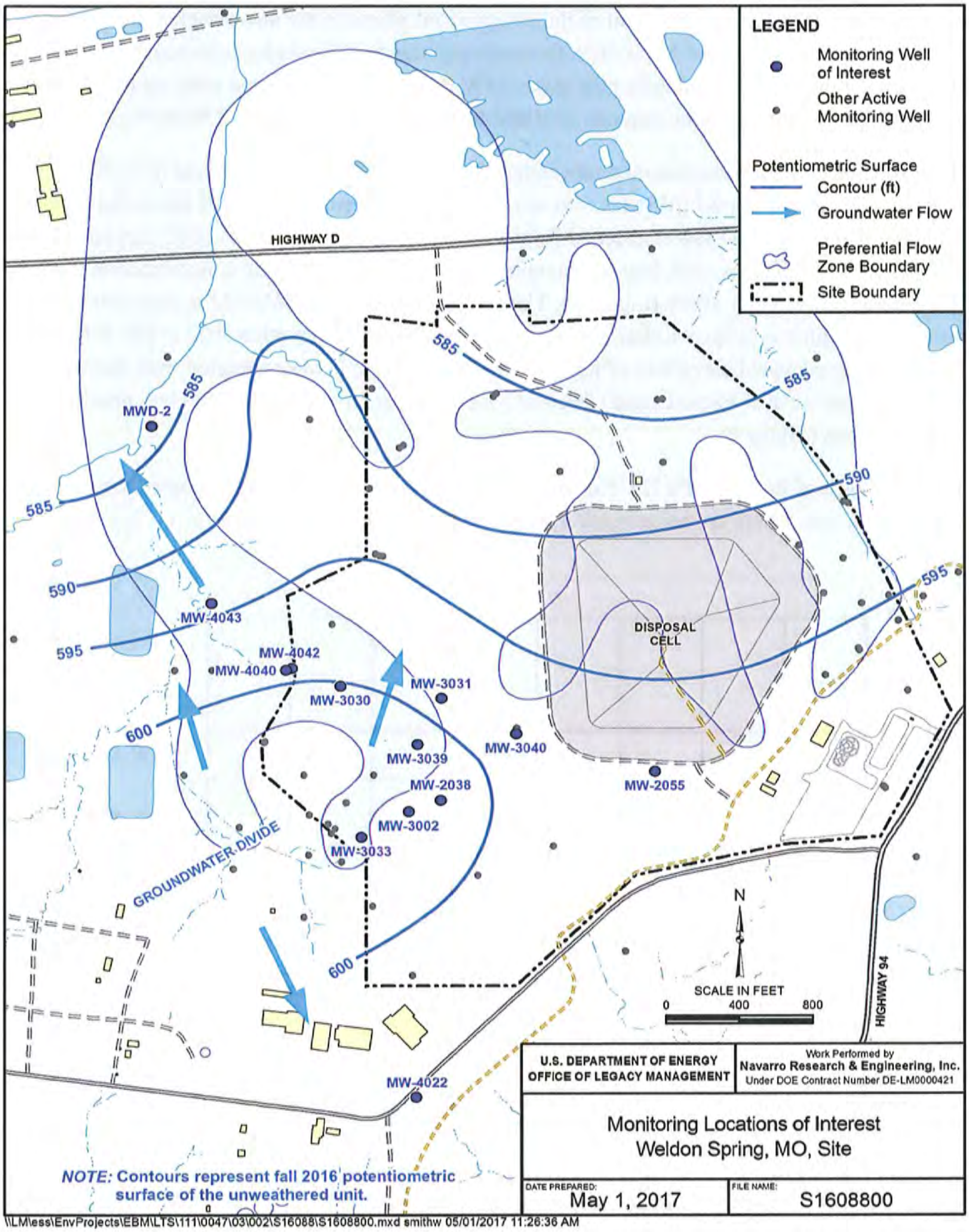

Figure 1. Map Showing Well Locations Discussed in Comment Responses

EPA Comment 3: The lateral extent of the contaminant plume in the unweathered zone is not delineated near MW-2038 or MW-3039. Groundwater samples should be collected at similar elevations in the unweathered zone near either MW-2038 or MW-3039 and north of Raffinate #3 to ensure that lateral migration remains confined to known areas of impact (Objective 3).

DOE Response 3: Decommissioned unweathered unit well MW-3002 (screened from 527 to 517 ft above mean sea level (MSL) is near this area and is screened 25 to 40 ft below the high-concentration wells MW-4040 (screened from 577 to 567 ft MSL) and MW-3040 (screened from 559 to 549 ft MSL). This well, though decommissioned, had low uranium concentrations when last sampled in the early 1990s (Figure 2). The former angled well MW-3033 is also near this area and, though it is in the weathered unit, the screened interval elevation (602 to 581 ft MSL) is just above the screened elevations of high concentration wells. It was an angled well that would intercept more vertical fractures and effectively sample a larger area. It also had low uranium concentrations (Figure 2).

The area north of Raffinate Pit No. 3 ***is not*** in a preferential flow area, and therefore has limited lateral migration. There are no unweathered unit wells in this area.

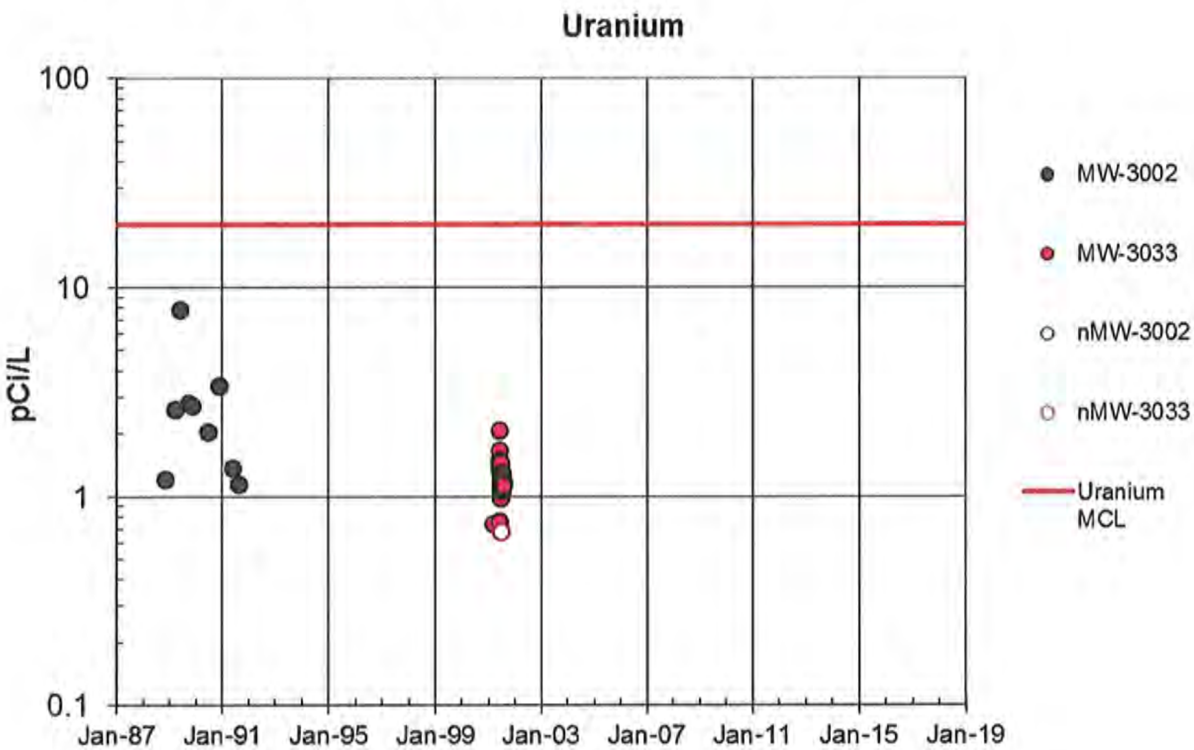

Figure 2. Uranium Concentrations in Wells MW-3002 and MW-3033

EPA Comment 4: The lateral extent of the contaminant plume within the preferential flow path has not been delineated. Groundwater samples should be collected within the preferential flow path from the areas downgradient of MW-4036 or MW-4043 to ensure that lateral migration within the preferential flow path remains confined to known areas of impact (Objective 3).

DOE Response 4: Unweathered unit well MWD-2 and its paired weathered unit well MWS-2 are about 1000 ft north and downgradient of the MW-4036/MW-4043 well pair and in the preferential flow path. Uranium concentrations at MWS-2/MWD-2 are at background levels (Figure 3).

There is no evidence that adding another weathered/unweathered well pair between these locations would provide additional benefit to this characterization, and any such data collected would be limited due to attenuation processes that are progressing at the MW-4036/MW-4043 location. Uranium concentrations at MW-4036 and MW-4043 should decrease to the 20 pCi/L uranium maximum contaminant level by 2035 (Figure 4).

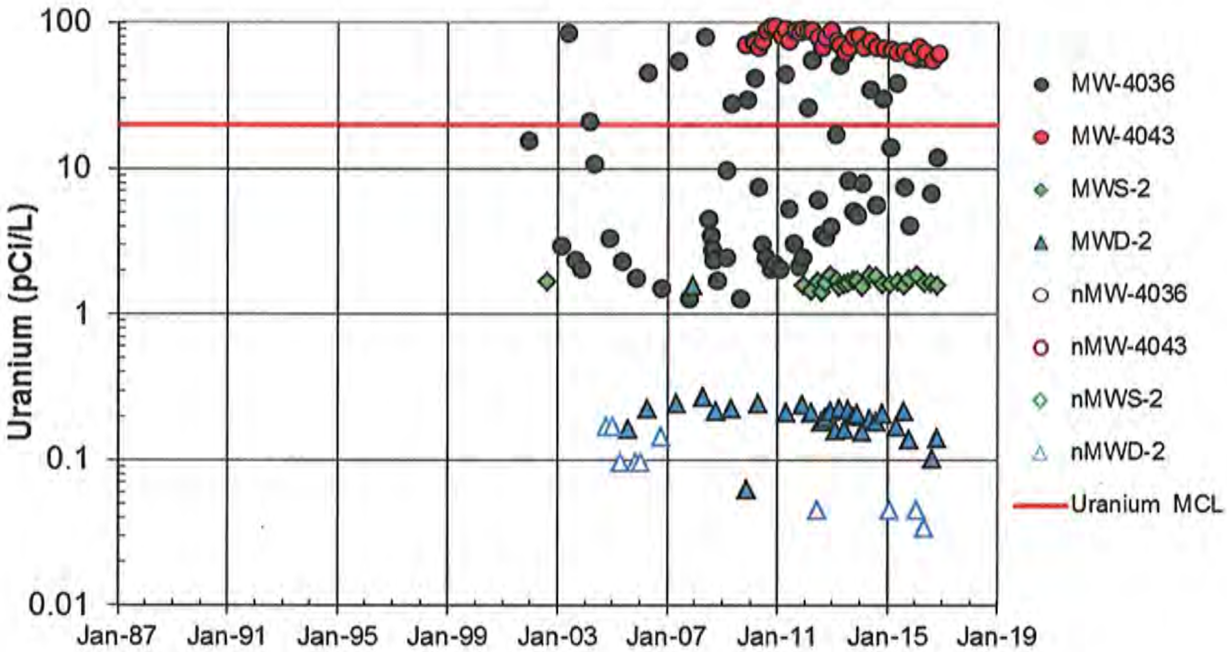

Figure 3. Uranium Concentrations in Wells MW-4036, MW-4043, MWS-2, and MWD-2

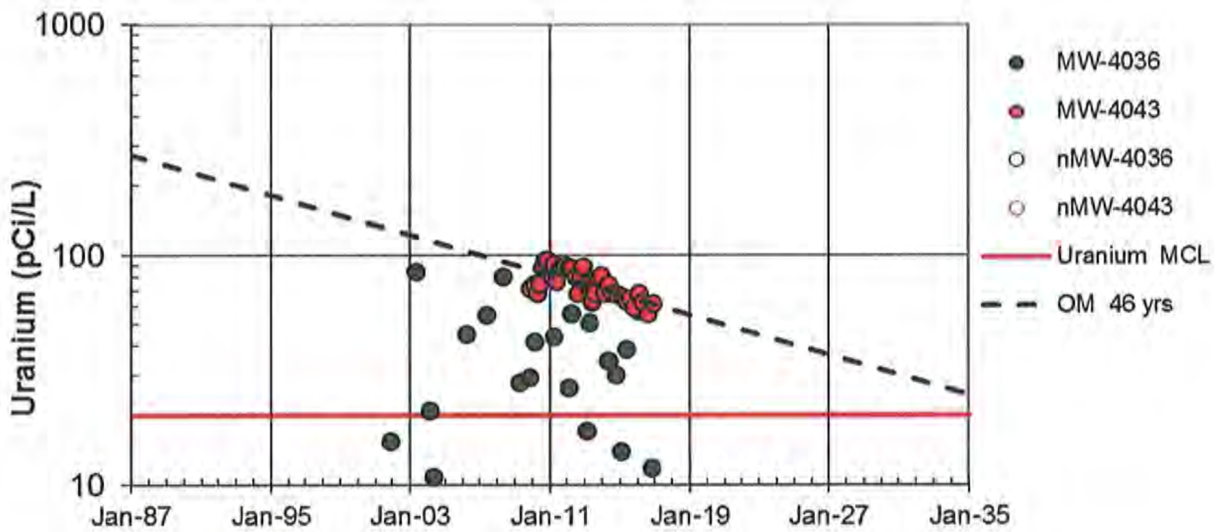

Figure 4. Uranium Concentrations in Wells MW-4036 and MW-4043 – Expanded Time-Scale

EPA Comment 5: The levels of uranium near MW-3024 or MW-3040 exceed trigger levels. This indicates that the vertical extent of the contaminant plume has not been delineated in this area. Groundwater samples should be collected near MW-3024 or MW-3040 to ensure there is no significant vertical migration of contaminants (Objective 4).

DOE Response 5: Uranium concentrations in these wells are above the 100 pCi/L impacted area uranium trigger value, but only slightly. Considering that the trigger value was set in the 2004 Remedial Design/Remedial Action Work Plan, which was prior to collecting a sufficient number of samples from newly installed wells, the more appropriate fixed trigger value should be set at 500 pCi/L (Figure 5) based upon that data.

Trigger values are used to monitor the effectiveness of the MNA remedy by providing an alert to increasing concentrations. The primary trigger value is statistical; a result is compared to the average of the previous 8 results plus 3 standard deviations. A relatively rapid increase in concentrations at a location would exceed the primary trigger value. However, gradually increasing concentrations might never exceed the primary trigger value that would also increase with each sample result. This possibility was addressed with a secondary, fixed trigger value.

Fixed trigger values were established for each analyte in 2004, and the value varies by location: higher trigger values for impacted areas where concentrations are relatively high and lower values for downgradient locations where concentrations are low. They were set at roughly 2 times the average concentration of results collected over several years with consideration for variability. For instance, the fixed trigger value for uranium in springs was set at 150 pCi/L. The combined uranium results from springs SP-5303, SP-5304, and SP-6301 averaged 53 pCi/L with a maximum of 145 pCi/L during the 5-years prior to fixed trigger level establishment. The impacted area uranium fixed trigger value was set at 100 pCi/L, utilizing data from MW-3024

(Figure 5). Uranium is the only analyte that has a lower fixed trigger value for the impacted area than for downgradient discharge areas.

The primary concern from an MNA perspective is to assess if the remedy is progressing as expected. Concentrations at discharge areas have been steadily decreasing with the highest uranium concentrations at Burgermeister Spring expected to be below the 20 pCi/L uranium MCL by the early 2040s (Figure 6).

It was expected that the removal of the raffinate pits could mobilize remnant contamination and thereby increase concentrations in the impacted area for a period of time. What was not expected was the extended duration of increasing concentrations that persisted for 10 years. Since 2013, however, concentrations in MW-3024 and MW-3040 have ***stabilized*** (Figure 5) and are expected to begin decreasing over the next 5 to 10 years. Uranium in the highest concentration well MW-4040 has ***been stable for about 10 years*** and recent results suggest the transition to decreasing concentrations could be underway (Figure 5).

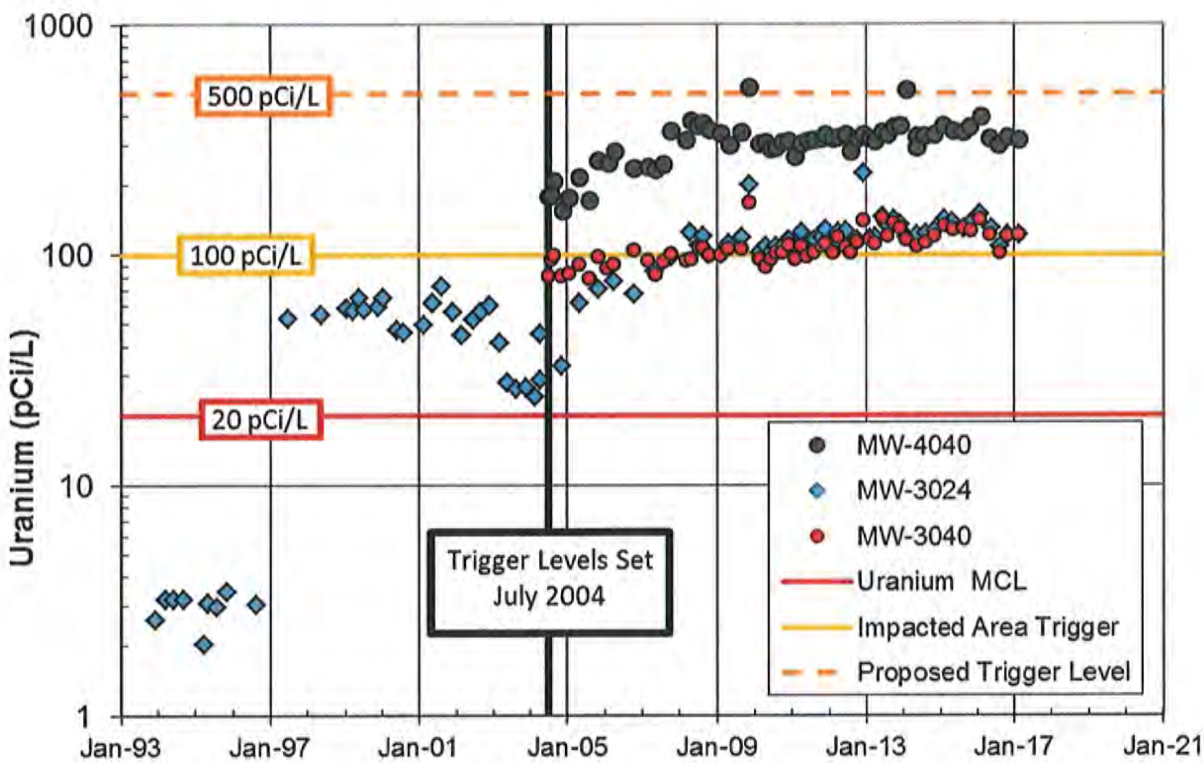

Figure 5. Uranium Concentrations in Wells MW-3024 and MW-3040

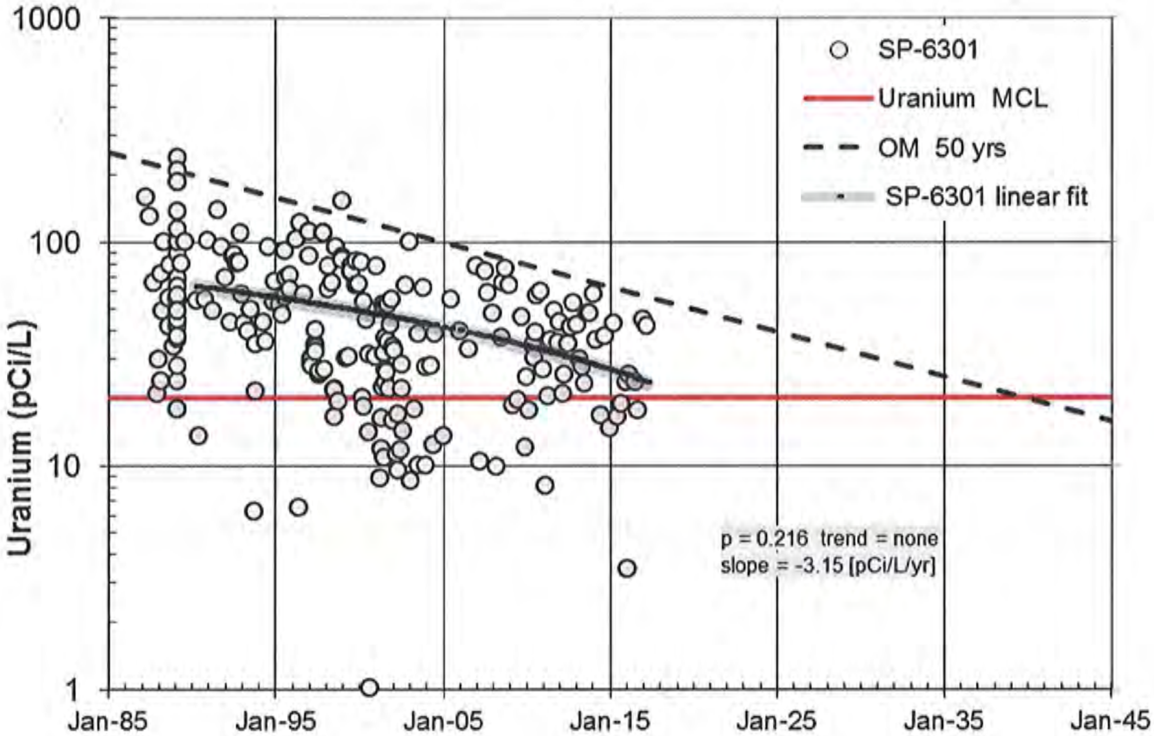

Figure 6. Uranium Concentrations in SP-6301 (Burgermeister Spring)

We would request a call or meeting to discuss the additional work requested by EPA in the April 2017 letter prior to any further action to install additional wells at the site. Please contact me at (303) 410-4801 or ken.starr@lm.doe.gov, or contact Yvonne Deyo at (636) 300-2612 or yvonne.deyo@lm.doe.gov as soon as practicable. DOE wants to continue its cooperation with both EPA and MDNR on these issues, as the goal is long-term protectiveness of the site. Please send any correspondence to:

U.S. Department of Energy
Office of Legacy Management
11025 Dover Street, Suite 1000
Westminster, Colorado 80021-5573

Sincerely

Kenneth I. Starr, PE
DOE Weldon Spring
Site Manager

cc:
T. Drake, MDNR
G. Hooten, DOE
S. Lipstein, DOE
Y. Deyo, Navarro
R. Hodges, Navarro
T. Uhlmeyer, Navarro
File: WEL 0510.20

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
CENTER FOR ENVIRONMENTAL SOLUTIONS AND EMERGENCY RESPONSE
GROUNDWATER CHARACTERIZATION AND REMEDIATION DIVISION
919 KERR RESEARCH DRIVE • ADA, OK 74820

7/21/2020

OFFICE OF
RESEARCH AND DEVELOPMENT

MEMORANDUM

SUBJECT: Monitored Natural Attenuation of Uranium, Weldon Spring Site, Missouri (20-R07-005)

FROM: Richard Wilkin, Ph.D., Geochemist
Office of Research and Development/Center for Environmental Solutions and Emergency Response

Randall Ross, Ph.D., Hydrologist
Office of Research and Development/Center for Environmental Solutions and Emergency Response

TO: Daniel O'Connor, Remedial Project Manager, Superfund and Emergency Management Division, U.S. EPA Region 7

The EPA Region 7 Superfund Program requested the Office of Research and Development (ORD) to provide an independent technical review of the monitored natural attenuation (MNA) remedy at the Groundwater Operable Unit, focused on the uranium contamination at the Weldon Spring Site (Missouri). Region 7 requested that this review examine whether the current monitoring well network is adequate to meet MNA objectives and if the MNA remedy is functioning properly. Region 7 requested that ORD provide any findings and recommendations it deemed appropriate regarding the groundwater restoration remedy at the Groundwater OU. In preparing this memo, ORD reviewed documents including "Optimization for the Groundwater Operable Unit Monitored Natural Attenuation Network for Uranium Impact in the Unweathered Unit of the Burlington-Keokuk Limestone at the Weldon Spring, Missouri, Site" (dated November 2014); "Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri" (dated July 1997); "Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site" (dated January 2004); "Weldon Spring, Missouri, Site Annual Report for Calendar Year 2018" (June 2019); "Response to U.S. Environmental Protection Agency Correspondence, Dated February 24, 2020" (dated May 2020); and other available site information and reports.

EPA's technical guidance on the application of MNA of inorganic contaminants in groundwater is described in three EPA reports (EPA, 2007a; 2007b; 2010). The most current policy guidance on MNA is described in *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites* (2015, OSWER Directive 9283.1-36). The 2015 OSWER policy document follows the science-based technical framework documents and it provides general expectations for assessing and implementing MNA remedies for groundwater contaminants. EPA's updated 2015 policy is intended to further clarify and expand on the 1999 MNA guidance (EPA, 1999). It is noted that DOE senior scientists participated in developing the EPA technical framework for evaluating and implementing MNA for inorganic contaminants in groundwater. Briefly, the EPA technical guidance outlines a 4-tiered approach, as follows (EPA, 2007a; 2007b; 2010; 2015):

- Tier 1 - Demonstrate active contaminant removal from groundwater & evaluate dissolved plume stability (based on site-specific data).
- Tier 2 - Determine rate and mechanism of contaminant attenuation.
- Tier 3 - Determine long-term capacity for attenuation and stability, i.e., is the attenuation mechanism irreversible under current and anticipated site conditions?
- Tier 4 - Design performance monitoring program, define triggers for MNA failure, and develop contingency planning.

While it is acknowledged that the ROD (DOE, 2004) for the Weldon Spring site was developed with the 1999 MNA guidance, it is accepted and expected practice during five-year reviews to revisit all technical and policy advances of selected remedies. It is noted that the DOE 2014 Optimization study and the annual reports prepared for Weldon Spring Site do not cite or acknowledge the updated technical guidance and policy guidance on MNA issued by EPA. Thus, a broad recommendation is that future efforts will explicitly acknowledge and incorporate EPA's most current guidance and recommended practices with respect to MNA.

For example, while the 1999 MNA guidance does include dilution and dispersion as viable attenuation processes, the 2015 OSWER Directive provides significant clarification: "Dispersion and dilution resulting from mixing with influent precipitation, up- or cross-gradient groundwater or leakage from overlying surface water bodies may be elements of an MNA response action for inorganic contaminants. However, dilution and dispersion generally are *not appropriate* (italics added) as primary MNA mechanisms because they reduce concentrations through dispersal of contaminant mass rather than destruction or immobilization of contaminant mass. Dilution and dispersion may be appropriate as a "polishing step" for distal portions of a plume when an active remedy is being used at a site…and source control is complete." Therefore, significant challenges are encountered in reviewing the MNA remedy at the Weldon Spring site because of the persistent source (specifically the elevated uranium in groundwater in the weathered portion of the aquifer adjacent to the former raffinate pits) and the reliance on dilution and dispersion as primary attenuation mechanisms. If there are indeed other attenuation processes that are considered viable at this site, then these should be documented and explained to EPA and the Missouri Department of Natural Resources (MDNR) as they have significance regarding the capacity, long-term stability, and potential re-mobilization of subsurface contamination (i.e., Tiers 2, 3, & 4 of the technical framework noted above).

Some of the past site work points to the importance of uranium sorption/desorption in the formations below the former raffinate pits. Sorbed uranium in this zone potentially represents a long-term source of uranium to groundwater. However, there is little supportive site characterization work that documents the (1) amount of uranium tied up at mineral-water interfaces and in secondary precipitates; and, (2) the triggers that potentially result in uranium mobilization and down-gradient attenuation. Understanding such geochemical mechanisms is a component of Tier 2 and Tier 3 investigations of MNA (EPA, 2007a; 2007b; 2010). Thus, a second broad recommendation is that future efforts will explicitly account for the full range of uranium sources, the potential for uranium mobilization, and the mechanisms of uranium attenuation; specifically, the attenuation mechanisms that do not rely on dilution/dispersion. Important factors to consider are solid-phase concentrations of uranium, solubility-controlling reactions, uranium speciation, sorption/desorption reactions, and the characterization of aquifer solids using modern techniques.

Further, the 1999 and 2015 guidance on MNA indicates that in complex geologic systems, the state-of-the-science may preclude adequate monitoring of a natural attenuation remedy. Karstic systems and/or fractured rock aquifers where groundwater moves preferentially through discrete pathways (e.g., solution channels, fractures, and joints) are specifically highlighted as problematic because the direction of groundwater flow through such heterogeneous (and often anisotropic) materials cannot be predicted directly from the hydraulic gradient and hydraulic conductivity. Thus, existing techniques may not be capable of identifying the pathway along which contaminated groundwater moves through the subsurface. It is specifically noted that "MNA *will not* (italics added) generally be appropriate where site complexities preclude adequate monitoring."

At the Weldon Spring site, source control measures were undertaken. Contaminated materials from the former raffinate pits and ponds were removed and isolated in the disposal cell. However, increasing uranium concentrations in source area unweathered unit monitoring wells caused the adequacy of the monitoring network to be questioned by EPA and MDNR. Sites where contaminant plumes are no longer increasing in extent, or are shrinking, are appropriate candidates for an MNA remedy. Thus, demonstration of plume stability must involve delineating contaminant distribution in all three dimensions and designing a monitoring network to assess the plume over time (EPA, 2015).
Given that there are concerns regarding the lack of responsiveness to developments in the technical and policy aspects of MNA guidance, as noted above, it is reasonable to examine several of the key expectations and desired outcomes of an MNA remedy (as outlined in Tier 1; EPA, 2007a), such as:

- Verify that the plume(s) is not expanding (either downgradient, laterally or vertically)
- Verify no unacceptable impact to downgradient receptors

At near-downgradient wells (e.g., MW-4043 positioned along the western preferential flow path), concentrations have been steadily decreasing (DOE, 2019). The uranium impact with the greatest migration potential is thought to be contained within the western paleochannel in the upper portion of the shallow aquifer. Uranium concentrations at far-downgradient wells (e.g., MWD2 and MWS2; unweathered and weathered formation aquifer) also have been consistently low for 20 years. It has been noted (DOE, 2020) that due to the karst hydrogeologic environment, some uncertainty about the extent of contamination will always exist. In karst environments, preferential flow paths may bypass well locations and their screened intervals, introducing uncertainty into plume delineation. Additionally, DOE does not believe that further characterization of the unweathered unit at the site would achieve increased protectiveness or change the remedy. This is because existing downgradient wells are suggestive that uranium has not migrated far from the source areas in the unweathered unit. Further, DOE notes that low concentrations in the downgradient wells and the continuing long-term decline in uranium concentrations in Burgermeister Spring support the conclusion that the MNA remedy is progressing and it is protective for the site.

Burgermeister Spring does represent a monitoring location to critically examine the effectiveness of the MNA remedy because it represents a far-downgradient receptor. Dye tracing tests indicated that hydraulic connections exist between the Chemical Plant site and Burgermeister Spring. The long-term data record supports decreasing concentrations in Burgermeister Spring. However, analysis of the recent uranium concentrations in the spring (~10 y) does not reveal a statistically significant downward trend (DOE, 2020; Figure 5). Implicit in this observation is that the uranium concentration trend may be asymptotic; consequently, there should be open acknowledgement that not all contaminant transport pathways have been discovered. Such acknowledgement would be consistent with the known challenges in monitoring karstic hydrogeologic environments and the admission that there is uncertainty about the extent of contamination at the site. For example, the weathered portion of the Burlington-Keokuk Limestone is highly fractured and exhibits solution voids and fractures. These features could be present too in the unweathered zone of the limestone formation, which is apparently quite variable in bedding thickness and potential for contaminant transport. Such uncertainties can be reduced by increasing the monitoring program which is common reality at sites with MNA remedies. Furthermore, the 2015 OSWER policy document states that “MNA is generally not appropriate for plumes that are considered stable, yet there is confirmed discharge to surface water bodies”.

Region 7 requested that this review examine whether the current monitoring well network is adequate to meet MNA objectives, i.e., do sampling locations (wells and springs) adequately fulfill the MNA monitoring objectives? Much of the groundwater movement is in the shallow aquifer. Localized zones of discrete fracture-controlled flow are also present. Most of the groundwater within the shallow aquifer flows horizontally to the north, and a minor amount of vertical groundwater movement to deeper formations is also thought to occur. With this conceptual model and inspection of the existing monitoring network, several recommendations can be made.

- Monitoring wells MW-4043 & MW-4036 are placed in a near-downgradient position. The deeper well (MW-4043) shows a gradual decreasing trend in uranium concentrations over about 10 years. The shallower well (MW-4036) has a longer history of monitoring and shows more variability in uranium concentrations (DOE, 2020; Figure 3). Together these two wells sample ~15 feet (MW-4043 has a 5-ft screened interval; DOE, 2014; Table 1) of at least 60 feet of relevant vertical extent. Additional monitoring points in the vertical dimension should be considered. The possibility of using nested, multi-level wells should also be considered to more fully access the vertical profile of uranium at this important near-downgradient location.

- Similarly, more complete vertical delineation should be considered at the far-downgradient location around wells MWS2 and MWD2. Together these wells sample approximately 20 feet of at least 80 feet of relevant vertical extent. In particular, the shallow region just below the water table is not monitored at this location (DOE, 2014; Table 1).
- Horizontal delineation could also be expanded at both the near-downgradient and far-downgradient locations noted above on the western preferential flow path. The map shown in the 2018 Annual Report (DOE, 2019; Figure 14) depicts the western preferential flow path to be >500 feet in width. This contaminant transport zone is monitored at only one location. Furthermore, north of the MWS2/MWD2 well pair, the width of the potential transport zone increases, yet there is sparse coverage in the monitoring network. For example, around spring sampling location 6201 there is are no wells, yet the depicted transport zone is ~1000 feet wide.

Primary to the evaluation of MNA is the delineation of plume boundaries and extent of contamination. The analysis of groundwater stability through natural attenuation processes is predicated on an adequate vertical and horizontal plume delineation. Additional wells will provide needed confidence that the remedy is effective and will be effective in the future. Additional wells will quantitatively improve the remedy by more completely delineating vertical and horizontal extent of contamination (EPA, 2015).

High uranium concentrations in wells MW-3040 and MW-4040 depict residual contamination in the weathered zone and a persistent source of contamination to down-gradient regions. DOE believes this issue should be addressed by raising the impacted area uranium trigger level by a factor of 5 from 100 picocuries per liter (pCi/L) to 500 pCi/L. The refined conceptual site model gained from the wells near the former raffinate pits added an additional level of uncertainty regarding the adequacy of the monitoring network and the ability to predict remedial timeframes. An alternate approach to raising trigger levels is a renewed evaluation of contingency remedies as addressed in Tier 4 of the MNA guidance. Because persistent sources provide additional uncertainty for estimating remedial timeframes, additional monitoring points and efforts to identify potential alternative remedies that best match site-specific conditions are broad recommendations.

To conclude, the main recommendations are as follows: i) future efforts at the Weldon Spring Site should explicitly acknowledge and incorporate EPA's most current guidance and recommended practices with respect to MNA remedies; ii) future efforts should explicitly account for the full range of uranium sources, the potential for uranium mobilization, and the mechanisms of uranium attenuation; specifically, the attenuation mechanisms that do not rely on dilution/dispersion; iii) additional sampling locations are needed to more fully account for vertical and lateral contaminant distribution to improve the delineation of plume boundaries and extent of contamination; and, iv) efforts are needed to evaluate alternative solutions for removing residual contamination at the site.

If you have any questions concerning these comments, please do not hesitate to call me at your convenience (Wilkin: 580-436-8874; Ross: 580-436-8611). We look forward to future interactions with you concerning this site and will be happy to look at any modified analysis that is developed for the site.

References

DOE, 2004. Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site. DOE/GJ/79491-936a.

DOE, 2019. Weldon Spring, Missouri, Site Annual Report for Calendar Year 2018. DOE/LMS/WEL/S23683.

DOE, 2020. Letter to EPA dated May 2020 "Response to U.S. Environmental Protection Agency Correspondence, Dated February 24, 2020."

EPA, 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER Directive 9200.4-17P, Office of Solid Waste and Emergency Response, Washington DC.

EPA, 2007a. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume I—Technical Basis for Assessment. EPA 600-R-07-139, Office of Research and Development, Washington, DC.

EPA, 2007b. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume II—Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium. EPA 600-R-07-140, Office of Research and Development, Washington, DC.

EPA, 2010. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume III—Assessment for Radionuclides Including Americium, Cesium, Iodine, Plutonium, Radium, Radon, Strontium, Technetium, Thorium, Tritium, and Uranium. EPA 600-R-10-093, Office of Research and Development, Washington, DC.

EPA, 2015. Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites. OSWER Directive 9283.1-36, Office of Solid Waste and Emergency Response, Washington DC.

cc: Jessica L. Kidwell, Region 7
Lisa Messinger, Region 7
Randolph Brown, Region 7
Brad Roberts, Region 7
Robert Weber, Region 7
David Bartenfelder, HQ
Linda Fiedler, HQ

Appendix B

Community Involvement

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WELDON SPRING SITE
A Legacy of Service

WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

THIS DOCUMENT MUST BE SAVED TO YOUR COMPUTER BEFORE COMPLETING

Community involvement is considered an integral part of Weldon Spring Site management and the Five-Year Review process.

Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that remedial actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review.

The U.S. Department of Energy (DOE) is currently conducting its sixth Five-Year Review for the Weldon Spring Site. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment.

WELDON SPRING SITE
A Legacy of Service

WELDON SPRING SITE
CERCLA FIVE-YEAR REVIEW SURVEY

DOE would like to solicit any input or comments you may have about the Weldon Spring Site and the cleanup as part of the sixth Five-Year Review. Please complete the survey below:

Name (optional): Taylor Grabner

City, State: Jefferson City, MO

What is your overall impression of the Weldon Spring Site cleanup project (general sentiment)?

Overall the Weldon Spring Site cleanup project has remediated much of the contamination at both the Chemical Plant and Quarry areas, placed the material in a secure disposal cell and continues to monitor residual groundwater contamination on and off site. The site administration staff conduct inspections, groundwater monitoring and other activities as part of the site long-term stewardship. The interpretive center provides a community oriented educational facility on the history of the site.

What effects have the completion of the site cleanup project had on the surrounding community?

The Weldon Spring Site is invested in providing a beneficial reuse to the surrounding community. Once active remediation was completed, the public gained access to the Hamburg and Katy Trails through the site. The disposal cell is also available for recreational activities and the new Interpretive Center will provide for more educational purposes and community involvement.

Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.

Over the past few years, interest in the St. Louis Manhattan era sites increased with the release of a documentary. During that time, a new Facebook group was established by individuals concerned with the history of contamination at the Weldon Spring site. This group has looked at historical documents regarding clean up of the contamination but has not been as active recently.

How did you learn about the site?

I am the State of Missouri site project manager.

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WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

Do you feel well informed about the site's activities and progress?

As the state project manager I stay informed about the site's activities and progress through discussions with the project team, annual inspections, calls, etc. Information such as Annual Reports, Five Year Reviews and decision documents are posted on the site's website for the public.

If not, how would you suggest the site keep the community adequately informed?

The site could consider updating the community via quarterly newsletters, photos, etc. Photos could show progress updates, such as the new interpretive center, site events, or even the types of grasses and plants found in the native prairie throughout the year.

Do you have any comments, suggestions, or recommendations regarding the site's management?

The Department has ongoing concerns that have been recently discussed with both DOE and EPA. The Department is hopeful that during this Five Year Review process a path forward to resolve these concerns will be determined.

Do you have any comments, suggestions, or recommendations regarding the site's activities?

Any other comments or suggestions?

As exhibits, videos, etc. are updated for the new Interpretive Center, the Department would like to encourage DOE to make sure that the displaced people who inhabited this area, both tribal and from the small towns, that historically lived in the area are properly represented and remembered.

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WELDON SPRING SITE
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WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

Your feedback supporting this Weldon Spring Site CERCLA Five-Year Review is greatly appreciated.

To submit this form:

1. **By email:** Turn in completed form to WSInterpretiveCenter@lm.doe.gov by clicking the submit button or emailing directly. Click the "SUBMIT" button, and your form will be uploaded as an attachment to your default email browser with an auto-populated email address (WSInterpretiveCenter@lm.doe.gov). Attach any additional materials and send the email.

2. **By mail:** Print, fold, tape, and apply first class postage to the address panel below.

SUBMIT

Fold at line, tape, apply first class postage, and mail.

Weldon Spring Site Interpretive Center
7295 Highway 94 South
St. Charles, MO 63304

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WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

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The U.S. Department of Energy (DOE) is currently conducting its sixth Five-Year Review for the Weldon Spring Site. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment.

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WELDON SPRING SITE
CERCLA FIVE-YEAR REVIEW SURVEY

DOE would like to solicit any input or comments you may have about the Weldon Spring Site and the cleanup as part of the sixth Five-Year Review. Please complete the survey below:

Name (optional): Nick Hand

City, State: St Louis MO

What is your overall impression of the Weldon Spring Site cleanup project (general sentiment)?

It is a very nice area for outdoor recreation. Clean and well maintained. Really interested in the new building.

What effects have the completion of the site cleanup project had on the surrounding community?

Not sure

Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.

No

How did you learn about the site?

Friends brought me 10 years ago.

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WELDON SPRING SITE
CERCLA FIVE-YEAR REVIEW SURVEY

Do you feel well informed about the site's activities and progress?

Not really, but I don't need to be. I just like to park there for bike riding.

If not, how would you suggest the site keep the community adequately informed?

Do you have any comments, suggestions, or recommendations regarding the site's management?

Do you have any comments, suggestions, or recommendations regarding the site's activities?

Any other comments or suggestions?

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WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

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2. **By mail:** Print, fold, tape, and apply first class postage to the address panel below.

SUBMIT

Fold at line, tape, apply first class postage, and mail.

____

____

____

Weldon Spring Site Interpretive Center
7295 Highway 94 South
St. Charles, MO 63304

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The U.S. Department of Energy (DOE) is currently conducting its sixth Five-Year Review for the Weldon Spring Site. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment.

WELDON SPRING SITE
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WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

DOE would like to solicit any input or comments you may have about the Weldon Spring Site and the cleanup as part of the sixth Five-Year Review. Please complete the survey below:

Name (optional): Jim Twellman

City, State: Lake St Louis, MO

What is your overall impression of the Weldon Spring Site cleanup project (general sentiment)?

Very nice. Useful to the public. Appreciated.

What effects have the completion of the site cleanup project had on the surrounding community?

Unsure.

Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.

No.

How did you learn about the site?

Thru my club.

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WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

Do you feel well informed about the site's activities and progress?

Yes.

If not, how would you suggest the site keep the community adequately informed?

Do you have any comments, suggestions, or recommendations regarding the site's management?

No.

Do you have any comments, suggestions, or recommendations regarding the site's activities?

No.

Any other comments or suggestions?

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WELDON SPRING SITE CERCLA FIVE-YEAR REVIEW SURVEY

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1. **By email:** Turn in completed form to WSInterpretiveCenter@lm.doe.gov by clicking the submit button or emailing directly. Click the "SUBMIT" button, and your form will be uploaded as an attachment to your default email browser with an auto-populated email address (WSInterpretiveCenter@lm.doe.gov). Attach any additional materials and send the email.
2. **By mail:** Print, fold, tape, and apply first class postage to the address panel below.

SUBMIT

Fold at line, tape, apply first class postage, and mail.

Weldon Spring Site Interpretive Center
7295 Highway 94 South
St. Charles, MO 63304

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INTERVIEW RECORD

Site Name: Weldon Spring Site	**EPA ID No.: MO3210090004**	
Subject: Annual Inspection	**Time: 10:23 am**	**Date: 11/2/20**
Type: ___ Telephone ___ Visit _x_ Email **Location of Visit: NA**	__ Incoming _x_ Outgoing	

Contact Made By:		
Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**
Individual Contacted:		
Name: Barry McFarland	**Title: Environmental Protection Specialist**	**Organization: 88th Regional Support Command, Army Contractor (Versar)**

Telephone No: (316) 681-1759, x1419 **Cell No. (316) 616-8649** **E-Mail Address: barry.l.mcfarland2.ctr@mail.mil**	**Street Address: 1LT Lanny J. Wallace USARC3130 George Washington Blvd.** **City, State, Zip: Wichita, KS 67210**

Summary Of Conversation

I contacted Barry McFarland to let him know that DOE would be conducting the annual LTS&M inspection on December 1 and 2, 2020. The email stated:

Barry, I am contacting you regarding the upcoming Department o fEnergy-Weldon Spring Site annual long-term surveillance and maintenance inspection, which is scheduled for December 1 and 2, 2020. You were copied on the notification letter with the agenda which was dated October 27, 2020. As part of the inspection we contact stakeholders to maintain contact with them and to determine if they have any concerns or issues about the site. We also touch base about the institutional control to ensure that landowners remain aware of the institutional controls on their properties. As you know we have the MOU with the Army(attached). We have also contacted a local representative of the Army property. We plan to be on the Army property checking DOE monitoring wells on the morning of December 1, 2020. Please respond and let me know if you have any questions, issues or concerns. The new Interpretive Center/Administrative Building at the Weldon Spring Site is near completion. The building will not be occupied until at least January 2021 and a grand opening is currently planned for next spring or summer.

Also, this inspection will serve as the Weldon Spring Site Sixth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below are a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30, 2021. Thanks!

Barry responded: Terri,

I've written my responses to the questions below. Thanks.

Respectfully,

Barry

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)? **The DOE project seems to be moving forward without any problems.**

2. What effects have the site operations had on the surrounding community? **The information center seems to be popular with the public.**

3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details**. I'm not aware of any specific concerns.**

4. Do you feel well-informed about the site's activities and progress? **Yes.**

5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation**? No.**

6. Any other general comments? **No.**

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INTERVIEW RECORD

Site Name: Weldon Spring Site	**CERCLIS ID No.: MO3210090004**	
Subject: Annual Inspection	**Time: 12:42 pm**	**Date: 10/29/19**
Type: ___ Telephone ___ Visit _x__ Email **Location of Visit:**	__ Incoming _x_ Outgoing	

Contact Made By:		
Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**
Individual Contacted:		
Name: Mike Hurlbert	**Title: Director**	**Organization: St. Charles Planning and Zoning Department**

Telephone No: 636-949-7900 x7221 **Fax No:** **E-Mail Address: mhurlbert@sccmo.org**	**Street Address: 201 N 2nd St #420** **City, State, Zip: St. Charles, MO 63301**

Summary Of Conversation

I contacted Mike Hurlbert, Director, Planning and Zoning for St. Charles County by email. The email stated the following:

Mike, I am contacting you regarding the upcoming Department of Energy – Weldon Spring Site annual long-term surveillance and maintenance inspection, which is scheduled for December 1 and 2, 2020. You were copied on the notification letter with the agenda which was dated October 27, 2020. As part of the inspection we contact stakeholders to maintain contact with them and to determine if they have any concerns or issues about the site. Please respond and let me know and if you have any questions, issues or concerns. We also check with your department each year during the inspection to see if there any planning and zoning activities currently in the one-quarter mile surrounding the chemical plant and quarry properties. The new Interpretive Center/Administrative Building at the Weldon Spring Site is near completion. The building will not be occupied until at least January 2021 and a grand opening is currently planned for next spring or summer.

Also, this inspection will serve as the Weldon Spring Site Fifth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below are a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30, 2021.

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)?
2. What effects have the site operations had on the surrounding community?
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
4. Do you feel well-informed about the site's activities and progress?

5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
6. Any other general comments?

Mike responded:

1. What is your overall impression of the project (general sentiment)?
There are no know concerns or issues about the Interpretive Center or the superfund site that our staff is aware of.

2. What effects have the site operations had on the surrounding community?
Properties within a quarter mile are almost exclusively State and Federal lands. Two exceptions are the County Highway Department facility immediately next door to the visitor's center and the Francis Howell High School. St. Charles County does not have any zoning permits within a quarter mile of the facility. An electrical permit and an interior finish permit have been issued for the School within the past few years. We closed out Land Disturbance Permit LD19-000035 on 10/13/20.

3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
T**here are no know concerns or issues about the Interpretive Center or the superfund site that our staff is aware of.**

4. Do you feel well-informed about the site's activities and progress?
No, we really have not heard much in terms of progress on constructing the new facility.

5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
No

6. Any other general comments?
This is a small matter and you may already be aware but someone changed Google Maps to label the visitor's center as "Nuclear Waste Adventure Trail and Museum". It's been shown on Google maps that way for a few years. I can't imagine that's the official name of the visitor's center.

Thanks.

Mike

INTERVIEW RECORD

Site Name: Weldon Spring Site	**EPA ID No.: MO3210090004**	
Subject: Annual Inspection	**Time: 10:36am**	**Date: 11/2/20**
Type: __ Telephone ___ Visit _x_ Email **Location of Visit: NA**	__ Incoming _x_ Outgoing	

Contact Made By:		
Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**
Individual Contacted:		
Name: Ryan Roberts	**Title: Assistant Fire Chief**	**Organization: Cottleville Fire Dept**

Telephone No: 636-447-6655 ext. 8702 **Fax No:** **E-Mail Address: ryroberts@cottlevillefpd.org**	**Street Address: PO Box 385** **City, State, Zip: Cottleville, MO 63338**

Summary Of Conversation

I contacted Ryan Roberts of the Cottleville Fire Department and notified him of the annual l LTS&M inspection. The emails sent are below:

Ryan, I am contacting you regarding the upcoming Department of Energy – Weldon Spring Site annual long-term surveillance and maintenance inspection, which is scheduled for December 1 and 2, 2020. You were copied on the notification letter with the agenda which was dated October 27, 2020. As part of the inspection we contact stakeholders to maintain contact with them and to determine if they have any concerns or issues about the site. Please respond and let me know us know if you have any questions, issues or concerns. We also responded to your email regarding entering into a contract with the Cottleville District on October 20, 2020 and wish to follow up on that issue. Thanks!

The new Interpretive Center/Administrative Building at the Weldon Spring Site is near completion. The building will not be occupied until at least January 2021 and a grand opening is currently planned for next spring or summer.

Also, this inspection will serve as the Weldon Spring Site Sixth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below are a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30, 2021. Thanks!

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)?
2. What effects have the site operations had on the surrounding community?
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
4. Do you feel well-informed about the site's activities and progress?

5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
6. Any other general comments?

Ryan's response is below:

Terri,
I thought that I had responded to this a couple of weeks ago, but maybe it didn't go through. I'll try it again.
1. My impression is that the project has been conducted thoughtfully and thoroughly. It seems as though everything is running smoothly, as we haven't had any emergency responses.
2. I am not aware of any effects the site operations have had on the community.
3. I am not aware of any community concerns regarding the site.
4. Although the site is not technically in our fire district, I feel that the fire district has been well-informed of the site's progress.
5. As the new interpretive center has been completed, I believe that a tour of the facility would be helpful for our firefighters, as we will be the initial first responders to any incident on-site.
6. I have no additional comments, except that we should probably meet to discuss entering into a contract for services again. Since I am relatively new as the fire marshal, and have never dealt with a contract for services, I will reach out to our attorney for guidance.

Respectfully,
Ryan Roberts
Assistant Chief/Fire Marshal
Cottleville Fire Protection District
(636) 447-6655, extension 8702

INTERVIEW RECORD

Site Name: Weldon Spring Site	**CERCLIS ID No.: MO3210090004**	
Subject: Annual Inspection	**Time: 7:21 am**	**Date: 11/2/20**
Type: ___ Telephone ___ Visit _x_ Email **Location of Visit: NA**	__ Incoming _x_ Outgoing	

Contact Made By:		
Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**
Individual Contacted:		
Name: Ryan Tilley	**Title: Director, Division of Environmental Health and Protection**	**Organization: St. Charles County**

Telephone No: 636-949-7406 **Fax No:** **E-Mail Address: RTilley@sccmo.org**	**Street Address: 201 North Second Street, Suite 537** **City, State, Zip: St. Charles, MO 63301**

Summary Of Conversation

I contacted Ryan Tilley, Director, Division of Environmental Health and Protection for St. Charles County by email. The email stated the following:

Ryan, I am contacting you regarding the upcoming Department of Energy – Weldon Spring Site annual long-term surveillance and maintenance inspection, which is scheduled for December 1 and 2, 2020. You were copied on the notification letter with the agenda which was dated October 27, 2020. As part of the inspection we contact stakeholders to maintain contact with them and to determine if they have any concerns or issues about the site. The new Interpretive Center/Administrative Building at the Weldon Spring Site is near completion. The building will not be occupied until at least January 2021 and a grand opening is currently planned for next spring or summer. Please respond and let me know us know if you have any questions, issues or concerns.

Also, this inspection will serve as the Weldon Spring Site Sixth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below are a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30, 2021. Thanks!

Five-Year Review Questions

Ryan responded the following:

I have no comments or concerns to address currently.

Answers are below in red.

1. What is your overall impression of the project (general sentiment)?

a. The time and effort into the project is impressive.

2. What effects have the site operations had on the surrounding community?

a. I think it has given the community some sense of ease.

3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.

a. No

4. Do you feel well-informed about the site's activities and progress?

a. Yes

INTERVIEW RECORD

Site Name: Weldon Spring Site	**CERCLIS ID No.: MO3210090004**	
Subject: Annual Inspection	**Time: 9:12 am**	**Date: 11/2/20**
Type: ___ Telephone ___ Visit _x_ Email **Location of Visit: NA**	__ Incoming _x_ Outgoing	

Contact Made By:		
Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**
Individual Contacted:		
Name: Craig Tajkowski	**Title: County Engineer**	**Organization: St. Charles County**
Telephone No: 636-949-7305 **Fax No:** **E-Mail Address: ctajkows@sccmo.org**	**Address: 201 N. 2nd St, Ste. 429** **City, State, Zip: St. Charles, Mo 63301**	

Summary Of Conversation

I contacted Craig Tajkowski of St. Charles County by email. They have taken over the former MoDOT facility and the groundwater restriction easement on that property was transferred from the MoDOT to the county.

Craig, I am contacting you to notify you of the Department of Energy Weldon Spring Site annual inspection which will take place on December 1 and 2, 2020. You were copied on the notification letter with the agenda which was dated October 27, 2020. This is considered our long-term surveillance and maintenance (LTS&M) inspection which we have conducted every year since we completed remediation of the site. We use this time to walk over the areas that we have institutional controls (ICs) in place to ensure that the restrictions are not being violated and to maintain contact with certain stakeholders, nearby property owners and institutional control contacts, such as yourself. We just like to remind the IC contacts about the ICs we have in place, such as the easement (attached) that was signed with MoDOT and transferred to the County and check if there are any concerns or issues. Please respond to this email or call me to let me know if you have any questions, concerns or issues. . The new Interpretive Center/Administrative Building at the Weldon Spring Site is near completion. The building will not be occupied until at least January 2021 and a grand opening is currently planned for next spring or summer.

Also, this inspection will serve as the Weldon Spring Site Sixth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below is a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30, 2021. Thanks!

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)?
2. What effects have the site operations had on the surrounding community?
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.

4. Do you feel well-informed about the site's activities and progress?

5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation?

6. Any other general comments?

Craig responded:

1. What is your overall impression of the project (general sentiment)? **Seems to be progressing smoothly**
2. What effects have the site operations had on the surrounding community**? No negative effects that I am aware of or have heard about**
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details. **None**
4. Do you feel well-informed about the site's activities and progress? **Yes**
5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation? **None**
6. Any other general comments? **No. Thank you for the opportunity to respond**

Craig Tajkowski, P.E.

County Engineer

St. Charles County Highway Dept.

highway@sccmo.org |636-949-7305

INTERVIEW RECORD

Site Name: Weldon Spring Site		**CERCLIS ID No.: MO3210090004**
Subject: Annual Inspection	**Time: 9:09 am**	**Date: 11/2/20**
Type: __ Telephone ___ Visit _X_ Email **Location of Visit: Weldon Spring Site**		__ Incoming _x_ Outgoing

Contact Made By:

Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**

Individual Contacted:

Name: John Vogel	**Title: Natural History Biologist**	**Organization: August A. Busch Memorial Conservation Area, Missouri Dept. of Conservation**

Telephone No: 636-300-1953 ext. 4131 **Fax No:** **E-Mail Address: John.Vogel@mdc.mo.gov**	**Street Address: 2360 Hwy D** **City, State, Zip: St. Charles, MO 63304**

Summary Of Conversation

I contacted John Vogel, to notify him of the annual inspection that was going to take place on December 1-2, 2020. The email stated:

John, I am contacting you regarding the upcoming Department of Energy – Weldon Spring Site annual long-term surveillance and maintenance inspection, which is scheduled for December 1 and 2, 2020. You were copied on the notification letter with the agenda which was dated October 27, 2020. As part of the inspection we contact stakeholders to maintain contact with them and to determine if they have any concerns or issues about the site. We also touch base about the institutional control areas to ensure that landowners remain aware of the institutional controls on their properties. As you know we have the easement, licenses and agreement with MDC (attached). I also wanted to check about any hunting seasons at that time. Please respond and let me know if you or a representative will attend the inspection or if you have any questions, issues or concerns. Thanks!

Also, this inspection will serve as the Weldon Spring Site Fifth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below are a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30, 2021.

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)?
2. What effects have the site operations had on the surrounding community?
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
4. Do you feel well-informed about the site's activities and progress?
5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
6. Any other general comments?

Terri,

I've copied Raenhard Wesselschmidt on this email response in case he has additional information to share. To my knowledge there will not be an MDC staff member attending the inspection. We have several staff vacancies at the moment and staff are involved in other priority projects. If questions come up during the inspection, please let us know and we can try to address those questions as needed. As far as hunting seasons, squirrel hunting season will be open during the inspection, but that has been the case during past inspections as well and I don't foresee any issues with the inspection taking place. I've provided answers to your questions below.

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)? Overall the project has done a good job of addressing concerns and communicating with stakeholders.
2. What effects have the site operations had on the surrounding community? Site operations have provided the community with educational information and a location to access the local trail system.
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details. No.
4. Do you feel well-informed about the site's activities and progress? Yes, communication is frequently shared about site activities.
5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation? I think it is worth exploring the potential for any partnerships between our educational program staff on more cooperative projects. If interested, I can provide contacts for our educational staff.
6. Any other general comments? Looking forward to seeing the new Interpretive Center in action!

Thank you,

John Vogel, CWB®
Natural History Biologist
Missouri Department of Conservation
St. Louis Region
2360 Highway D
St. Charles, MO 63304
636-300-1953 ext. 4131
John.Vogel@mdc.mo.gov

INTERVIEW RECORD

Site Name: Weldon Spring Site	**CERCLIS ID No.: MO3210090004**	
Subject: Annual Inspection	**Time: 7:35 am**	**Date: 1/2/20**
Type: ___ Telephone ___ Visit _x_ Email **Location of Visit: NA**	__ Incoming _x_ Outgoing	

Contact Made By:		
Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**
Individual Contacted:		
Name: Quinn Kellner	**Title: Natural Resource Manager** **Jones-Confluence State Park**	**Organization: MDNR-Parks**

Telephone No: 636-899-1135 **Fax No:** **E-Mail Address: Quinn.kellner@dnr.mo.gov**	**Street Address: PO Box 67** **City, State, Zip: West Alton, MO 63386**

Summary Of Conversation

I contacted Quinn Kellner, MDNR-Parks and emailed him about the LTS&M annual inspection at the Weldon Spring site on December 1 and 2, 2020. The email stated:

Quinn, I am contacting you to notify you of the Department of Energy Weldon Spring Site annual inspection which will take place on December 10 and 11 2019. This is considered our long-term surveillance and maintenance (LTS&M) inspection which we have conducted every year since we completed remediation of the site. You were copied on the notification letter with the agenda which was dated October 27, 2020. We use this time to walk over the areas that we have institutional controls in place to ensure that the restrictions are not being violated and to maintain contact with certain stakeholders, nearby property owners and institutional control contacts, such as yourself. We just like to remind the IC contacts about the ICs we have in place, such as the easement that was signed with MDNR-Parks and the licenses and check if there are any concerns or issues. I have attached these documents and the amendment that was made to the LTS&M Plan concerning coordination issues with MDNR-Parks. Please respond to this email or call me to let me know if you have any questions, concerns or issues. Thanks

Also, this inspection will serve as the Weldon Spring Site Fifth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below is a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30, 2021. Thanks!

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)?
2. What effects have the site operations had on the surrounding community?
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
4. Do you feel well-informed about the site's activities and progress?
5. Do you have any comments, suggestions, or recommendations regarding the site's management or

operation?
6. Any other general comments?

Quinn responded as follows:

1. What is your overall impression of the project (general sentiment)? The project has promoted public outreach and provides regular updates.
2. What effects have the site operations had on the surrounding community? The protection and restoration of natural resources has been positive.
3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details. I am not aware of any community concerns regarding the site or its administration.
4. Do you feel well-informed about the site's activities and progress? Yes
5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation? The Busch-Weldon Greenspace map has been very popular.
6. Any other general comments? No

Quinn Kellner
Park Supt.
Jones-Confluence Point / Katy Trail State Park
636-899-1135
314-807-1511 (cell)
quinn.kellner@dnr.mo.gov

INTERVIEW RECORD

Site Name: Weldon Spring Site	**CERCLIS ID No.: MO3210090004**	
Subject: Annual Inspection	**Time: 9:29 am**	**Date: 11/2/20**
Type: ___ Telephone ___ Visit _x_ Email **Location of Visit: NA**	__ Incoming _x_ Outgoing	

Contact Made By:		
Name: Terri Uhlmeyer	**Title: Compliance Manager**	**Organization: Navarro**
Individual Contacted:		
Name: Robert Price/Melanie Smith	**Title: Real Estate Manager/Deputy Regional Director, Northern Region** **Katy Trail Coordinator**	**Organization: MDNR-Parks**

Telephone No: (573)526-4786 **Fax No:** **E-Mail Address: Robert.price@dnr.mo.gov** **Melanie.Price@dnr.mo.gov**	**Street Address: PO Box 176** **City, State, Zip: Jefferson City, MO 65102**

Summary Of Conversation

I contacted Robert Price, Real Estate Manager with MDNR-Parks, by email as follows:

Robert, I am contacting you to notify you of the Department of Energy Weldon Spring Site annual inspection which will take place on December 1 and 2, 2020. This is considered our long-term surveillance and maintenance (LTS&M) inspection which we have conducted every year since we completed remediation of the site. You were copied on the notification letter with the agenda which was dated October 27, 2020. I have also contacted Quinn Kellner. We use this time to walk over the areas that we have institutional controls in place to ensure that the restrictions are not being violated and to maintain contact with certain stakeholders, nearby property owners and institutional control contacts, such as yourself. We just like to remind the IC contacts about the ICs we have in place, such as the easement that was signed with MDNR-Parks and the licenses that we recently renewed and check if there are any concerns or issues. I have attached these documents and the amendment that was made to the LTS&M Plan concerning coordination issues with MDNR-Parks. Please respond to this email or call me to let me know if you have any questions, concerns or issues.

Also, this inspection will serve as the Weldon Spring Site Sixth Five-Year Review inspection. The purpose of a Five-Year Review is to ensure that the remedy that was implemented to clean up the site continues to protect human health and the environment. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that clean-up actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be subject to a Five-Year Review. Community involvement is an integral part of the Five-Year Review process and DOE is soliciting your input or suggestions regarding the Weldon Spring Site and its cleanup. Below are a list of questions provided by Environmental Protection Agency (EPA) guidance for the Five-Year Review that we are requesting that you respond to. The Five-Year Review Report is scheduled to be completed by September 30 2021. Thanks!

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)?
2. What effects have the site operations had on the surrounding community?

3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
4. Do you feel well-informed about the site's activities and progress?
5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
6. Any other general comments?

Robert Price forwarded the email to Melanie Smith and she responded as follows:

Five-Year Review Questions

1. What is your overall impression of the project (general sentiment)?
   The project has promoted public outreach and provided regular updates to DSP.

2. What effects have the site operations had on the surrounding community?
   The protection and restoration of natural resources has been positive in our experience.

3. Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
   We are not aware of any community concerns.

4. Do you feel well-informed about the site's activities and progress?
   Yes

5. Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
   The Busch-Weldon Greenspace map has been very well received by the public.

6. Any other general comments?
   Not at this time.

We appreciate the opportunity to provide feedback.
Happy Thanksgiving!

Melanie Robinson-Smith
Deputy Regional Director, Northern Region
Katy Trail Coordinator
Missouri State Parks
573-449-7402