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U.S. Department of Energy
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Weldon Spring Site Environmental Report for Calendar Year 2011

August 2012

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Weldon Spring, Missouri, Site Environmental Report for Calendar Year 2011

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Abbreviations

AEC	U.S. Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
BTL	baseline tolerance limit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COD	chemical oxygen demand
CWA	Clean Water Act
DCF	dose conversion factor
DNB	dinitrobenzene
DNT	dinitrotoluene
DOE	U.S. Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
Eh	oxidation potential (millivolts)
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference
FFA	Federal Facility Agreement
ft	feet
GPS	Global Positioning System
GWOU	Groundwater Operable Unit
L	liter(s)
LCRS	leachate collection and removal system
LTS&M	Long-Term Surveillance and Maintenance
MCL	maximum contaminant level
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mg/L	milligram(s) per liter
MNA	monitored natural attenuation
MoDOT	Missouri Department of Transportation
mrem	millirem
MSD	Metropolitan St. Louis Sewer District
µg	microgram(s)
µg/L	microgram(s) per liter
N	nitrogen
NB	nitrobenzene
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
ORP	oxidation-reduction potential
OU	Operable Unit

PAH	polycyclic aromatic hydrocarbon
pCi	picocurie(s)
pCi/L	picocurie(s) per liter
QROU	Quarry Residuals Operable Unit
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RPD	relative percent difference
TED	total effective dose
TCE	trichloroethene
TDS	total dissolved solids
TNB	trinitrobenzene
TNT	trinitrotoluene
TOC	total organic carbon
WSSRAP	Weldon Spring Site Remedial Action Project
yr	year

Executive Summary

This *Weldon Spring Site Environmental Report for Calendar Year 2011* (Site Environmental Report) has been prepared as required by U.S. Department of Energy (DOE) Order 231.1B, *Environment, Safety and Health Reporting*, to provide information about the environmental and health protection programs conducted at the Weldon Spring Site. The Weldon Spring Site is in southern St. Charles County, Missouri, approximately 30 miles west of St. Louis. The site consists of two main areas, the former Weldon Spring Chemical Plant and the Weldon Spring Quarry, located on Missouri State Route 94, southwest of U.S. Route 40/61.

The objectives of the Site Environmental Report are to summarize data from the environmental monitoring program, to characterize environmental conditions at the site and identify trends, and to confirm compliance with environmental and health protection standards and requirements. The report also presents the status of remedial activities, and the results of monitoring these activities in 2011, to assess their impacts on the public and environment. Since environmental cleanup at the site has reached physical completion, the long-term surveillance and maintenance (LTS&M) activities have become the main focus at the site. Therefore, this report has been restructured and revised to reflect the reduction in physical activities and emphasize LTS&M activities.

Compliance Summary

The Weldon Spring Site is listed on the National Priorities List and is governed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Under CERCLA, the Weldon Spring Site has been subject to meeting or exceeding applicable or relevant and appropriate requirements of federal, state, and local laws. Primary regulations have included the Resource Conservation and Recovery Act and the Clean Water Act. Because DOE is the lead agency for the site, National Environmental Policy Act (NEPA) values are incorporated into CERCLA documents as outlined in the Secretarial Policy statement on NEPA (http://energy.gov/nepa/downloads/doe-secretarial-policy-statement-national-environmental-policy-act). Many of these regulations no longer apply due to the reduction in physical activities and waste handling at the site.

The site has reached construction completion under CERCLA. The completion was documented in a preliminary closeout report, which the U.S. Environmental Protection Agency (EPA) issued on August 22, 2005.

Because contamination remains at some of the areas of the site at levels above those that allow unlimited use and unrestricted exposure, CERCLA requires that the remedial actions be reviewed at least every 5 years. These reviews are commonly called 5-year reviews. DOE issued the fourth 5-year review for the site in September 2011. The EPA and Missouri Department of Natural Resources (MDNR) concurred with the 5-year review and associated protectiveness statement.

A revised Federal Facility Agreement (FFA) between EPA, DOE, and MDNR was signed by all parties by March 31, 2006. The focus of the FFA is LTS&M activities.

Environmental Monitoring Summary

The environmental monitoring program at the Weldon Spring Site includes sampling and analysis of water collected from wells at the Chemical Plant, the Quarry, adjacent properties, and selected springs in the vicinity of the Chemical Plant. Surface water in the vicinity of the Chemical Plant and Quarry are also sampled. A separate monitoring program has been established for the disposal cell.

Groundwater monitoring at the Chemical Plant focuses on the selected remedy of monitored natural attenuation (MNA) for the Groundwater Operable Unit. Total uranium, nitroaromatic compounds, trichloroethene, and nitrate have been monitored at selected locations throughout the Chemical Plant area and offsite. Sampling has targeted areas of highest impact in the shallow aquifer and migration pathways associated with paleochannels in the weathered unit of the Burlington-Keokuk Limestone. 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 expected.

The performance of the MNA remedy is assessed through the sampling of monitoring wells that are within the areas of impact. These wells are monitored to verify that contaminant concentrations are declining or remaining stable and that cleanup standards will be met within a reasonable time frame. Overall, natural attenuation of the contaminants of concern is occurring as expected, and concentrations are stable or decreasing, with the exception of uranium in the unweathered unit of the Burlington-Keokuk Limestone beneath the former Raffinate Pits area. This impact is be assessed as part of an ongoing special study.

Detection monitoring is performed to ensure that lateral and vertical migration remains confined to the current area of impact and that expected lateral downgradient migration within the paleochannels is minimal or nonexistent. Detection monitoring is performed by sampling selected wells, springs, and a surface water location. Concentrations in downgradient (laterally and vertically) and fringe locations have been behaving as expected; however, uranium levels in one downgradient well in the Raffinate Pits area are higher than predicted. This impact is being assessed as part of an ongoing special study. While uranium levels in the former Raffinate Pits area have changed since the implementation of the MNA remedy for uranium, overall the remedy remains protective. Groundwater flow directions are unchanged, and impacted groundwater is contained within the paleochannels in this area and is migrating along the expected pathways.

Groundwater monitoring at the Quarry focuses on the selected remedy of long-term groundwater monitoring for the Quarry Residuals Operable Unit. Total uranium, nitroaromatic compounds, and geochemical parameters have been monitored in the area of impact and in the Missouri River alluvium. Groundwater is sampled under two programs that focus on the area of impact in the Quarry proper and north of the Femme Osage Slough and the unimpacted Missouri River alluvium south of the Femme Osage Slough. Overall, uranium levels in the area of impact are decreasing or remaining stable. Results from the monitoring wells south of the slough indicate that uranium levels are similar to background for the Missouri River alluvium. The data continue to indicate that a strongly reducing environment is prevalent in the groundwater immediately south of the slough. This type of environment is not favorable for the migration of uranium.

Groundwater, spring, and leachate samples are collected as part of the detection monitoring program for the disposal cell. Under the monitoring program, signature parameter (barium and uranium) data from each location are compared to baseline tolerance limits to track general changes in groundwater quality and determine whether statistically significant evidence of contamination due to cell leakage exists. The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if changes are occurring in the groundwater system. The results indicate that there is no evidence of leakage into the groundwater beneath the disposal cell. The general groundwater quality in the detection monitoring wells and spring is consistent with historical data. Leachate is sampled to verify its composition, and its composition has remained relatively unchanged for the past few years.

Surface water monitoring was conducted in the vicinity of the Chemical Plant and the Quarry to measure the effects of groundwater and surface water discharge on the quality of downstream surface water. Monitoring results for the surface waters in the vicinity of the Chemical Plant show relatively low levels of uranium that are consistent with levels from previous years. Uranium levels in the slough continued to be elevated in 2010, a condition that began in 2006 when the slough dried out due to drought conditions.

Historical water quality and water level data for existing wells can be found on the DOE Office of Legacy Management website: http://www.lm.doe.gov/land/sites/mo/weldon/weldon.htm. Photographs, maps, and physical features can also be viewed on this website.

LTS&M Activity Summary

The *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri, Site* (DOE 2008) (LTS&M Plan) was revised and finalized in December 2008 after review by EPA, MDNR, and the public in accordance with the FFA. Revisions to the LTS&M Plan included changes to the monitoring programs at the Chemical Plant and the Quarry, the addition of the Special Use Area Well Drillers' Rule as a final institutional control, the addition of language regarding the potential discovery of contamination on MDNR Division of State Parks property within the proposed institutional control easement areas, and minor edits to the text and appendixes.

The Weldon Spring Site Interpretive Center is part of DOE's LTS&M activities at the site. Attendance for calendar year 2011 totaled 26,445. The total attendance from 2002 through 2011 is 157,833. The attendance numbers also include the number of attendees at outreaches.

The eighth annual public meeting, required by the LTS&M Plan, was held on June 1, 2011. This meeting was held to discuss the 2010 annual inspection, which took place in October 2010. Also discussed were a summary of environmental data, institutional control status, the upcoming CERCLA 5-year review report, and the Interpretive Center and prairie activities.

The 2011 annual inspection took place from October 25 through 27, 2011. The main areas inspected were the disposal cell, the Quarry, the leachate collection and removal system, and monitoring wells. Areas where future institutional controls will be established were also inspected to verify that no groundwater or resource uses were incompatible with the necessary restrictions. The EPA and MDNR participate in the annual inspections at the site.

1.0 Introduction

This *Weldon Spring Site Environmental Report for Calendar Year 2011* (Site Environmental Report) summarizes the environmental monitoring results obtained in 2011 and presents the status of federal and state compliance activities.

In 2011, environmental monitoring activities were conducted to support remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); the National Environmental Policy Act (NEPA); the Clean Water Act (CWA); and other applicable regulatory requirements. The monitoring program at the Weldon Spring Site has been designed to protect the public and to evaluate the effects on the environment, if any, from remediation activities.

The purposes of the Site Environmental Report include:

- Providing general information on the Weldon Spring Site and the current status of remedial activities and long-term surveillance and maintenance (LTS&M) activities.
- Presenting summary data and interpretations for the environmental monitoring program.
- Reporting compliance with federal, state, and local requirements and U.S Department of Energy (DOE) standards.
- Providing dose estimates for public exposure to radiological constituents due to activities at the Weldon Spring Site.
- Summarizing the trends of and changes in contaminant concentrations to support remedial actions, ensure public safety, maintain surveillance monitoring requirements, and demonstrate the effectiveness of the remediation.

1.1 Site Description

The Weldon Spring Site is located 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 Chemical Plant and Raffinate Pit sites (Chemical Plant) and the Weldon Spring Quarry (Quarry). The Chemical Plant is located about 2 miles southwest of the junction of Missouri State Route 94 and U.S. Highway 40/61. The Quarry is about 4 miles southwest of the 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 the 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 Chemical Plant and Quarry, the U.S. Army Reserve Weldon Spring Training area, the Missouri Department of Conservation (MDC), the Missouri Department of Natural Resources (MDNR) Division of State Parks (MDNR-Parks), Francis Howell High School, a Missouri Department of Transportation (MoDOT) maintenance facility, the Public Water Supply District #2 (formerly St. Charles County) water treatment facility and the law enforcement training center, the village of Weldon Spring Heights, and a University of Missouri research park.

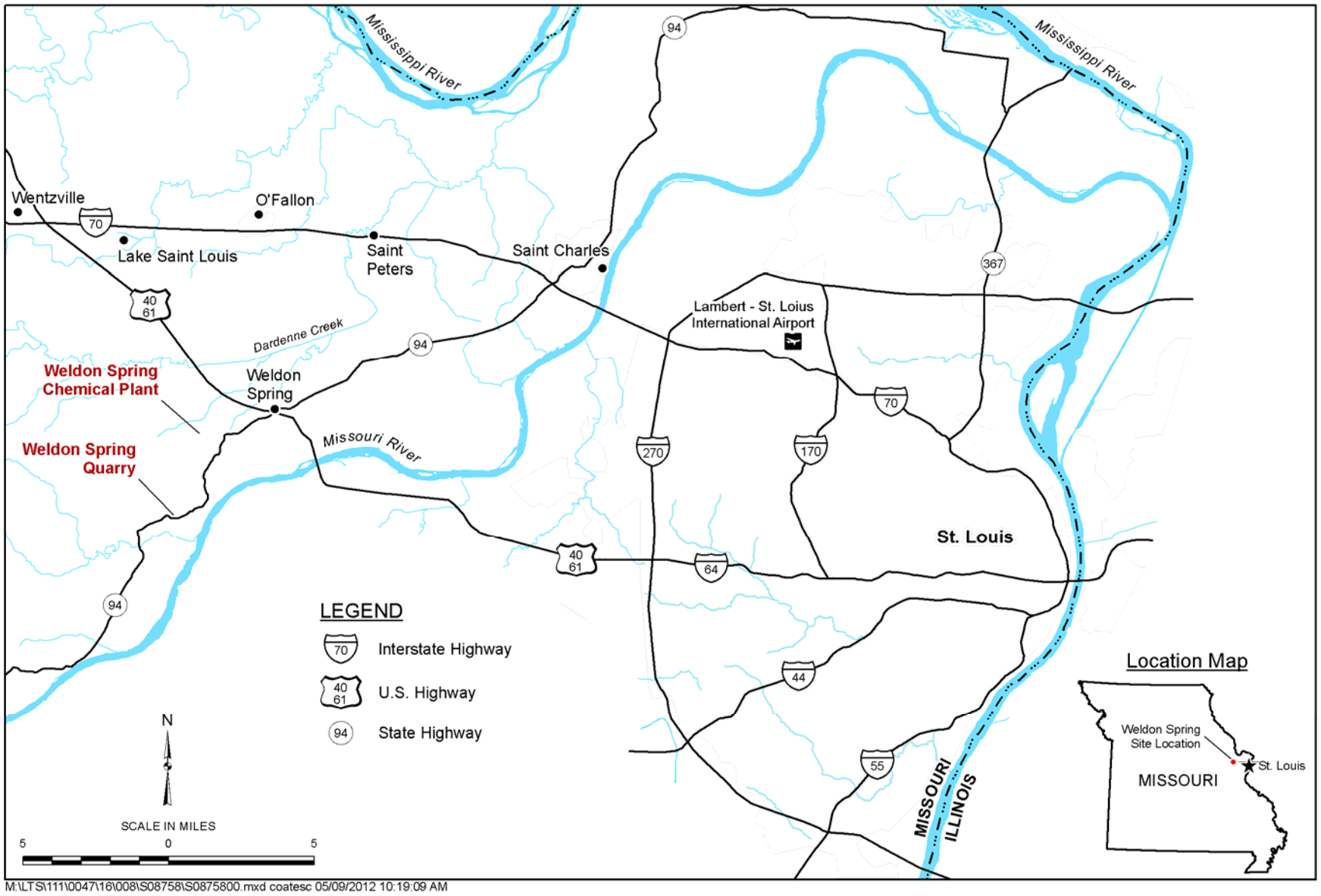

Figure 1. Location of the Weldon Spring, Missouri, Site

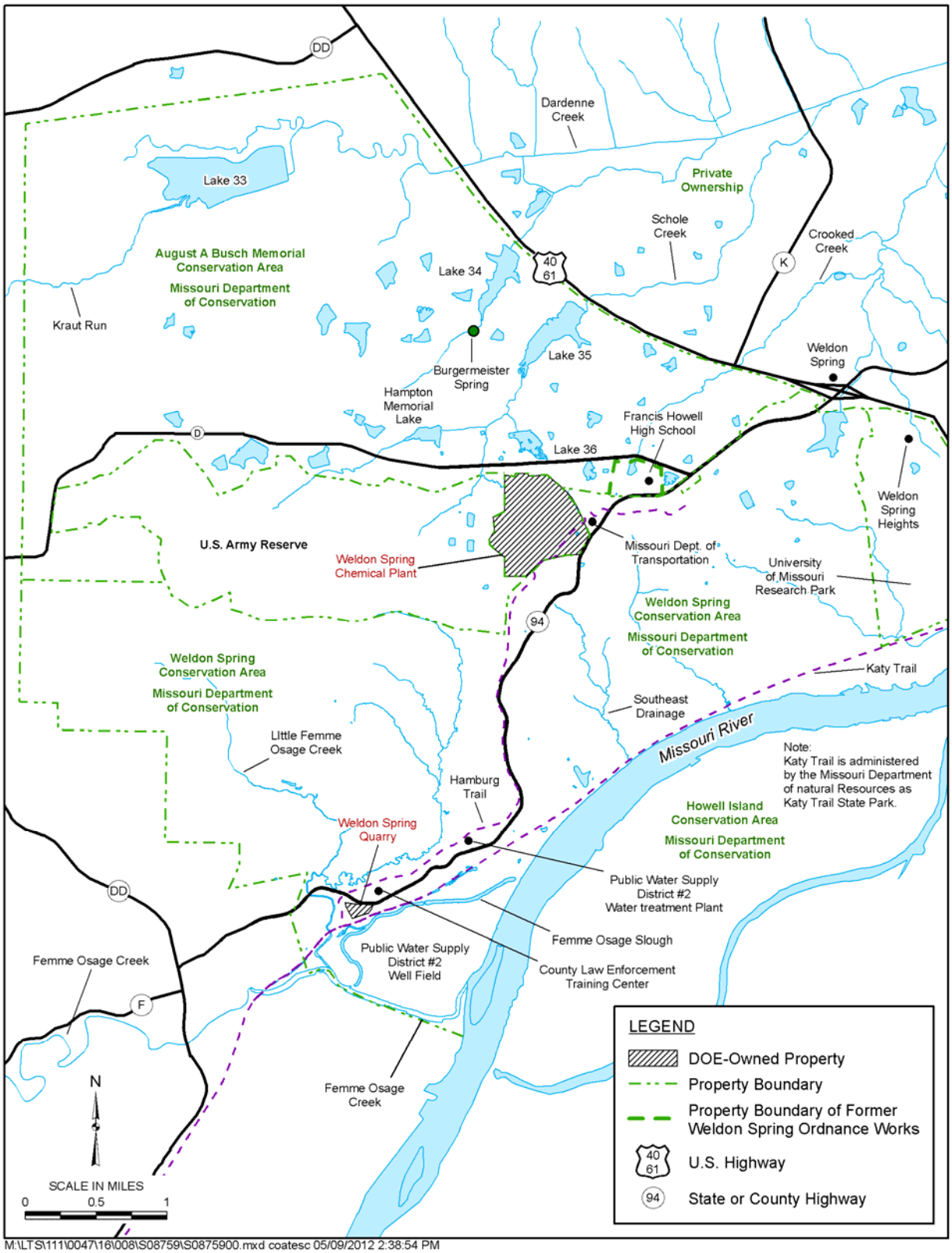

Figure 2. Vicinity Map of the Weldon Spring, Missouri, Site

The Chemical Plant and Quarry areas total 228.16 acres. The Chemical Plant property is located on 219.50 acres; the Quarry occupies 8.66 acres.

1.2 Site History

1.2.1 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 Department of 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, groundwater, and some offsite springs.

Following a considerable amount of explosives decontamination of the facility by the Army and the Atlas Powder Company, 205 acres of the former Ordnance Works property were transferred to the U.S. Atomic Energy Commission (AEC) in 1956 for the 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 the radiological contamination of the same locations previously contaminated by former Army operations.

The Quarry was mined for limestone aggregate used in the construction of the Ordnance Works. The Army also used the Quarry for burning wastes from explosives manufacturing and disposal of TNT-contaminated rubble during Ordnance Works operations. These activities resulted in the nitroaromatic contamination of the soil and groundwater at the Quarry.

In 1960, the Army transferred the Quarry to AEC, which used it from 1963 to 1969 as a disposal area for uranium and thorium residues (both drummed and uncontained) from the Chemical Plant and for the disposal of contaminated building rubble, process equipment, and soils from the demolition of a uranium-processing facility in St. Louis. Radiological contamination occurred in the same locations as the nitroaromatic contamination.

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 canceled before any process equipment was installed, 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, at which

time DOE designated the control and decontamination of the Chemical Plant, raffinate pits, and Quarry as a major project.

1.2.2 Remedial Action History

The U.S. Environmental Protection Agency (EPA) placed the Quarry and Chemical Plant areas on the National Priorities List in 1987 and 1989, respectively. Initial remedial activities at the Chemical Plant, a series of Interim Response Actions authorized through the use of Engineering Evaluation/Cost Analysis (EE/CA) reports, included:

- The removal of electrical transformers, electrical poles and lines, and overhead piping and asbestos that presented an immediate threat to workers and the environment.
- The construction of an isolation dike to divert runoff around the Ash Pond area to reduce the concentration of contaminants going offsite in surface water.
- A detailed characterization of onsite debris, the separation of radiological and nonradiological debris, and the transport of materials to designated staging areas for interim storage.
- The dismantling of 44 Chemical Plant buildings under four separate Interim Response Actions.
- The treatment of contaminated water at the Chemical Plant and the Quarry.

The remediation of the Weldon Spring Site was administratively divided into four operable units (OUs): the Quarry Bulk Waste OU, the Quarry Residuals OU (QROU), the Chemical Plant OU, and the Groundwater OU (GWOU). The Southeast Drainage was remediated as a separate action through an EE/CA report (DOE 1996). The following sections describe the selected remedies.

1.2.2.1 Chemical Plant OU

In the *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1993), DOE established the remedy for controlling contaminant sources at the Chemical Plant (except groundwater) and disposing of contaminated materials in an onsite disposal cell.

The selected remedy included:

- The removal of contaminated soils, sludge, and sediment.
- The treatment of wastes by chemical stabilization/solidification, as appropriate.
- The disposal of wastes removed from the Chemical Plant and stored Quarry bulk wastes in an engineered onsite disposal facility.

The remedy included the remediation of 17 offsite vicinity properties affected by Chemical Plant operations. The vicinity properties were remediated in accordance with Chemical Plant Record of Decision (ROD) cleanup criteria.

The *Chemical Plant Operable Unit Remedial Action Report* (DOE 2004a) was finalized in January 2004.

1.2.2.2 Quarry Bulk Waste OU

DOE implemented remedial activities for the Quarry Bulk Waste OU set forth in the *Record of Decision for Management of the Bulk Wastes at the Weldon Spring Quarry* (DOE 1990b).

The selected remedy included:

- Excavation and removal of bulk waste (i.e., structural debris, drummed and unconfined waste, process equipment, sludge, soil).
- Transportation of waste along a dedicated haul road to a temporary storage area located at the Chemical Plant.
- Staging of bulk wastes at the temporary storage area.

1.2.2.3 Quarry Residuals OU

The QROU remedy was described in the *Record of Decision for the Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri* (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 selected remedy included:

- Long-term monitoring and institutional controls to prevent exposure to contaminated groundwater north of the Femme Osage Slough.
- Long-term monitoring and institutional controls to protect the quality of the public water supply in the Missouri River alluvium and the implementation of a well-field contingency plan.
- Confirming the model assumptions regarding the extraction of contaminated groundwater and establishing controls to protect naturally occurring attenuation processes.

The *Quarry Residuals Operable Unit Interim Remedial Action Report* (DOE 2003b) was finalized in November 2003.

1.2.2.4 Groundwater OU

DOE implemented the *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site* (DOE 2000a), which was approved on September 29, 2000, to investigate the practicability of remediating trichloroethene (TCE) contamination in Chemical Plant groundwater using in situ chemical oxidation. It was determined, based on extensive monitoring, that in situ oxidation did not perform adequately under field conditions; therefore, the remediation of TCE was reevaluated with the remaining contaminants of concern.

In 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), DOE established the remedy of monitored natural attenuation (MNA) to address contaminated groundwater and springs.

The selected remedy included:

- Sampling of groundwater and surface water, including springs, to verify the effectiveness of naturally occurring processes to reduce contaminant concentrations over time.
- Institutional controls to prevent exposure to contaminated groundwater at the Chemical Plant and to the north toward Burgermeister Spring.

The *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site* (DOE 2005b) was finalized in March 2005.

1.2.2.5 Southeast Drainage

Remedial action for the Southeast Drainage was addressed as a separate action under CERCLA. The *Engineering Evaluation/Cost Analysis for the Proposed Removal Action at the Southeast Drainage near the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1996) was prepared in August 1996 to evaluate the human and ecological health risks within the drainage. The EE/CA recommended that selected sediment in accessible areas of the drainage should be removed with track-mounted equipment and transported by off-road haul trucks to the Chemical Plant. The excavated materials would be stored temporarily at an onsite storage area until final placement in the disposal cell. Soil removal occurred in two phases: 1997 to 1998, and in 1999 post-remediation soil sampling was conducted. More details are included in the *Southeast Drainage Closeout Report Vicinity Properties DA4 and MDC7* (DOE 1999).

1.3 Final Site Conditions

Contamination remains at the Weldon Spring Site at the following locations:

- An onsite disposal cell contains approximately 1.48 million cubic yards of contaminated material.
- Residual groundwater contamination remains in the shallow aquifer beneath the Chemical Plant, at the Quarry, and at some surrounding areas.
- Several springs near the Chemical Plant discharge contaminated groundwater.
- Residual soil and sediment contamination remain in the Southeast Drainage.
- Contamination remains at a culvert along Missouri State Route 94.
- Residual soil contamination remains at inaccessible locations within the Quarry.

1.4 Geology and Hydrogeology

Due to lithologic differences, including geologic features that influence groundwater flow, and the geographical separation of the Chemical Plant and Quarry areas, separate groundwater monitoring programs have been established for the two sites. This section presents generalized geologic and hydrologic descriptions of the two sites, and Figure 3 provides a generalized stratigraphic column for reference. Hydrogeologic descriptions of lithologies monitored for each program are discussed in Sections 3.1.1.1 and 3.1.2.1. The appropriate cleanup standards for groundwater in each area of the Weldon Spring Site are summarized in Section 3.1.

System	Series	Stratigraphic Unit	Typical Thickness (feet)[a]	Physical Characteristics	Hydrostratigraphic Unit
Quaternary	Holocene	Alluvium	0–120	Gravelly, silty loam	Alluvial aquifer
	Pleistocene	Loess and glacial drift[b]	10–60	Silty clay, gravelly clay, silty loam, or loam over residuum from weathered bedrock	Locally a leaky confining unit
Mississippian	Meramecian	Salem Formation[c]	0–15	Limestone, limey dolomite, finely to coarsely crystalline, massively bedded, and thin-bedded shale	
		Warsaw Formation[c]	0–80	Shale and thin- to medium-bedded finely crystalline limestone with interbedded chert	
	Osagean	Burlington-Keokuk Limestone	100–200	Cherty limestone, very fine to very coarsely crystalline, fossiliferous, thickly bedded to massive	Shallow aquifer system
		Fern Glen Limestone	45–70	Cherty limestone, dolomitic in part, very fine to very coarsely crystalline, medium to thickly bedded	
	Kinderhookian	Chouteau Limestone	20–50	Dolomitic argillaceous limestone, finely crystalline, thin to medium bedded	Upper leaky confining unit
Devonian	Upper	Sulphur Springs Group Bushberg Sandstone[d]	40–55	Quartz arenite, fine to medium grained, friable	
		Lower part of Sulphur Springs Group undifferentiated		Calcareous siltstone, sandstone, oolitic limestone, and hard carbonaceous shale	
Ordovician	Cincinnatian	Maquoketa Shale[e]	0–30	Calcareous to dolomitic silty shale and mudstone, thinly laminated to massive	
	Champlainian	Kimmswick Limestone	70–100	Limestone, coarsely crystalline, medium to thickly bedded, fossiliferous and cherty near base	Middle aquifer system
		Decorah Group	30–60	Shale with thin interbeds of very finely crystalline limestone	Lower confining unit
		Plattin Limestone	100–130	Dolomitic limestone, very finely crystalline, fossiliferous, thinly bedded	
		Joachim Dolomite	80–105	Interbedded very finely crystalline, thinly bedded dolomite, limestone, and shale; sandy at base	
		St. Peter Sandstone	120–150	Quartz arenite, fine to medium grained, massive	Deep aquifer system
	Canadian	Powell Dolomite	50–60	Sandy dolomite, medium to finely crystalline, minor chert and shale	
		Cotter Dolomite	200–250	Argillaceous, cherty dolomite, fine to medium crystalline, interbedded with shale	
		Jefferson City Dolomite	160–180	Dolomite, fine to medium crystalline	
		Roubidoux Formation	150–170	Dolomitic sandstone	
		Gasconade Dolomite	250	Cherty dolomite and arenaceous dolomite (Gunter Member)	
Cambrian	Upper	Eminence Dolomite	200	Dolomite, medium to coarsely crystalline, medium bedded to massive	
		Potosi Dolomite	100	Dolomite, fine to medium crystalline, thickly bedded to massive; drusy quartz common	

[a] Thickness estimates vary depending on data source.
[b] Glacial drift unit includes the Ferrelview Formation and is saturated in the northern portion of the Ordnance Works where this unit behaves locally as a leaky confining unit.
[c] The Warsaw and Salem Formations are not present in the Weldon Spring area.
[d] The Sulphur Springs Group also includes the Bachelor Sandstone and the Glen Park Limestone.
[e] The Maquoketa Shale is not present in the Weldon Spring area.

Figure 3. Generalized Stratigraphy and Hydrostratigraphy of the Weldon Spring, Missouri, Site

The Weldon Spring Site is situated near the boundary between the Central Lowland and the Ozark Plateau physiographic provinces. This boundary nearly coincides with the southern edge of Pleistocene glaciation that covered the northern half of Missouri over 10,000 years ago (Kleeschulte et al. 1986).

The uppermost bedrock unit underlying the Weldon Spring Chemical Plant is the Mississippian Burlington-Keokuk Limestone. Overlying the bedrock are unconsolidated units consisting of fill, topsoil, loess, glacial till, and limestone residuum of thicknesses ranging from a few feet to several tens of feet.

Three bedrock aquifers underlie St. Charles County. The shallow aquifer consists of the Mississippian Burlington-Keokuk Limestone and Fern Glen Formation, and the middle aquifer consists of Ordovician Kimmswick Limestone. The deep aquifer includes formations from the top of the Ordovician St. Peter Sandstone to the base of the Cambrian Potosi Dolomite. Alluvial aquifers of Quaternary age are present near the Missouri and Mississippi Rivers.

The Weldon Spring Quarry is located in low limestone hills near the northern bank of the Missouri River. The middle Ordovician bedrock of the Quarry area includes, in descending order, Kimmswick Limestone, Decorah Formation, and Plattin Limestone. These formations are predominantly limestone and dolomite. Massive Quaternary deposits of Missouri River alluvium cover the bedrock to the south and east of the Quarry.

1.5 Surface Water System and Use

The Chemical Plant and Raffinate Pits areas are on the Missouri−Mississippi River surface drainage divide. Elevations on the site range from approximately 608 feet (ft) above mean sea level near the northern edge of the site to 665 ft above mean sea level near the southern edge. (The disposal cell is not included in these elevation measurements.) The natural topography of the site is gently undulating in the upland areas, typical of the Central Lowlands physiographic province. South of the site, the topography changes to the narrow ridges and valleys and short, steep streams common to the Ozark Plateau physiographic province (Kleeschulte et al. 1986).

No natural drainage channels traverse the site. Drainage from the southeastern portion of the site generally flows southward to a tributary referred to as the Southeast Drainage (or 5300 Drainage, based on the site's nomenclature) that flows to the Missouri River.

The northern and western portions of the Chemical Plant site drain to tributaries of Schote Creek and Dardenne Creek, which ultimately drain to the Mississippi River. The manmade lakes in the August A. Busch Memorial Conservation Area, which are used for public fishing and boating, are located within these surface drainages. No water from the lakes or creeks is used for irrigation or for public drinking-water supplies.

Before the remediation of the Chemical Plant and Raffinate Pits areas began, there were six surface water bodies on the site: the four raffinate pits, Frog Pond, and Ash Pond. The water in the raffinate pits was treated prior to release, and the pits were remediated and confirmed clean. The Frog Pond and Ash Pond were flow-through ponds that were monitored prior to being remediated and confirmed clean. Throughout the project, retention basins and sedimentation basins were constructed and used to manage potentially contaminated surface

water. During 2001, the four sedimentation basins that remained were remediated, and the entire site was brought to final grade and seeded with temporary vegetation. Final seeding was conducted during 2002.

The Weldon Spring Quarry is situated within a bluff of the Missouri River Valley about 1 mile northwest of the Missouri River at approximately River Mile 49. Because of the topography of the area, no direct surface water entered or exited the Quarry before it was remediated. A 0.2-acre pond within the Quarry proper acted as a sump that accumulated direct rainfall within the Quarry. Past dewatering activities in the Quarry suggested that the sump interacted directly with the local groundwater. All water pumped from the Quarry before remediation was treated before it was released. Bulk waste removal, which included the removal of some sediment from the sump area, was completed during 1995. The Quarry was partially backfilled, graded, and seeded during 2002.

The Femme Osage Slough, located approximately 700 ft south of the Quarry, is a 1.5-mile section of the original Femme Osage Creek and Little Femme Osage Creek. The University of Missouri redirected the creek channels between 1960 and 1963 during the construction of a levee system around the university's experimental farms (DOE 1990a). The slough is essentially landlocked and is currently used for recreational fishing. The slough is not used for drinking water or irrigation.

1.6 Ecology

The Weldon Spring Site is surrounded primarily by state conservation areas that include the 6,988-acre Busch Conservation Area to the north, the 7,356-acre Weldon Spring Conservation Area to the east and south, and the 2,548-acre Howell Island Conservation Area, which is an island in the Missouri River (Figure 2).

The wildlife areas are managed for multiple uses, including timber, fish and wildlife habitat, and recreation. Fishing constitutes a relatively large portion of the recreational use. Seventeen percent of the area consists of open fields that are leased to sharecroppers for agricultural production. In these areas, a percentage of the crop is left for wildlife use. The main agricultural products are corn, soybeans, milo, winter wheat, and legumes (DOE 1992b). The Busch and Weldon Spring Conservation Areas are open year-round, and the number of annual visits to both areas totals about 1,200,000.

The Quarry is surrounded by the Weldon Spring Conservation Area, which consists primarily of forest with some old-field habitat. Prior to bulk waste removal, the Quarry floor consisted of old-field habitat containing a variety of grasses, herbs, and scattered wooded areas. When bulk waste removal began, this habitat was disturbed. The rim and upper portions of the Quarry still consist primarily of slope and upland forest, including cottonwood, sycamore, and oak (DOE 1990a).

1.7 Climate

The climate in the Weldon Spring area is continental, with warm to hot summers and moderately cold winters. Air masses that are alternately warm and cold, wet and dry converge and pass through the area, causing frequent changes in the weather. Although winters are generally cold and summers are generally hot, prolonged periods of very cold or very warm to hot weather are

unusual. Occasional mild periods with temperatures above freezing occur almost every winter, and cool weather interrupts periods of heat and humidity in the summer (Ruffner and Bair 1987).

On its website, the National Oceanic and Atmospheric Administration has published information based on an analysis of long-term meteorological records for the St. Louis area (NOAA 2005). The page, titled *The Climatology of the St. Louis Area*, states the following:

> St. Louis is located at the confluence of the Mississippi and Missouri Rivers, and near the geographical center of the US. Its position in the middle latitudes allows the area to be affected by warm moist air that originates in the Gulf of Mexico, as well as cold air masses that originate in Canada. The alternate invasion of these air masses produces a wide variety of weather conditions, and allows the region to enjoy a true four-season climate.
>
> During the summer months, air originating from the Gulf of Mexico tends to dominate the area, producing warm and humid conditions. Since 1870, records indicate that temperature of 90 degrees or higher occur on about 35-40 days per year. Extremely hot days (100 degrees or more) are expected on no more than 5 days per year.
>
> Winters are brisk and stimulating, but prolonged periods of extremely cold weather are rare. Records show that temperatures drop to zero or below an average of 2 or 3 days per year, and temperatures as cold as 32 degrees or lower occur less than 25 days in most years. Snowfall has averaged a little over 18 inches per winter season, and snowfall of an inch or less is received on 5 to 10 days in most years.
>
> Normal annual precipitation for the St. Louis area is a little less than 34 inches. The three winter months are the driest, with an average total of about 6 inches of precipitation. The spring months of March through May are normally the wettest with normal total rainfall of just under 10.5 inches. It is not unusual to have extended dry periods of one to two weeks during the growing season.
>
> Thunderstorms normally occur on between 40 and 50 days per year. During any year, there are usually a few of these thunderstorms that are severe, and produce large hail and damaging winds.

The precipitation and temperature results in Table 1 are from the National Weather Service. Precipitation and average temperature were all within historical ranges for the St. Louis area.

Table 1. Monthly Precipitation and Temperature

Month	Total Precipitation (inches)	Average Temperature (°F)
January	1.33	27.7
February	3.37	36.6
March	4.74	47.2
April	7.88	60.5
May	4.16	66.4
June	9.10	78.5
July	2.91	85.7
August	1.04	81.6
September	3.18	67.7
October	1.66	60.5
November	4.68	50.9
December	3.12	40.8

1.8 Land Use and Demography

The 2009 census (U.S. Census Bureau) estimated the population of St. Charles County to be about 355,367. The three largest communities in St. Charles County are O'Fallon (population: est. 74,000), St. Charles (population: est. 62,000), and St. Peters (population: est. 58,000) (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 5,000. No private residences exist between Weldon Spring Heights and the site.

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 members, and about 1,780 students attend school there. Approximately 50 bus drivers park their school buses in the adjacent parking lot. The school recently constructed a new school building, which was completed in time for the start of the 2011–2012 school year.

The MoDOT Weldon Spring maintenance facility, adjacent to the north side of the Chemical Plant, closed on November 1, 2011. The Army Reserve Training Area is to the west of the Chemical Plant; the Army Reserve currently uses the Training Area for storing equipment. A Naval Reserve Center was built on the site in 2008 and is currently operational. The Army has constructed a new Reserve center outside its fence line and plans to build a larger center inside the fence in the next few years.

The University of Missouri owns about 741 acres of land east and southeast of the high school. The northern third of this land is being developed into a high-technology research park. MDC operates the conservation areas adjacent to the Chemical Plant and employs about 50 people.

2.0 Compliance Summary

2.1 Compliance Status for 2011

The Weldon Spring Site is listed on the National Priorities List and is therefore governed by the CERCLA process. Under CERCLA, the Weldon Spring Site Remedial Action Project (WSSRAP) was subject to meeting or exceeding the applicable or relevant and appropriate requirements (ARARs) of federal, state, and local laws and statutes, such as the Resource Conservation and Recovery Act (RCRA), the CWA, the Clean Air Act, the National Historic Preservation Act, the Safe Drinking Water Act (SDWA), the Endangered Species Act, and Missouri State regulations. Because DOE is the lead agency for the site, NEPA values must be incorporated. The requirements of DOE orders must also be met. Section 2.1.1 summarizes compliance with applicable federal and state regulations, Section 2.1.2 summarizes compliance with major DOE orders, and Section 2.1.3 discusses compliance agreements and permits. The physical completion of the project has reduced or, in some cases, eliminated the applicability of certain ARARs.

2.1.1 Federal and State Regulatory Compliance

2.1.1.1 Comprehensive Environmental Response, Compensation, and Liability Act

The Weldon Spring Site has integrated the procedural and documentation requirements of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, and NEPA. Section 1.2.2 discusses the remedial actions conducted under CERCLA.

The site has reached construction completion under CERCLA. The completion was documented in a preliminary closeout report, which EPA issued on August 22, 2005.

Because some areas of the site are still contaminated beyond levels that would allow unlimited use and unrestricted exposure, CERCLA requires that the remedial actions be reviewed at least every 5 years. These reviews are commonly called 5-year reviews. DOE completed the fourth 5-year review report for the site in September 2011.

2.1.1.2 Resource Conservation and Recovery Act

Hazardous wastes at the Weldon Spring Site have been managed as required by RCRA, a substantive ARAR. Waste management has included the characterization, consolidation, inventory, storage, treatment, disposal, and transportation of hazardous wastes that remained on site after the closure of the Weldon Spring Uranium Feed Materials Plant and wastes that were generated during remedial activities.

A RCRA treatment, storage, and disposal permit was not required at the site because the remediation was performed in accordance with decisions reached under CERCLA. Section 121(e)(1) of CERCLA states that no federal, state, or local permit shall be required for the portion of any removal or remedial action conducted entirely onsite.

The Weldon Spring Site no longer generates any hazardous waste and has deactivated its RCRA generator identification number.

The disposal cell contents are not regulated under RCRA, but RCRA post-closure disposal cell monitoring and maintenance requirements are ARARs. The RCRA groundwater protection standard (Title 40 *Code of Federal Regulations* [CFR] Part 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 groundwater quality as well as groundwater passing the point of compliance. For a more complete description, see the *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan* (Appendix K of the *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri Site* [DOE 2008] [LTS&M Plan]), which was developed to address these requirements. Additional post-closure requirements for the cell are identified in 40 CFR 264 Subpart N and include action leakage rate and leachate collection and removal requirements. The LTS&M Plan (DOE 2008) addresses these requirements. Subpart N also includes requirements to maintain the integrity of the final cover, including making repairs as necessary.

2.1.1.3 Clean Water Act

Effluents discharged to waters of the United States are regulated under the CWA through regulations promulgated and implemented by the State of Missouri. The federal government has granted regulatory authority for the implementation of CWA provisions to states with regulatory programs that are at least as stringent as the federal program.

Compliance with the CWA at the site has included meeting parameter limits and permit conditions specified in the National Pollutant Discharge Elimination System (NPDES) permits. Under these permits, both effluent and erosion-control monitoring have been performed. The majority of these permits were terminated in 2003. See Section 2.1.3 for additional discussion of the remaining permits.

2.1.1.4 Safe Drinking Water Act

Safe Drinking Water Act regulations are not applicable because maximum contaminant levels (MCLs) apply only to drinking water at the tap, not in groundwater. However, under the National Contingency Plan, MCLs are relevant and appropriate to groundwater that is a potential drinking water source. The principal ARARs for the impacted groundwater at the Chemical Plant are the MCLs and Missouri water quality standards, which were established in the GWOU ROD (DOE 2004b) and are shown in Table 2.

Long-term groundwater monitoring for the QROU consists of two programs. Groundwater monitoring is necessary to continue to ensure that uranium-contaminated groundwater has a negligible potential to affect the well field that was formerly owned by St. Charles County and is now owned by Public Water Supply District #2. 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 they attain a predetermined target level indicating negligible potential to affect groundwater south of the slough.

Table 2. Federal and State Water Quality Standards for the Chemical Plant GWOU

Constituent	Standard	Citation
Nitrate (as N)	10 mg/L	40 CFR 141.62
Total Uranium	20 pCi/L	40 CFR 141
1,3-DNB	1.0 µg/L	10 CSR 20-7[a]
2,4-DNT	0.11 µg/L	10 CSR 20-7[a]
NB	17 µg/L	10 CSR 20-7[a]
TCE	5 µg/L	40 CFR 141.61
2,6-DNT	1.3 µg/L	Risk-based[b]
2,4,6-TNT	2.8 µg/L	Risk-based[c]

[a] Missouri Groundwater Quality Standard, *Code of State Regulations* (CSR).
[b] Risk-based concentration equivalent to 10^{-5} for a residential scenario.
[c] Risk-based concentration equivalent to 10^{-6} for a residential scenario.

DNB = dinitrobenzene; DNT = dinitrotoluene; NB = nitrobenzene; mg/L = milligrams per liter; µg/L = micrograms per liter; pCi/L = picocuries per liter; TNT = trinitrotoluene

The objective for monitoring groundwater south of the slough is to verify that the groundwater is not impacted. Uranium concentrations south of the slough and in the area of production wells at the well field remain within the observed natural variation within the aquifer; therefore, the MCL for uranium of 20 picocuries per liter (pCi/L) has been established as a trigger level only in this area. If concentrations in groundwater south of the slough exceed the MCL of 20 pCi/L, DOE will evaluate risk and take appropriate action.

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 percent of the 1999 maximum) 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.

2.1.1.5 Emergency Planning and Community Right-to-Know Act

The site no longer stores large quantities of chemicals and none above a threshold level; therefore, the site is not required to submit a 2011 Emergency Planning and Community Right-to-Know Act Tier II report.

The Toxic Release Inventory report for 2011 is due on July 1, 2012. Based on the chemical usage in 2011, the Weldon Spring Site is not required to submit a Toxic Release Inventory report.

2.1.2 DOE Order Compliance

2.1.2.1 DOE Order 458.1, Radiation Protection of the Public and the Environment

DOE Order 458.1 which replaced DOE Order 5400 in June 2011, establishes primary standards and requirements for DOE operations to protect members of the public and the environment against undue risk from radiation. DOE operates its facilities and conducts its activities so that radiation exposures to members of the public are maintained within established limits.

The estimated total effective dose to the hypothetical maximally exposed individual was due to consumption of water from Spring SP-5304 in the Southeast Drainage. This dose was calculated to be 0.17 millirem (mrem), which is well below the 100 mrem guideline for all potential exposure pathways.

2.1.2.2 DOE Order 231.1B, Environment, Safety and Health Reporting

DOE Order 231.1B, *Environment, Safety and Health Reporting*, ensures the collection and reporting of information on environment, safety, and health that is required by law or regulation. This Site Environmental Report fulfills the requirement of the order to summarize the environmental data annually. This directive also includes requirements for occurrence reporting. There were no occurrences as defined by this directive at the site during 2011.

2.1.2.3 DOE Order 436.1, Departmental Sustainability

DOE Order 436.1 requires that contractors integrate numerous environmentally related requirements already placed on them by existing statutes, regulations, and policies through the use of an Environmental Management System (EMS) incorporated into an Integrated Safety Management System (ISMS). EMS requirements must be addressed in the contractor's ISMS, which must be submitted for DOE review and approval under DEAR 970.5223-1, "Integration of Environment, Safety and Health into Work Planning and Execution" (48 CFR 970.5223-1).

DOE Order 436.1 incorporates the sustainability requirements of Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance.*

DOE Order 436.1 also requires the implementation of an EMS that reflects the elements and framework found in the International Organization for Standardization (ISO) 14001:2004(E), *Environmental Management Systems—Requirements with Guidance for Use*, or the equivalent. DOE's Office of Legacy Management (LM) EMS integrates the four core elements of ISO 14001:2004(E): (1) planning, (2) implementation and operation, (3) checking and corrective action, and (4) management review. These elements are commonly referred to as a Plan-Do-Check-Act continuous cycle and apply to all LM and contractor work processes and activities. LM and its contractors are committed to systematically integrating environmental protection, safety, and health into management and work practices at all levels so that the LM mission is accomplished in a manner that continually integrates environmental aspects during planning, implementation, monitoring, and project evaluation and closeout. Guidance for identifying environmental aspects, objectives, and targets that are related to proposed activities is included in the EMS and ensures that LM staff and contractors maintain compliance with applicable regulations and appropriately plan and implement activities.

The Legacy Management Support contractor's EMS adheres to the Plan-Do-Check-Act core principles of DOE Order 436.1 outlined in the *Environmental Management System Description* (LMS/POL/S04346) and the guiding principles outlined in the *Integrated Safety Management System with Embedded Worker Safety and Health Program* (LMS/POL/S04328).

The EMS provides mechanisms for planning and mitigating the negative impacts that proposed projects or actions could have on the environment by mandating environmental compliance;

promoting the use of post-recycled-content materials; recycling to the extent practicable; conserving fuel, energy, and natural resources; minimizing the generation of greenhouse gases and hazardous wastes and the use of toxic chemicals; and enhancing disrupted ecosystems.

See the *Integrated Safety Management System Description with Embedded Worker Safety and Health Program*, *Environmental Management System Description*, *Environmental Protection Manual* (LMS/POL/S04329) and the *Environmental Management System Programs Manual* (LMS/POL/S04388) for the requirements, processes, and methods used in LM facilities to implement the EMS.

During 2011, the Weldon Spring Site recycled the following items:

- Paper 3,466 pounds
- Cardboard 446 pounds
- Plastic 116 pounds
- Batteries 32 pounds
- Glass 151 pounds
- Scrap Metal 580 pounds
- Toner Cartridges 3

2.1.3 Permit and Agreement Compliance

2.1.3.1 NPDES Permits

Currently, the Weldon Spring Site has two NPDES permits. The first permit (MO 0107701), which covers discharges from the leachate collection and removal system (LCRS), is maintained as a contingency to current disposal methods (see Section 2.1.3.3). No water has been discharged under this permit since 2002. The current permit expires in April 2013.

The second permit (MO 0129917) is for the sanitary sewer system for the site. This permit was recently transferred back to DOE from Lindenwood University after Lindenwood left the site.

2.1.3.2 Federal Facility Agreement

EPA and DOE signed a Federal Facility Agreement (FFA) in 1986 and amended it in 1992. The main purpose of the FFA is to establish a procedural framework and schedule for developing, implementing, and monitoring appropriate response actions at the site in accordance with CERCLA. DOE issued an FFA report to EPA and MDNR each quarter. It documented compliance with the FFA and reported on activities at the site.

EPA, DOE, and MDNR subsequently signed an updated FFA; EPA provided the final signature on March 31, 2006. The FFA focuses on LTS&M activities and no longer requires a quarterly report.

2.1.3.3 Metropolitan St. Louis Sewer District (MSD) Agreement

The Weldon Spring Site has approval from the MSD to discharge treated disposal cell leachate and purge water at their Bissell Point Plant. DOE received notification in April 2004 that the leachate must meet the radiological drinking-water standard for uranium of 30 µg/L (20 pCi/L) prior to acceptance. The disposal cell leachate was very close to this limit in 2004; therefore, DOE exercised a pretreatment contingency process and began treating the leachate through a system of cartridge filters and ion exchange media that is selective for uranium. The leachate was sampled after treatment and found to be significantly below the 30 µg/L limit. The pretreated levels continued to be close to the 30 µg/L limit during 2011, so the leachate continued to be treated by the same process with the same results (that is, the levels continued to be significantly lower than the 30 µg/L limit). On November 3, 2006, DOE received a 5-year extension letter from MSD, extending the agreement to December 21, 2011. A request to extend the MSD agreement was submitted and a response was received from MSD on November 16, 2011, that extended the agreement to December 14, 2013.

3.0 Environmental Monitoring Summary

3.1 Groundwater Monitoring

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

3.1.1 Chemical Plant Groundwater

EPA signed the GWOU ROD (DOE 2004b) on February 20, 2004. The final GWOU ROD specified a remedy of MNA with institutional controls to limit groundwater use during the period of remediation. 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.

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 2004c). This network has since been modified as presented in the *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site* (DOE 2005b).

3.1.1.1 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 occurs 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).

A groundwater divide is located along the southern boundary of the site. 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 by generally diffuse flow with localized zones of discrete fracture-controlled flow.

The aquifer of concern beneath the Chemical Plant is the shallow bedrock aquifer comprised of Mississippian Burlington-Keokuk Limestone (the uppermost bedrock unit) and the underlying Fern Glen Formation. 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 in the vicinity of 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 less in the unweathered zone than in the weathered zone.

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. Some wells screened in the unweathered zone of the Burlington-Keokuk Limestone are used to assess the vertical migration of contaminants. Monitoring wells within the boundaries of the Chemical Plant are located near historical contaminant sources and preferential flow pathways (paleochannels) to assess the movement of contaminated groundwater in the shallow aquifer. Additional wells are located outside the Chemical Plant boundary to detect and evaluate the potential offsite migration of contaminants (Figure 4).

Numerous springs, a common feature in carbonate terrains, are present in the vicinity of the site. Four springs that are monitored routinely (Figure 5) have been historically influenced by Chemical Plant discharge water, or by groundwater, that contained one or more of the contaminants of concern.

The presence of elevated total uranium and nitrate levels at Burgermeister Spring (SP-6301), which is 1.2 miles north of the site, indicates that discrete subsurface flow paths are present in the vicinity of the site. Groundwater tracer tests performed in 1995 (DOE 1997) 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 preglacial stream channels present beneath the site.

3.1.1.2 Contaminants of Interest

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 occurs 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 sources for the groundwater contamination beneath the site. The distribution of contaminants in the shallow aquifer at the site is controlled by several processes, such as transformation, adsorption, desorption, dilution, or dispersion; the primary attenuation mechanisms are dilution and dispersion.

The raffinate pits were the primary historical source of uranium contamination in groundwater. Uranium entered the shallow aquifer via infiltration through the thin overburden beneath the pits. The extent of uranium in groundwater was limited, because uranium is partially sorbed to the clays in the overburden materials. At locations 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.

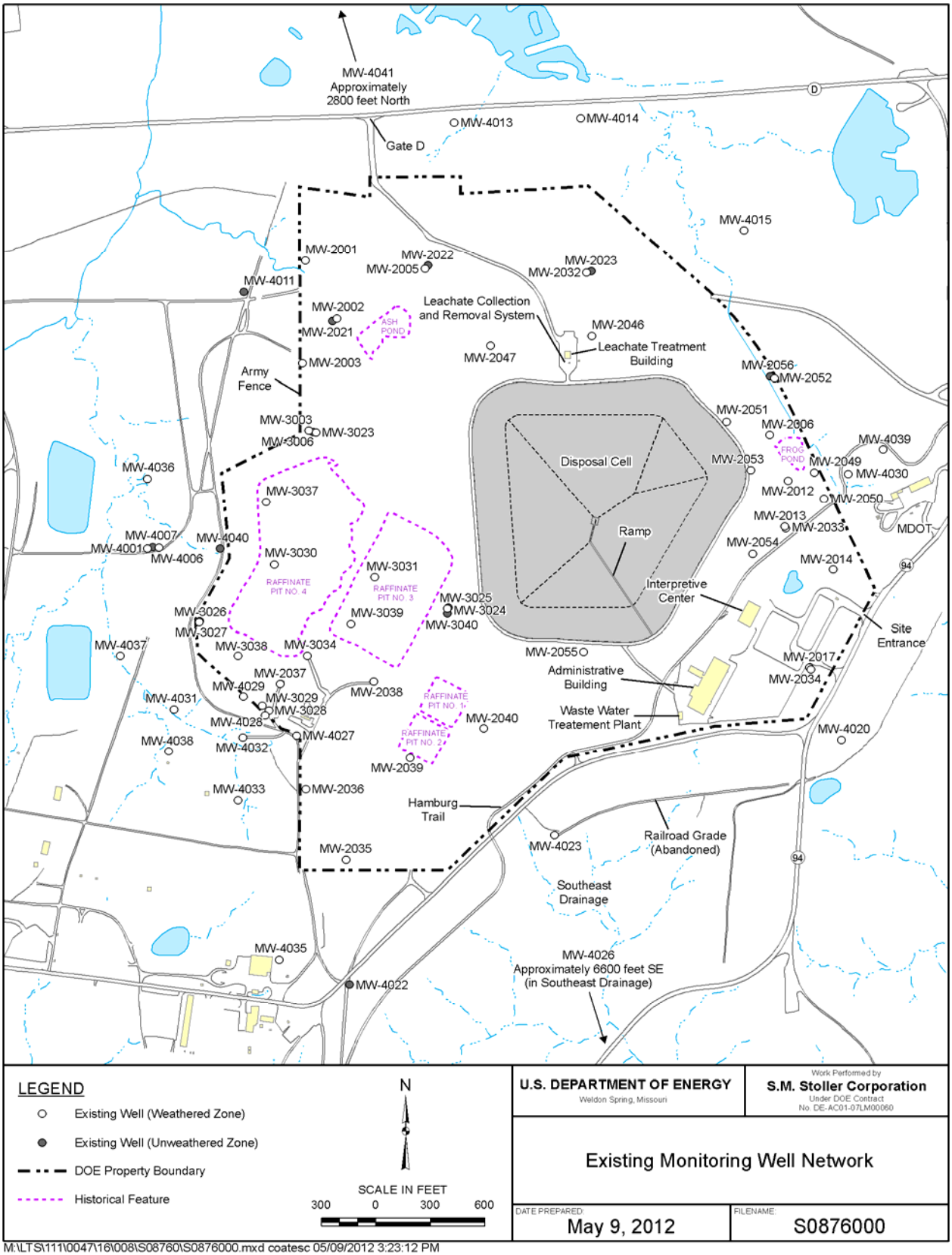

Figure 4. Existing Monitoring Well Network

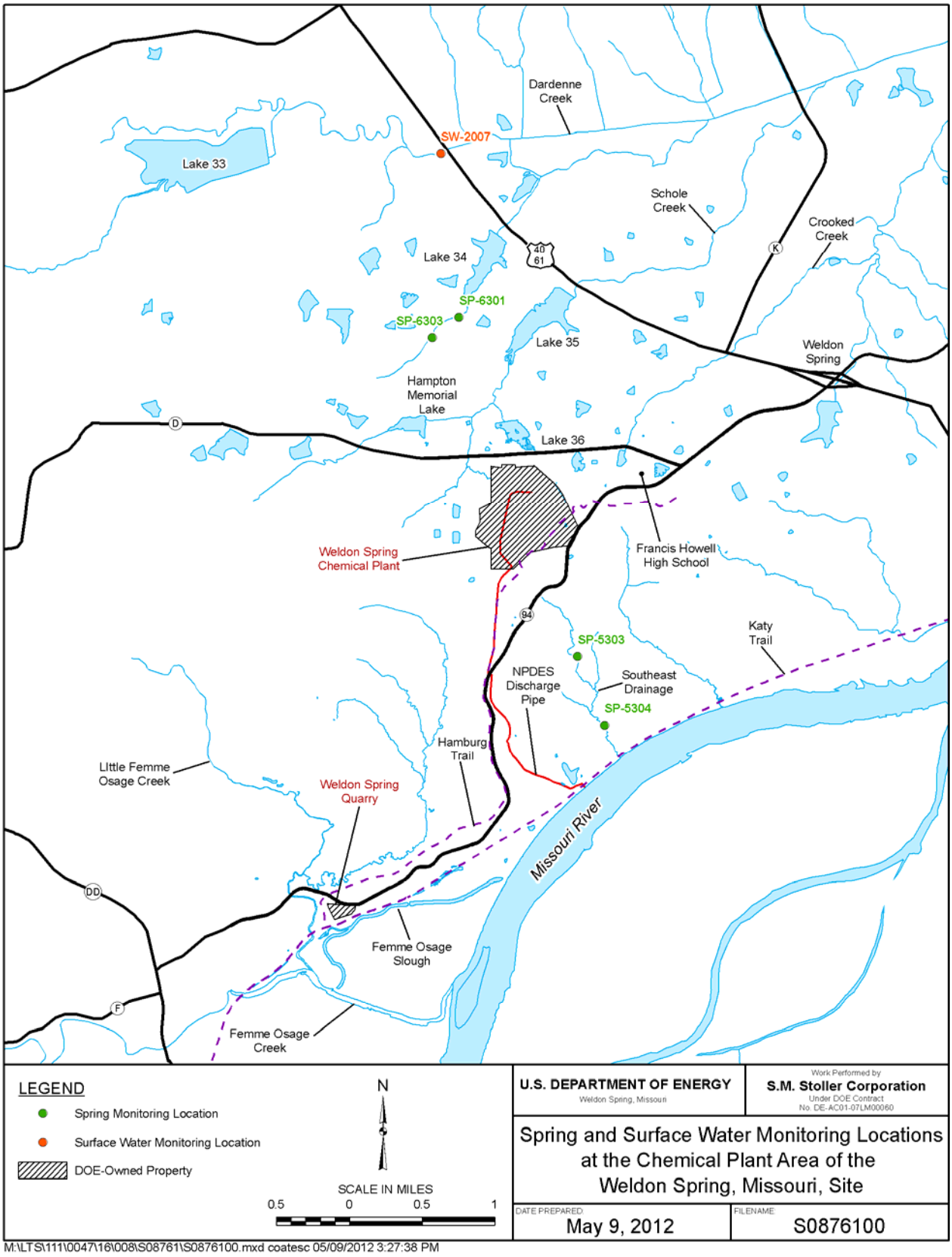

Figure 5. Spring and Surface Water Monitoring Locations at the Chemical Plant Area of the Weldon Spring, Missouri, Site

Nitrate is present in the groundwater near the former raffinate pits and the Ash Pond area, which are the historical sources of this contaminant. Nitrate is mobile in the shallow groundwater system, as it is not readily sorbed 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.

Groundwater contaminated with TCE is localized in the weathered portion of the bedrock aquifer in the vicinity of Raffinate Pit 4. The source of TCE contamination was drums that were disposed of in Raffinate Pit 4. The oxidizing conditions in the shallow bedrock aquifer do not promote the biodegradation of organic compounds.

Nitroaromatic compounds (1,3-dinitrobenzene [DNB]; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; and nitrobenzene) in the groundwater system coincide with former 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. The mobility of nitroaromatic compounds in the bedrock aquifer is high due to little sorption to the bedrock materials. Microorganisms indigenous to the soils and the shallow aquifer have the ability to transform and degrade TNT and DNT.

3.1.1.3 Chemical Plant (GWOU) Monitoring Program

Monitoring at the Chemical Plant was changed in July 2004 to focus on MNA, the selected remedy. Under the new monitoring program, total uranium, nitroaromatic compounds, TCE, and nitrate (as N) 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 are sampled to assess potential vertical movement.

The monitoring network consists of 50 wells, 4 springs, and 1 surface water location. The locations are depicted on Figure 4 and Figure 5. Each well was selected to fulfill objectives specified in the GWOU ROD (DOE 2004b) for the MNA monitoring network (Table 3). The objectives are as follows:

- Objective 1 is to monitor the unimpacted water quality at upgradient locations 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 plumes.
- 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.

Table 3. Monitoring Program for GWOU MNA Remedy

Location	Objective	Unit	Sampling Frequency	TCE	Nitrate (as N)	Uranium	1,3-TNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB
MW-2017	1	Weathered	A				✓	✓	✓	✓	✓
MW-2035	1	Weathered	A	✓	✓	✓			✓		
MW-4022	1	Unweathered	A		✓	✓					
MW-4023	1	Weathered	A		✓	✓					
MW-2012	2	Weathered	S				✓	✓	✓	✓	✓
MW-2014	2	Weathered	S						✓	✓	
MW-2038	2	Weathered	S		✓				✓		
MW-2040	2	Weathered	S		✓						
MW-2046	2	Weathered	S					✓			
MW-2050	2	Weathered	S						✓	✓	
MW-2052	2	Weathered	S						✓	✓	
MW-2053	2	Weathered	S					✓	✓	✓	
MW-2054	2	Weathered	S						✓	✓	
MW-3003	2	Weathered	S		✓	✓					
MW-3024	2	Unweathered	Q			✓ (Q)					
MW-3030	2	Weathered	S	✓		✓			✓		
MW-3034	2	Weathered	S	✓	✓				✓		
MW-3039	2	Weathered	S						✓		
MW-3040	2	Unweathered	Q		✓	✓ (Q)					
MW-4013	2	Weathered	S		✓						
MW-4029	2	Weathered	S	✓	✓						
MW-4031	2	Weathered	S		✓						
MW-4036	2	Weathered	S		✓						
MW-4040	2	Unweathered	Q		✓	✓ (Q)					
MW-2032	3	Weathered	A				✓	✓	✓	✓	✓
MW-2051	3	Weathered	A				✓	✓	✓	✓	✓
MW-3031	3	Weathered	A	✓		✓ (S)					
MW-3037	3	Weathered	A	✓		✓ (S)			✓		
MW-4013	3	Weathered	A						✓	✓	✓
MW-4014	3	Weathered	A		✓		✓	✓	✓	✓	✓
MW-4015	3	Weathered	A						✓	✓	✓
MW-4026	3	Alluvium/SED	A			✓ (S)					
MW-4036	3	Weathered	A	✓		✓ (Q)					
MW-4039	3	Weathered	A				✓	✓	✓	✓	✓
MW-4040	3	Unweathered	A	✓					✓		
MW-4041	3	Weathered	A	✓	✓	✓ (S)	✓	✓	✓	✓	✓

Table 3 (continued). Monitoring Program for GWOU MNA Remedy

Location	Objective	Unit	Sampling Frequency	TCE	Nitrate (as N)	Uranium	1,3-TNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB
MWS-1	3	Weathered	A	✓	✓	✓ (S)			✓		
MWS-4	3	Weathered	A	✓	✓	✓ (S)					
MW-2021	4	Unweathered	A		✓						
MW-2022	4	Unweathered	A	✓			✓	✓			
MW-2023	4	Unweathered	A				✓	✓	✓	✓	✓
MW-2056	4	Unweathered	A				✓	✓	✓	✓	✓
MW-3006	4	Unweathered	A	✓	✓	✓ (S)			✓		
MW-4007	4	Unweathered	A	✓	✓						
MW-4042	4	Unweathered	Q		✓	✓					
MWD-2	4	Unweathered	A		✓	✓ (S)					
SP-5303	5	Spring/SED	Q			✓					
SP-5304	5	Spring/SED	Q			✓					
SP-6301	5	Spring	Q	✓	✓	✓	✓	✓	✓	✓	✓
SP-6303	5	Spring	Q	✓	✓	✓	✓	✓	✓	✓	✓
SW-2007	5	Stream	A			✓					

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

A = annual; DNT = dinitrotoluene; Q = quarterly; NB = nitrobenzene; S = semiannual; SED = Southeast Drainage; TNB = trinitrobenzene; TNT = trinitrotoluene

- 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 are either not impacted or 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 in and influenced by the unweathered zone. No significant impacts should be observed at these locations.
- 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 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 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:

- 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.

Trigger levels were set for each contaminant at the performance and detection monitoring locations in the event that unexpected increases occur. There are two trigger levels for each contaminant (Table 4). The first trigger level is set at what would be considered a statistically significant increase of a contaminant at a location and is defined as the mean plus three standard deviations for the previous eight data points. The second trigger level was established as a fixed concentration that indicates unacceptable increases within the area of impact (Objective 2), outside the area of impact (Objectives 3 and 4), or at discharge points (Objective 5).

Table 4. Trigger Levels for Performance and Detection Monitoring for the GWOU

Analyte	Cleanup Standard	Objective 2	Objective 3 (near)	Objective 3 (far)	Objective 4	Objective 5
Nitrate as N (mg/L)	10	1,350	30	10	20	20
Uranium (pCi/L)	20	100	50	20	40	150
TCE (μg/L)	5	1,000	15	5	10	5
2,4-DNT (μg/L) – FP	0.11	2,300	1.1	0.11	0.22	0.22
2,4-DNT (μg/L) – RP		5	0.55			
2,6-DNT (μg/L)	1.3	2,000	13	1.3	2.6	1.3
2,4,6-TNT (μg/L)	2.8	500	11.2	2.8	5.6	2.8
1,3-DNB (μg/L)	1.0	20	4	1	2	1
NB (μg/L)	17	50	34	17	17	17

DNB = dinitrobenzene; DNT = dinitrotoluene; FP = Frog Pond; mg/L = milligrams per liter; μg/L = micrograms per liter; NB = nitrobenzene; pCi/L = picocuries per liter; RP = Raffinate Pits; TNT = trinitrotoluene

Groundwater data from the upgradient locations are compared with the previously collected data from each respective location. If a statistically significant increase (mean plus 3 standard deviations for the previous eight data points) is measured, then the value is evaluated for its validity. For those locations that are "nondetect," a statistically significant increase is considered to be the respective cleanup standard measured for two consecutive sampling periods. Contingency actions are defined in Appendix M of the LTS&M Plan.

Testing for temporal trends was performed using uranium, nitrate, TCE, and nitroaromatic compound data, 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 2004c) using data from the previous 5 years (2006 through 2011). 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 discharge points.

The Mann-Kendall test is used for temporal trend identification because it can easily facilitate 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 where there are a high number of nondetect data points. Data reported as trace concentrations or less than the detection limit can be used by assigning them a common value that is smaller than the smallest measured value in the data set (i.e., one-half the specified detection limit). 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 between sampling events. One-half the specified detection limit (on the date of analysis) was used in place of all concentrations reported at or below the detection limit. Estimated time frames of when a location may reach the MCL are provided only for those locations where statistically significant downward trends were identified.

3.1.1.4 Baseline Monitoring Results for the GWOU

Baseline conditions are monitored in four upgradient wells 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 determine if baseline conditions have remained unchanged. Each of these wells was sampled once during 2011. The concentration for each parameter is presented in Table 5. The concentrations measured in 2011 are similar to those from previous years and indicate no change in upgradient groundwater quality.

Table 5. 2011 Baseline Monitoring for the GWOU MNA Remedy

Location	MW-2017	MW-2035	MW-4022	MW-4023
Zone	Weathered	Weathered	Unweathered	Weathered
Parameters				
Uranium (pCi/L)	NR	0.44	2.5	1.9
Nitrate (as N) (mg/L)	NR	0.71	0.32	0.89
TCE (μg/L)	NR	ND (<1.0)	NR	NR
1,3-DNB (μg/L)	ND (<0.014)	ND (<0.013)	NR	NR
2,4,6-TNT (μg/L)	ND (<0.021)	ND (<0.021)	NR	NR
2,4-DNT (μg/L)	ND (<0.018)	ND (<0.018)	NR	NR
2,6-DNT (μg/L)	ND (<0.021)	ND (<0.021)	NR	NR
Nitrobenzene (μg/L)	ND (<0.032)	ND (<0.031)	NR	NR

DNB = dinitrobenzene; DNT = dinitrotoluene; mg/L = milligram per liter; μg/L = microgram per liter;
ND = analyte not detected above reporting limit indicated in parentheses; NR = analyte not required;
pCi/L = picocurie(s) per liter; TNT = trinitrotoluene

3.1.1.5 Performance Monitoring Results 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.

Contaminant concentrations are monitored using 20 wells (Figure 4) within the areas of highest impact of each contaminant plume at the site. These wells were sampled at least semiannually during 2011. The data are discussed in the following sections.

Uranium

The area of uranium impact is in the former Raffinate Pits area in the western portion of the site. Uranium levels exceed the MCL of 20 pCi/L in both the weathered and unweathered units of the Burlington-Keokuk Limestone. A summary of the uranium data for 2011 is presented in Table 6. Sampling frequencies were increased to bimonthly starting in April 2010 in support of a special study (see Section 3.1.1.7).

Table 6. 2011 Uranium Data from GWOU Objective 2 Wells

Location	Uranium (pCi/L)					
Weathered Unit	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
MW-3003		3.5	3.5	2.8	2.8	3.3
MW-3030	28.0	29.2	28.8	28.0	27.6	31.0
Unweathered Unit	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
MW-3024	108	124	102	115	118	127
MW-3040	94.8	108	96.8	102	108	110
MW-4040	264	300	308	311	315	331

pCi/L = picocuries per liter; B1, B2, B3, B4, B5, B6 = bimonthly sampling periods

Uranium impact in the weathered unit is monitored in two wells. The highest uranium levels in this unit are measured in MW-3030 (Figure 6) installed within the footprint of the former Raffinate Pits. The Objective 2 wells screened in the weathered unit show decreasing uranium levels. The levels in MW-3003 have consistently been less than the MCL since 2000.

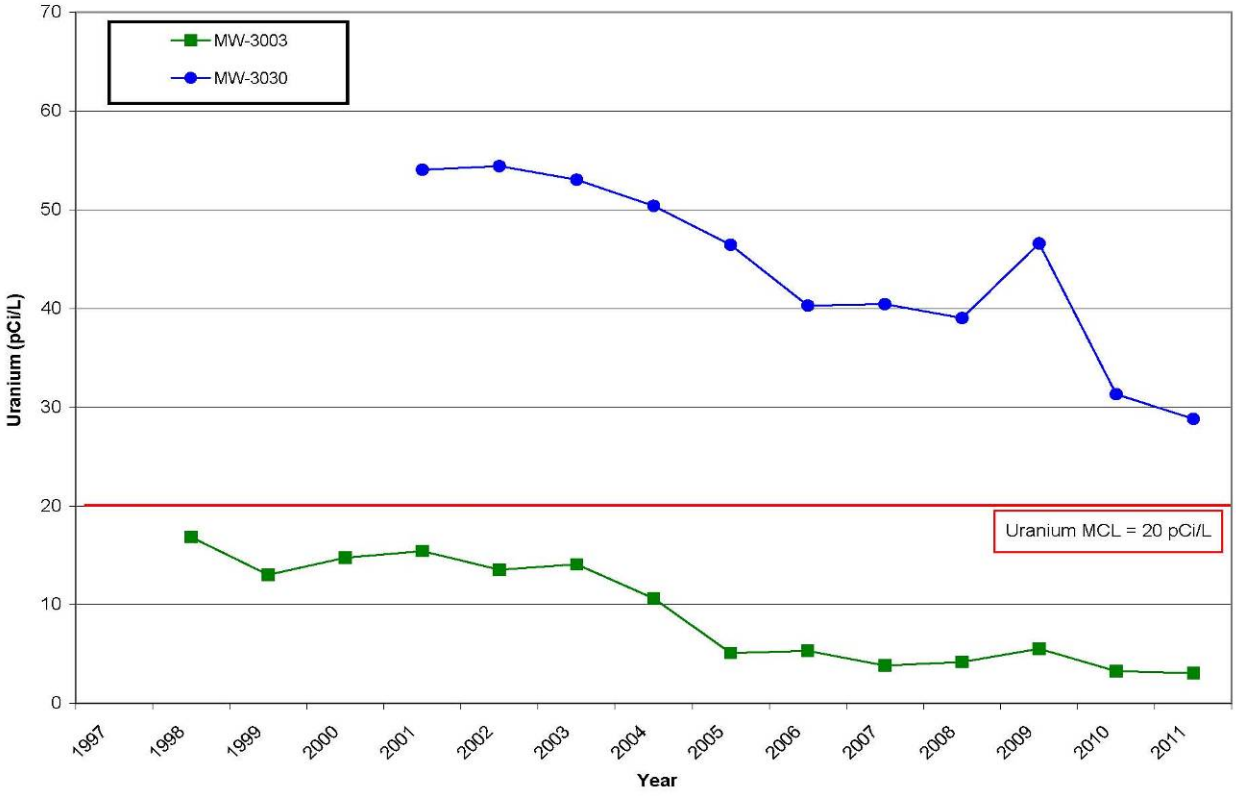

Figure 6. Average Uranium Levels in Objective 2 Wells Screened in the Weathered Unit (1997–2011)

Results for trend analysis of uranium data from the weathered unit wells (Table 7) indicate that uranium levels for the past 5 years have shown an overall decline, as indicated by negative slopes. A statistically significant downward trend was determined from the data from MW-3030.

If the current decrease in uranium levels continues in MW-3030, the MCL of 20 pCi/L could be reached by 2015, based on an estimate derived from an exponential curve model.

Table 7. Trending Analysis for Uranium in Objective 2 MNA Weathered Unit Wells (2007–2011)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
MW-3003	15	None	–0.38	–0.64	0
MW-3030	18	**Down**	–3.1	–3.6	–2.3

pCi/L/yr = picocurie(s) per liter per year

Uranium impact is greatest in the wells that were installed in the unweathered unit within the footprint and immediately downgradient of the former Raffinate Pits. Removal of the raffinate pits was 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 levels in these wells have consistently been greater than the MCL of 20 pCi/L (Figure 7). Overall, the uranium levels in these two wells have increased since installation. Trigger values for uranium impact in the unweathered unit are being evaluated through the continuation of a special study that was started in 2008 (see Section 3.1.1.7).

Results from the trend analyses for uranium in the unweathered unit (Table 8) indicate increasing uranium levels in the three Objective 2 wells screened in the unweathered unit, as indicated by positive slopes. A statistically significant upward trend was calculated for well MW-3040, using data from the past 5 years. Analysis of the uranium data from MW-3024 and MW-4040 indicates no trend, either upward or downward.

Table 8. Trending Analysis for Uranium in Objective 2 MNA Unweathered Unit Wells (2007–2011)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
MW-3024	22	None	3.7	0	7.3
MW-3040	25	**Up**	2.3	0.37	4.4
MW-4040	25	None	0.28	–14.6	16.4

pCi/L/yr = picocurie(s) per liter per year

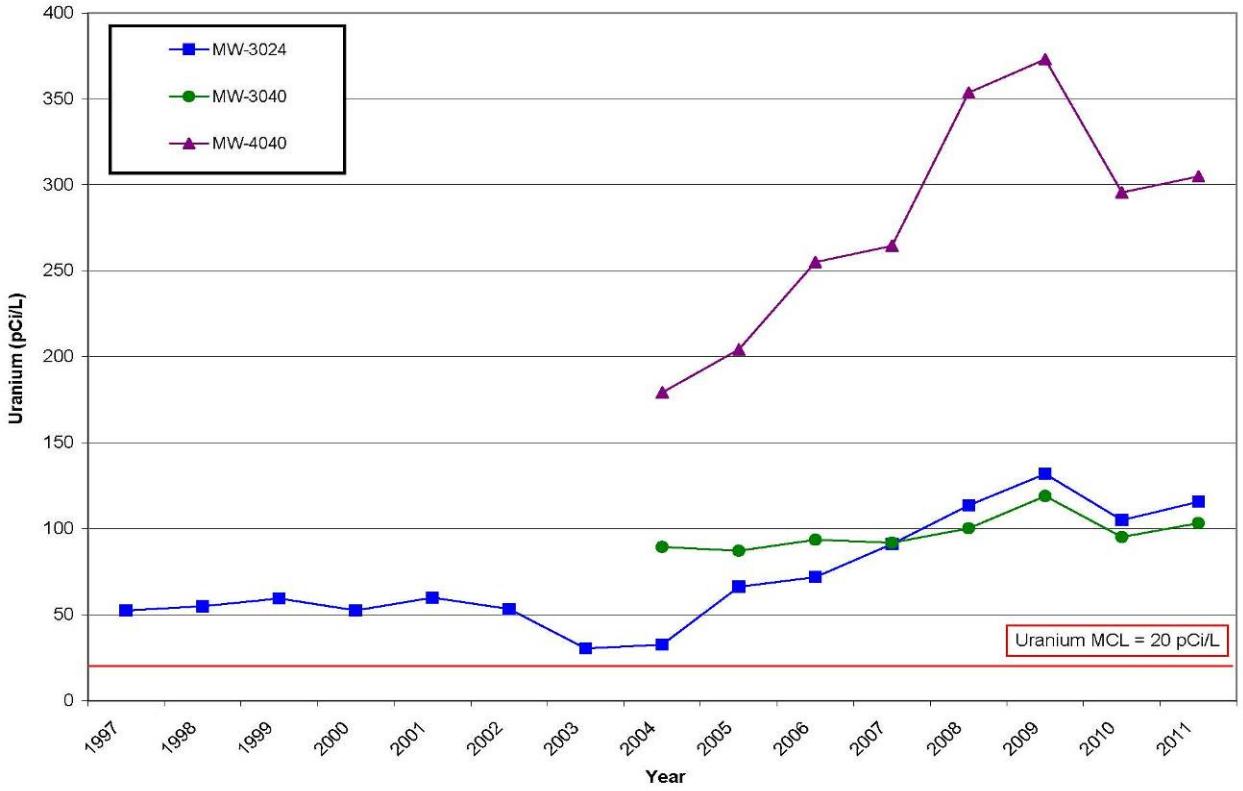

Figure 7. Average Uranium Levels in Objective 2 Wells Screened in the Unweathered Unit (1997−2011)

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). The MCL for uranium could be attained in this portion of the shallow aquifer by 2015 if decreases continue at the current rate. Uranium levels within the less-permeable unweathered unit are increasing due to desorption of uranium from residual materials as a result of reduced recharge at greater depths in the aquifer, where flushing is more limited. Any recharge that does enter the system is more likely to move horizontally through the weathered unit than vertically into the unweathered unit due to greater hydraulic conductivity in the horizontal direction and the lack of a vertical driving force to move the water downward as was previously exerted by water in the Raffinate Pits.

Nitrate (as N)

The highest concentrations of nitrate have been measured in the former Raffinate Pits area. Elevated nitrate concentrations are also present in the former Ash Pond area. Both are historical sources of this contaminant. The higher mobility of nitrate, as compared to other contaminants at the site, has resulted in a larger distribution in the shallow aquifer. Nitrate levels exceed the MCL of 10 milligrams per liter (mg/L) (for nitrate as N) in both the weathered and unweathered units of the Burlington-Keokuk Limestone. A summary of the nitrate data for 2011 is presented in Table 9.

Nitrate concentrations are highest in the weathered unit of the Burlington-Keokuk Limestone and are measured in wells that are in the former Raffinate Pits area (MW-2038, MW-3003, and

MW-4029) (Figure 8). Recent data show stable nitrate concentrations in all of the wells for the past 3 or 4 years. The overall general decline in concentrations is the result of source removal in the Raffinate Pits and Ash Pond areas.

Table 9. 2011 Nitrate Data from GWOU Objective 2 Wells

Location	Nitrate (as N) Concentration (mg/L)	
Weathered Unit	**S1**	**S2**
MW-2038	490	480
MW-2040	85.0	93.5
MW-3003	470	462
MW-3034	190	190
MW-4013	90.0	101
MW-4029	427	425
MW-4031	220	161
MW-4036	21.0	45.5
Unweathered Unit	**S1**	**S2**
MW-3040	125	106
MW-4040	122	116

mg/L = milligrams per liter; S1, S2 = semiannual sampling periods.

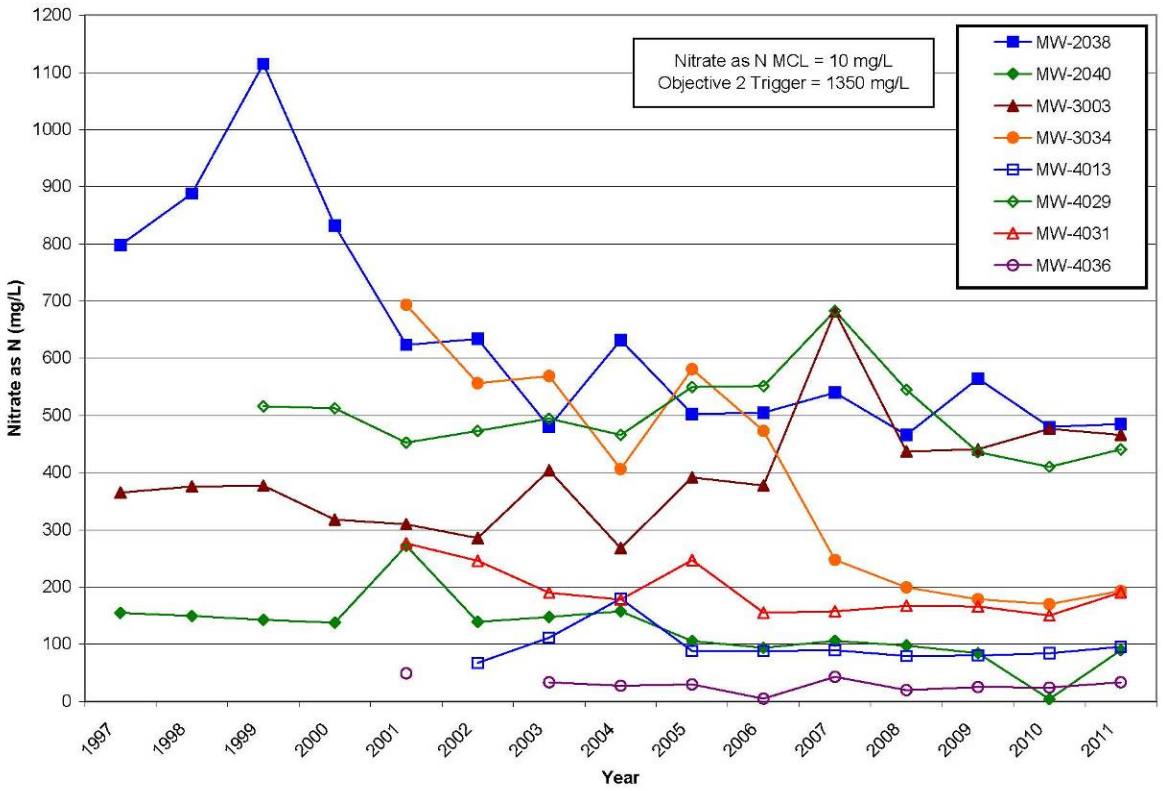

Figure 8. Average Nitrate Concentrations in Objective 2 Wells Screened in the Weathered Unit (1997−2011)

Results of trend analysis of nitrate data from the weathered unit indicate decreasing levels over the past 5 years in all of the wells except MW-4031 and MW-4036, as indicated by negative slopes (Table 10). No statistically significant trends, either upward or downward, were calculated for any of the Objective 2 wells.

Table 10. Trending Analysis for Nitrate (as N) in Objective 2 MNA Weathered Unit Wells (2007–2011)

Location	No. of Samples	Trend	Slope (mg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2038	10	None	0	–35.6	20.7
MW-2040	10	None	–6.2	–14.7	8.9
MW-3003	14	None	–17.2	–40.6	21.8
MW-3034	11	None	–13.0	–32.7	3.3
MW-4013	9	None	2.6	–2.7	8.8
MW-4029	10	None	–25.8	–110	2.9
MW-4031	10	None	6.8	–14.3	22.6
MW-4036	17	None	3.2	–3.4	9.0

mg/L/yr = milligram(s) per liter per year

Nitrate concentrations in the unweathered unit exceed the MCL only in the Raffinate Pits area. The nitrate concentrations in MW-3040 have decreased since monitoring was started in 2004 (Figure 9). Nitrate concentrations in MW-4040 increased in 2008; however, the concentrations have declined since that time. Well MW-4040 is downgradient of MW-3040, and the historical increase observed in MW-4040 is likely the eventual migration of groundwater with higher nitrate concentrations that were measured at MW-3040. Presently the concentrations of nitrate are similar in both wells.

Results of trend analysis show decreasing concentrations over the past 5 years, as indicated by negative slopes (Table 11). A statistically significant downward trend was calculated for MW-3040. If the current decreases in nitrate concentrations continue in MW-3040, the MCL of 10 mg/L (for nitrate as N) could be reached by 2038, based on an estimate derived from an exponential curve model.

Table 11. Trending Analysis for Nitrate (as N) in Objective 2 MNA Unweathered Unit Wells (2007–2011)

Location	No. of Samples	Trend	Slope (mg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-3040	20	**Down**	–11.0	–15.5	–6.0
MW-4040	21	None	–7.1	–17.9	6.7

mg/L/yr = milligram(s) per liter per year

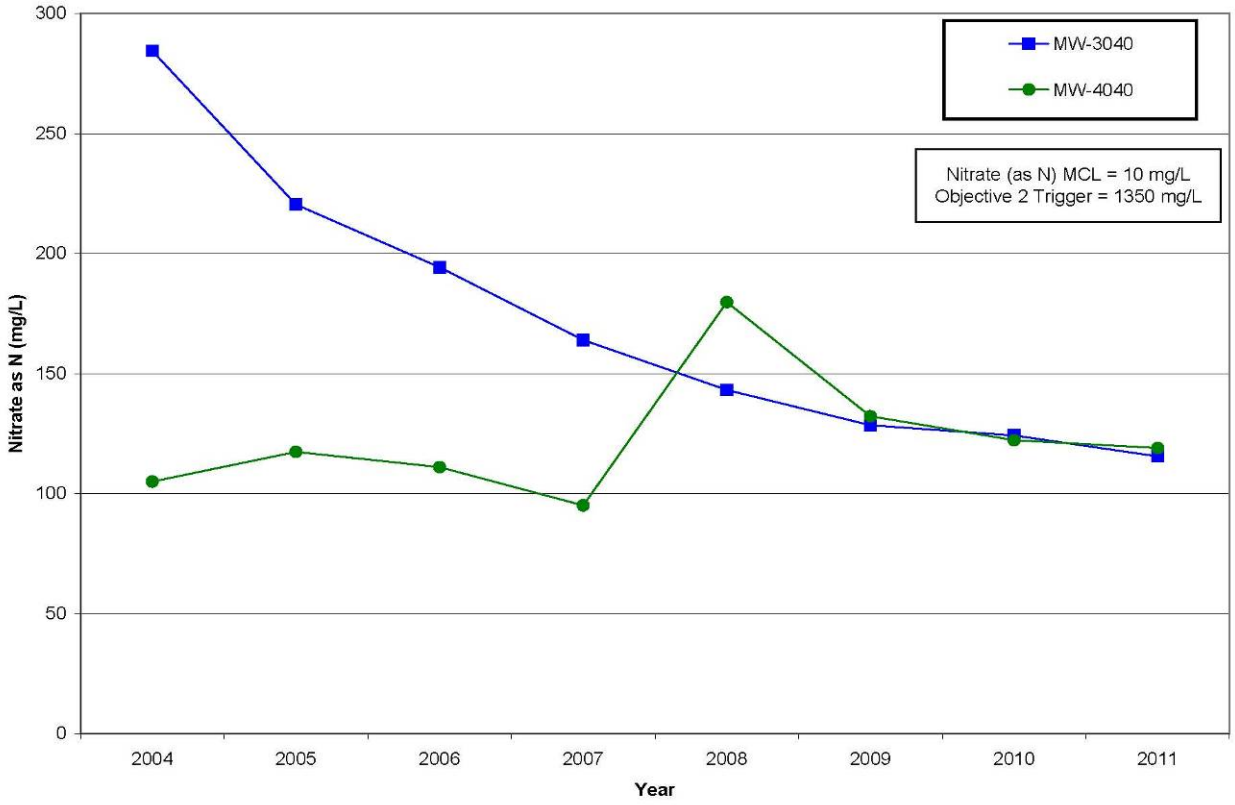

Figure 9. Average Nitrate Concentrations in Objective 2 Wells Screened in the Unweathered Unit (2004−2011)

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 (MW-4031). 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. Trigger values were developed to account for these expected increases. The higher mobility of nitrate, as compared to other contaminants at the site, has resulted in more rapid flushing of this contaminant from the aquifer system.

Trichloroethene

TCE contamination in the shallow groundwater is located in the vicinity of former Raffinate Pit 4, where drums containing TCE residues are suspected to have been discarded. TCE impact is detected in only the weathered unit of the Burlington-Keokuk Limestone. A summary of the TCE data for 2011 is presented in Table 12.

Table 12. 2011 TCE Data from GWOU Objective 2 Wells

Location	TCE Concentration (µg/L)	
	S1	S2
MW-3030	265	232
MW-3034	160	146
MW-4029	400	239

µg/L = micrograms per liter; S1, S2 = semiannual sampling periods

TCE impact is highest in MW-4029, along a preferential flow pathway in the area. The TCE concentrations in MW-3030 and MW-3034 have varied over time (Figure 10); however, some historical changes are a result of rebound from field studies (in situ chemical oxidation and pump and treat) performed in 2001 and 2002. Data from recent years indicate an overall decrease in TCE concentrations in these three wells since MNA monitoring started in 2004. Concentrations of TCE in all of the Objective 2 wells continue to exceed the MCL.

Low levels of the TCE breakdown product *cis*-1,2-dichloroethene (DCE) are measured in the three Objective 2 wells and the concentrations are significantly less than the MCL of 70 µg/L. Estimated detections of *trans*-1,2-DCE less than 1 µg/L are reported in the three Objective 2 wells. No detectable concentrations of vinyl chloride were reported in any of the Objective 2 wells. Oxidizing conditions are present in groundwater at the chemical plant; therefore, reductive dechlorination of TCE is limited. Dilution and dispersion are the primary attenuation mechanisms for TCE in groundwater.

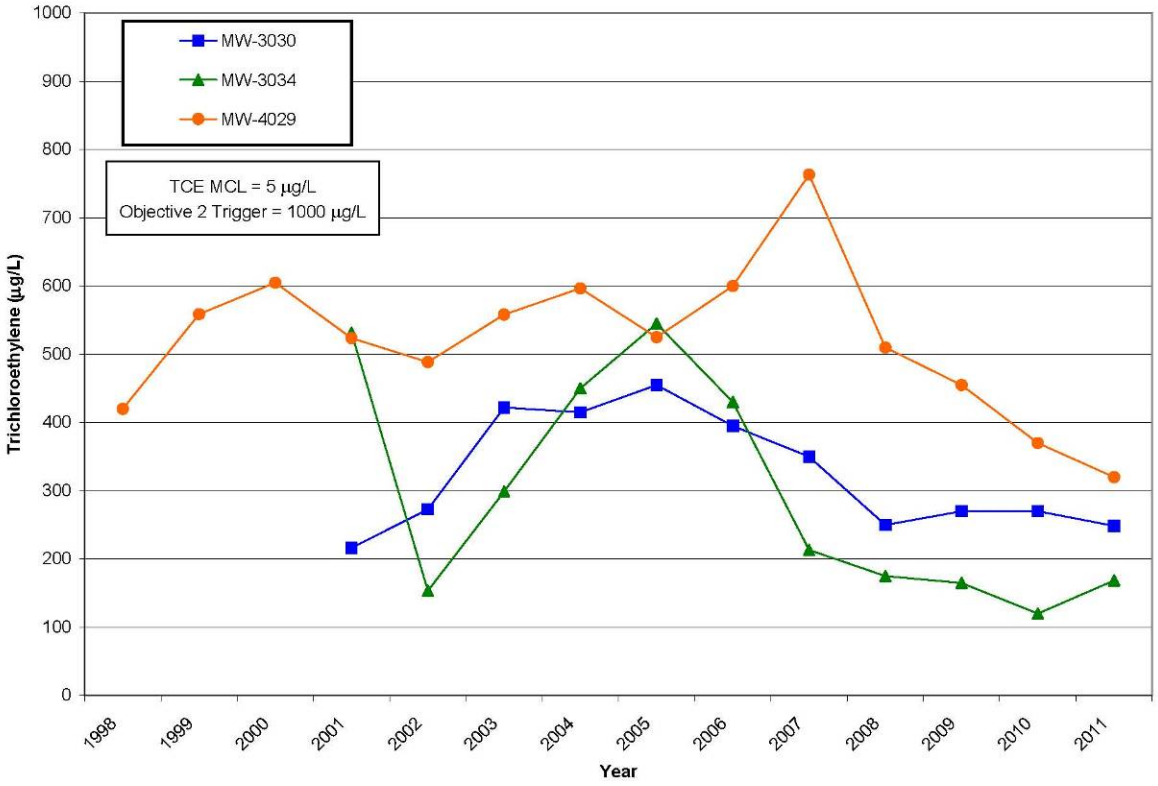

Figure 10. Annual Average TCE Concentrations in Objective 2 Wells (1998−2011)

Results of the trend analysis for the Objective 2 TCE wells indicate that concentrations in groundwater are decreasing, as indicated by negative slopes (Table 13). Statistically significant downward trends for MW 3034 and MW 4029 were calculated from the data collected over the last 5 years. If the current decreases in TCE concentrations continue in MW-3034 and MW-4029, the MCL of 5 µg/L could be reached by 2023 in MW-3034 and 2033 in MW-4029, based on estimates derived from an exponential curve model.

Table 13. Trending Analysis for TCE in Objective 2 MNA Wells (2007–2011)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-3030	11	None	–19.4	–67.8	14.6
MW-3034	11	**Down**	–14.7	–28.6	0
MW-4029	11	**Down**	–79.4	–199	–42.1

µg/L/yr = micrograms per liter per year

Overall, TCE impact is confined to a discrete area near the former Raffinate Pits site and is limited to the weathered unit of the Burlington-Keokuk Limestone. TCE concentrations in the weathered unit are decreasing in the area of impact. The MCL for TCE could be attained by 2033, if decreases continue at the current rate.

Nitroaromatic Compounds—Former Frog Pond Area

The area of greater nitroaromatic compound groundwater impact at the site is in the former Frog Pond area and is limited to the weathered unit of the Burlington-Keokuk Limestone. Groundwater in this area has historically shown impact above the cleanup standards for 1,3-DNT; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; and nitrobenzene (NB). Recent data have indicated that several Objective 2 wells have concentrations less than cleanup standards for some compounds.

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). Some contribution to the nitroaromatic contamination originates from Army Lagoon #1. The preferential flow path in the vicinity of Frog Pond has been identified from the bedrock topography, and the contaminant distribution is controlled somewhat by the topography. Nitroaromatic compound impact in the former Frog Pond area is isolated to the weathered unit of the Burlington-Keokuk Limestone.

In recent years, nitroaromatic compound concentrations, primarily the DNT isomers, have varied 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 the U.S. Army Corps of Engineers in nearby Army Lagoon 1. Also during this time frame, groundwater elevations steadily decreased, likely in response to the removal of the Frog Pond and redirection of surface water runoff, both of which reduced the amount of infiltration into the groundwater system. Nitroaromatic compound concentrations in several wells in this area dramatically decreased in 2004. The suspected cause

was the infiltration of surface water runoff into the groundwater system through a subsidence feature that formed near MW-2012. Continued influence of surface water infiltration has been observed in the fluctuation of groundwater elevations in this area. In recent years, groundwater elevations have generally increased in wells along the preferential pathway, and the increase is likely attributable to surface water contribution in a natural drainage channel that is beginning to establish in this area.

Concentrations of 1,3-DNB in MW-2012 were reported as estimated values (Table 14). Starting in 2006, the average concentration decreased below the cleanup standard of 1.0 µg/L (Figure 11). Decreases in 1,3-DNB are expected, as this nitroaromatic compound is a photodegradation breakdown product of 2,4-DNT. Increases in concentration 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.

Table 14. 2011 1,3-DNB Data from GWOU Objective 2 Wells

Location	1,3-DNB Concentration (µg/L)	
	S1	S2
MW-2012	0.043 (J)	0.051 (J)

µg/L = microgram per liter; J = estimated value less than the reporting limit

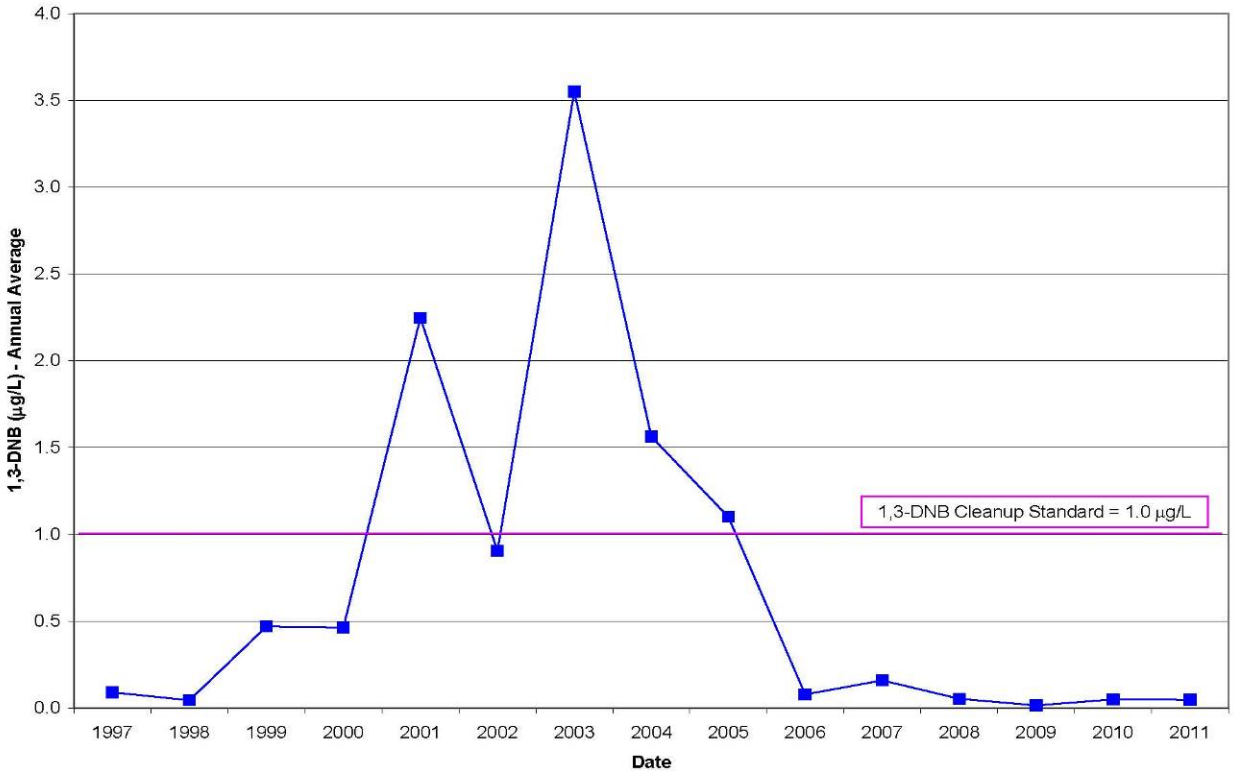

Figure 11. Annual Average 1,3-DNB Concentrations in MW-2012 (1997–2011)

Results of the trend analyses for 1,3-DNB (Table 15) indicated decreasing concentrations, as indicated by the negative slope in the Objective 2 well in the former Frog Pond area. Analysis of the data for MW-2012 indicates no trend either upward or downward; however, concentrations for the past 6 years have been less than the cleanup standard and can be regarded as stable due to the small slope and confidence intervals.

Table 15. Trending Analysis for 1,3-DNB in Objective 2 MNA Wells (2007–2011)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2012	9	None	–0.004	–0.036	0.014

µg/L/yr = microgram per liter per year

The highest 2,4,6-TNT concentrations are monitored in MW-2012 and MW-2053, which are close to where TNT production buildings once stood (Table 16). Concentrations of TNT have generally decreased in the Frog Pond area (Figure 12), with the largest decrease in MW-2012. Well MW-2046 monitors a discrete area of TNT impact that is located in the north-central portion of the site. Concentrations of 2,4,6-TNT were variable in MW-2012 and MW-2053 and may be the result of fluctuating groundwater levels. The annual average TNT concentrations in all of the Objective 2 wells have been less than the cleanup standard of 2.8 µg/L since 2009.

Table 16. 2011 2,4,6-TNT Data from GWOU Objective 2 Wells

Location	2,4,6-TNT Concentration (µg/L)	
	S1	S2
MW-2012	0.28	1.6
MW-2046	0.68	0.61
MW-2053	0.19	1.9

µg/L = microgram(s) per liter

Trend analysis of 2,4,6-TNT data collected from 2007 through 2011 indicates decreasing concentrations in all of the Objective 2 wells, as indicated by negative slopes (Table 17). Statistically significant downward trends were calculated for MW-2012 and MW-2046. Analysis of the data from MW-2053 indicated no trend, either upward or downward.

Table 17. Trending Analysis for 2,4,6-TNT in Objective 2 MNA Wells (2007–2011)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2012	8	**Down**	–2.0	–8.5	–0.04
MW-2046	7	**Down**	–1.1	–2.4	–0.07
MW-2053	8	None	–0.70	–5.6	0.79

µg/L/yr = microgram(s) per liter per year

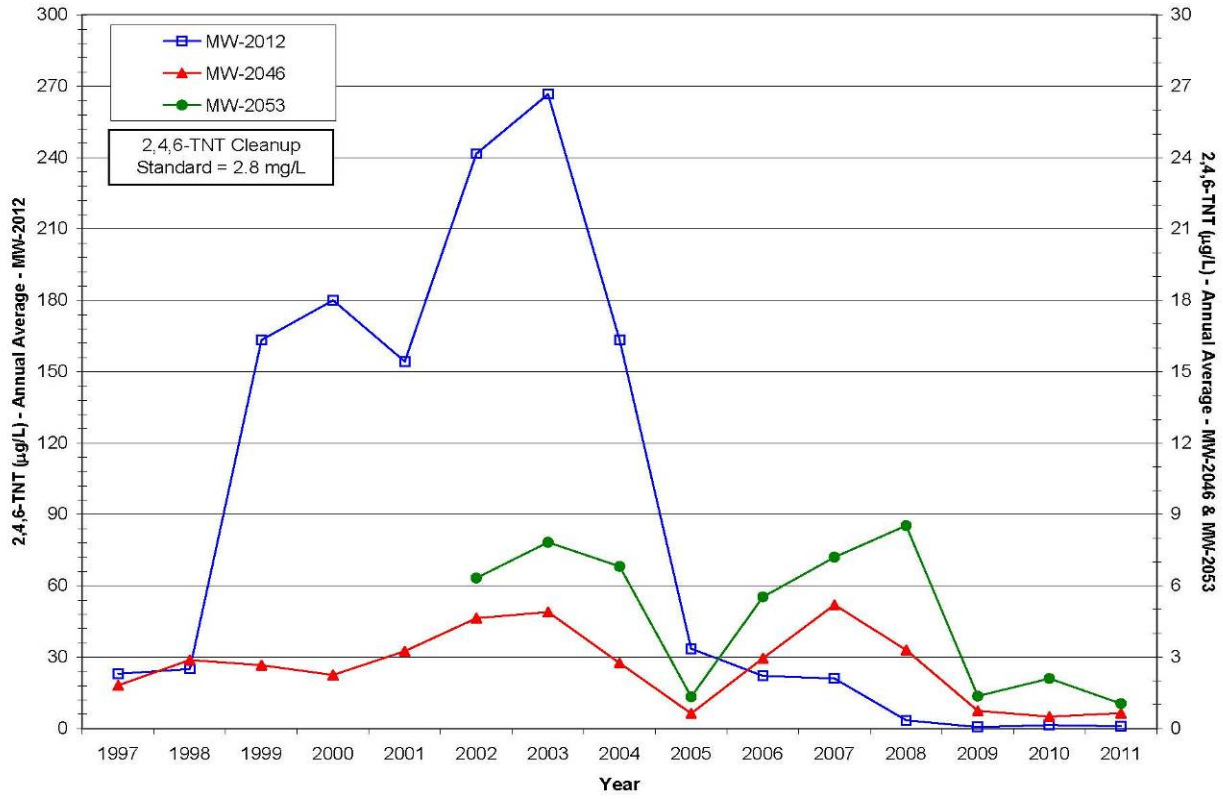

Figure 12. Annual Average 2,4,6-TNT Concentrations in Objective 2 Wells (1997–2011)

The nitroaromatic compounds 2,4-DNT and 2,6-DNT are the most persistent in groundwater at the site. Data continue to indicate that concentrations of DNT are variable in most of the Objective 2 wells (Table 18 and Table 19). The concentrations of these compounds can vary significantly between sampling events. This variability in 2,4-DNT and 2,6-DNT may be attributed to the introduction of surface water into the groundwater system during the spring when the first samples were collected. Concentrations of these compounds are typically higher during periods of low groundwater elevations and decrease as groundwater elevations rise. The introduction of surface water infiltration temporarily dilutes the concentrations in groundwater.

The changes in 2,4-DNT and 2,6-DNT concentrations in the former Frog Pond area are generally similar in each well. The highest concentrations of 2,4-DNT and 2,6-DNT are reported in MW-2012, MW-2050, and MW-2053 (Figure 13, Figure 14, and Figure 15), which are downgradient of the TNT-production buildings and Army Lagoon 1. Data from these wells exceed the cleanup standards for both 2,4-DNT and 2,6-DNT. Data from MW-2012 are similar in magnitude to those measured since 2008. Concentrations in well MW-2050 have decreased since 2008. The concentrations reported for MW-2053 in 2010 were new highs and decreased significantly in 2011. The concentrations reported for these locations are significantly less than the Objective 2 triggers. Concentrations of 2,4-DNT in MW-2052 and MW-2054 were less than the cleanup standard of 0.11 µg/L, and concentrations of 2,6-DNT in MW-2014, MW-2052, and MW-2054 were less than the cleanup standard of 1.3 µg/L in 2011 (Figure 16).

Table 18. 2011 2,4-DNT Data from GWOU Objective 2 Wells in the Frog Pond Area

Location	2,4-DNT Concentration (μg/L)	
	S1	S2
MW-2012	0.33	6.3
MW-2014	0.12	0.12
MW-2050	22.0	19.0
MW-2052	0.050 (J)	0.074 (J)
MW-2053	ND (<0.019)	11.0
MW-2054	0.091 (J)	0.062 (J)

μg/L = microgram(s) per liter

Table 19. 2011 2,6-DNT Data from GWOU Objective 2 Wells

Location	2,6-DNT Concentration (μg/L)	
	S1	S2
MW-2012	3.0	34.0
MW-2014	0.34	0.36
MW-2050	32.0	27.0
MW-2052	0.098 (J)	0.21
MW-2053	19.0	86.0
MW-2054	0.23	0.16

μg/L = microgram(s) per liter

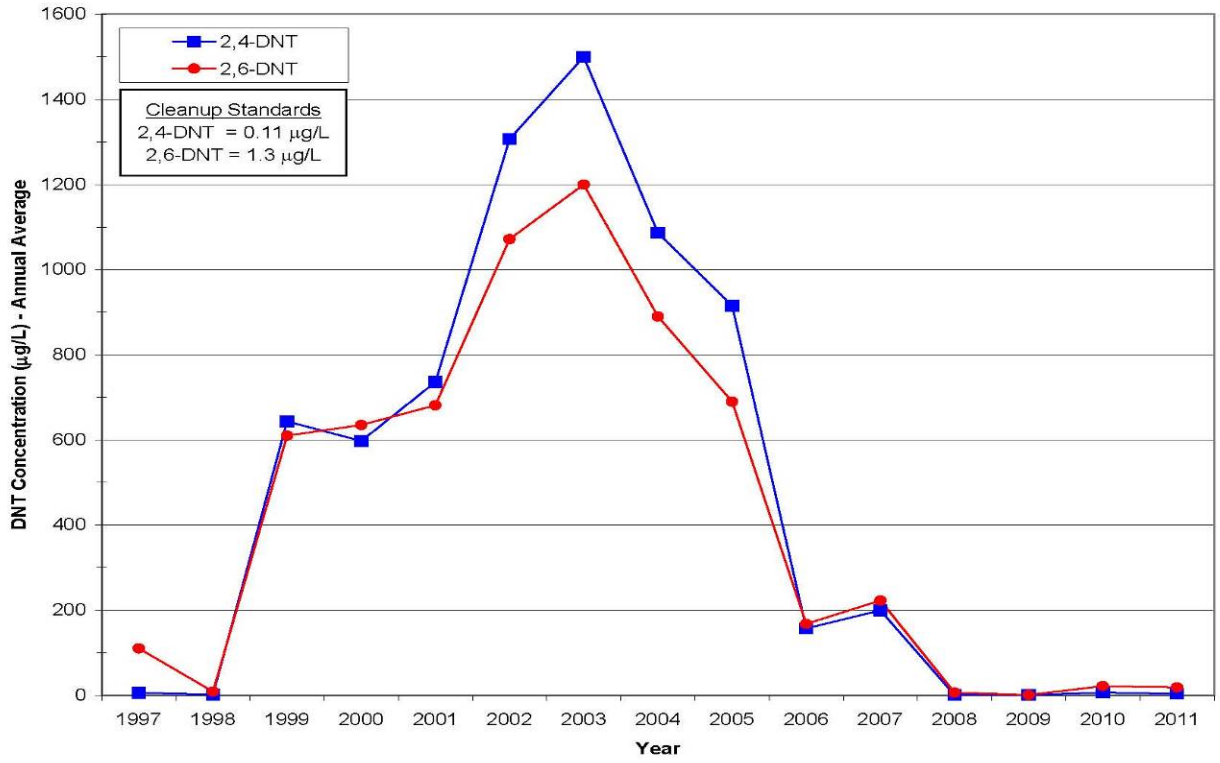

Figure 13. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2012 (1997–2011)

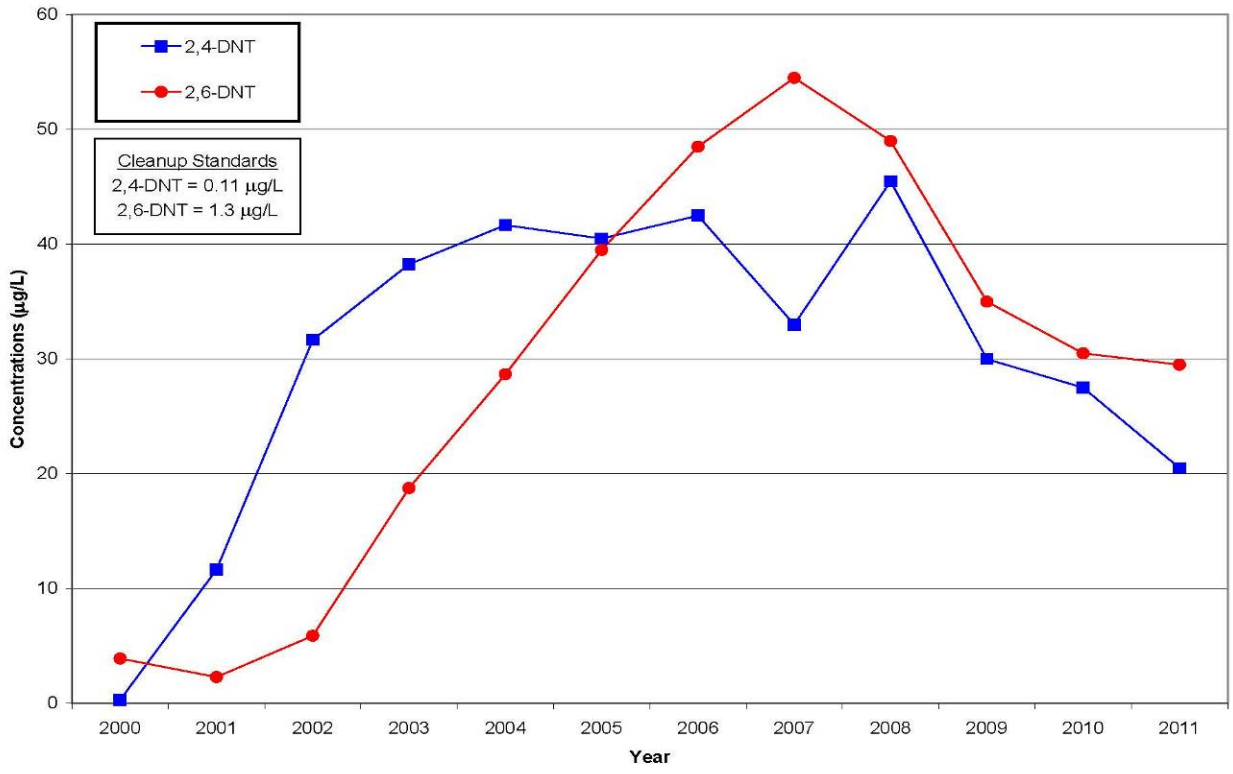

Figure 14. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2050 (2000–2011)

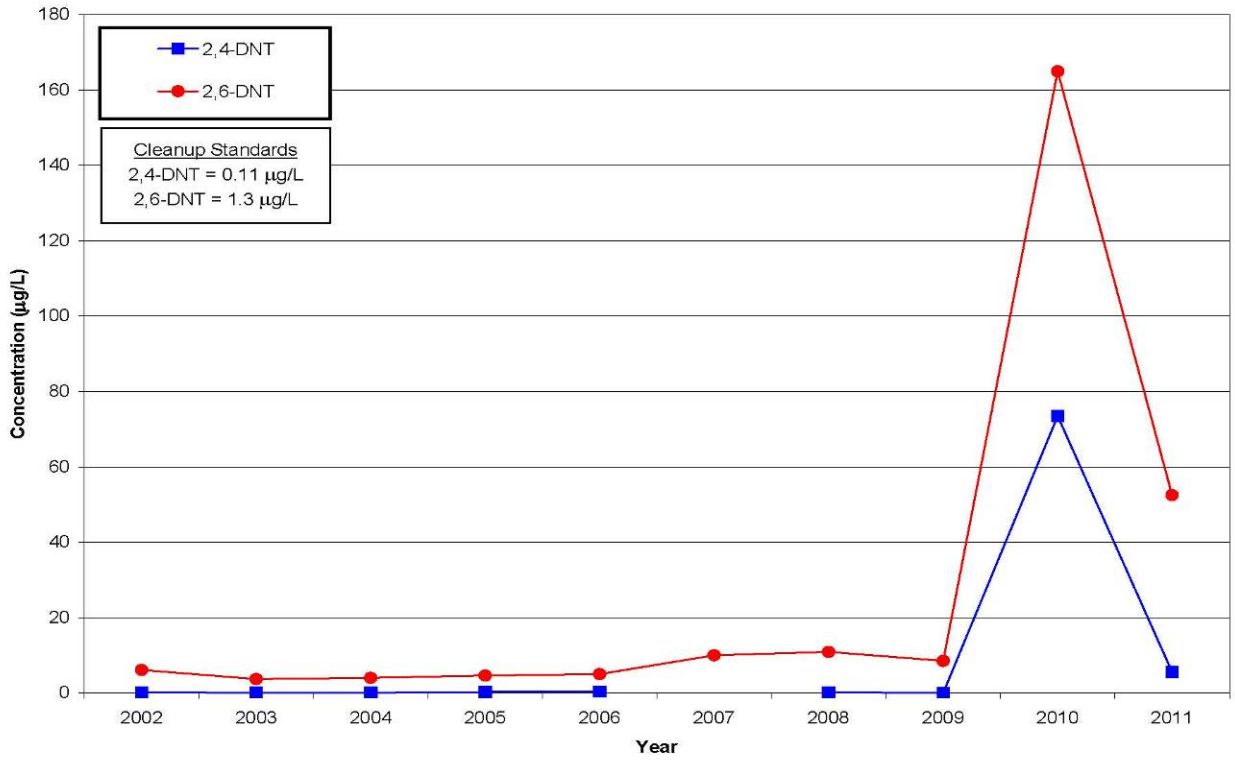

Figure 15. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2053 (2002–2011)

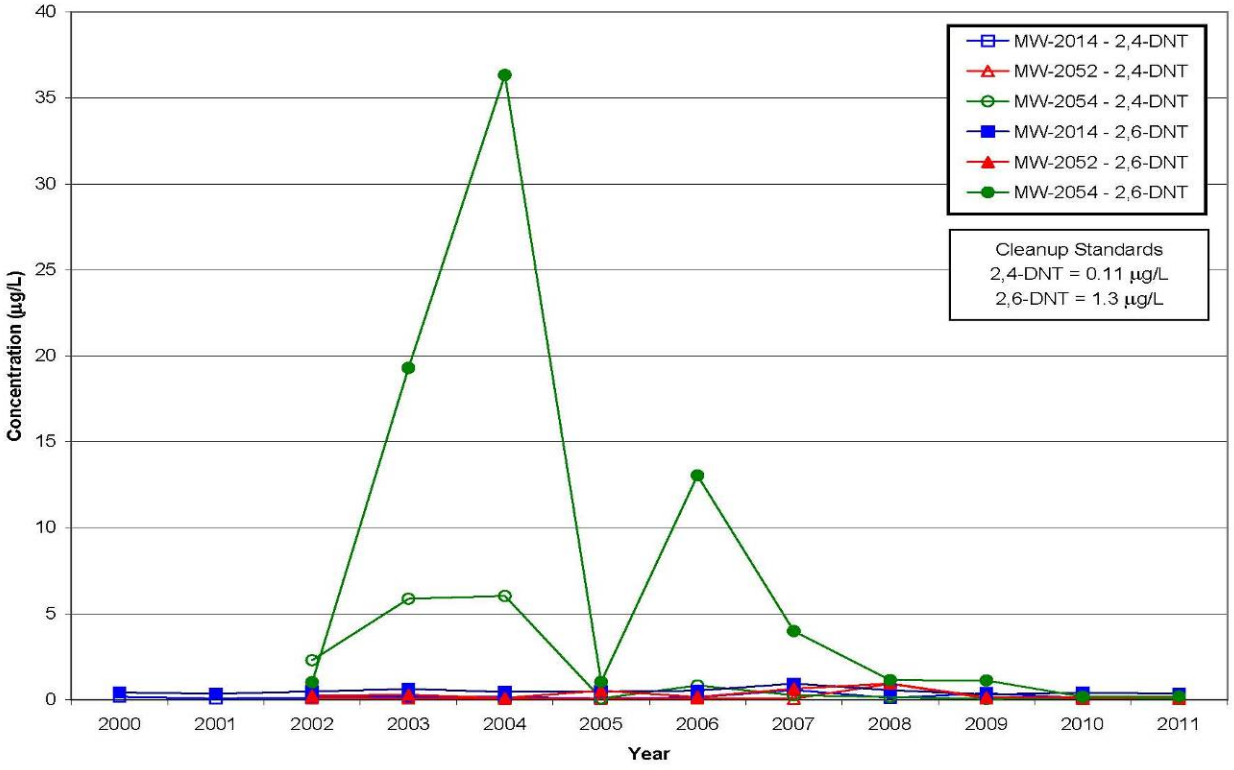

Figure 16. Annual Average 2,4-DNT and 2,6-DNT Concentrations in MW-2014, MW-2052, and MW-2054 (2000–2011)

Trend analysis of 2,4-DNT data from 2007 through 2011 indicate decreasing concentrations in all of the Objective 2 wells except MW-2053, as indicated by negative slopes (Table 20). A statistically significant downward trend was calculated for MW-2050. If current decreases continue, the cleanup standard of 0.11 µg/L for 2,4-DNT could be attained by 2049, based on an estimate derived from an exponential curve model. A review of the trend data suggests that concentrations of 2,4-DNT are relatively stable in wells MW-2014, MW-2052, and MW-2054, where slopes and confidence intervals are small.

Trend analysis of 2,6-DNT data, using the data from 2007 through 2011, indicates decreasing concentrations in all of the wells except MW-2053, as indicated by negative slopes (Table 21). A statistically significant downward trend was calculated for wells MW-2050. If current decreases continue, the cleanup standard of 1.3 µg/L for 2,6-DNT could be attained by 2029, based on an estimate derived from an exponential curve model. A review of the trend data suggests that concentrations of 2,6-DNT are relatively stable in wells MW-2014, MW-2052, and MW-2054, where slopes and confidence intervals are small.

Table 20. Trending Analysis for 2,4-DNT in Objective 2 MNA Wells in the Frog Pond Area (2007–2011)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2012	10	None	–0.45	–11.2	1.9
MW-2014	10	None	–0.04	–0.21	0.04
MW-2050	10	**Down**	–4.3	–9.9	0
MW-2052	9	None	–0.01	–0.04	0.01
MW-2053	8	None	1.8	–0.26	36.4
MW-2054	10	None	–0.02	–0.10	0.02

µg/L/yr = microgram(s) per liter per year

Table 21. Trending Analysis for 2,6-DNT in Objective 2 MNA Wells (2007–2011)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2012	10	None	–1.0	–48.5	12.4
MW-2014	10	None	–0.04	–0.30	0.02
MW-2050	10	**Down**	–7.2	–10.1	–3.6
MW-2052	10	None	–0.02	–0.34	0.04
MW-2053	10	None	4.9	–0.90	54.7
MW-2054	10	None	–0.01	–1.6	0.04

µg/L/yr = microgram(s) per liter per year

Well MW-2012 is the only location where NB is monitored. NB has not been detected at this location since 2002, when a one-time detection of 69 µg/L was reported. The cleanup standard for NB is 17 µg/L.

Overall, nitroaromatic compound impact in the former Frog Pond area is confined to the weathered unit of the Burlington-Keokuk Limestone. The concentrations of 2,4-DNT and 2,6-DNT continue to be variable; however, samples from only a few locations exceed the cleanup standards, and no statistically significant upward trends have been identified in the data from the past 5 years. Concentrations of 1,3-DNB, 2,4,6-TNT, and NB are less than the cleanup standards in the Objective 2 wells. The cleanup standard for 2,4-DNT and 2,6-DNT in MW-2050 could be attained by 2049 and 2029, respectively, if decreases continue at the current rate.

Nitroaromatic Compounds—Former Raffinate Pits Area

The other area of nitroaromatic compound impact at the Chemical Plant site 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. Nitroaromatic compound impact is isolated to the weathered unit of the Burlington-Keokuk Limestone. A summary of the 2,4-DNT data from the former Raffinate Pits area for 2011 is presented in Table 22.

Table 22. 2011 2,4-DNT Data from GWOU Objective 2 Wells in the Raffinate Pits Area

Location	2,4-DNT Concentration (µg /L)	
	S1	S2
MW-2038	0.13	0.12
MW-3030	0.62	0.64
MW-3034	0.075 (J)	0.057 (J)
MW-3039	0.20 (J)	0.17

µg/L = microgram per liter

The highest concentrations of 2,4-DNT continued to be monitored in MW-3030 (Figure 17). Concentrations in wells MW-2038, MW-3034, and MW-3039 have been variable, showing substantial decrease in 2008 and then an increase during 2009. Concentrations in these wells have remained unchanged since that time. The annual average concentrations of 2,4-DNT in MW-3034 have been less than or equal to the cleanup standard of 0.11 µg/L since 2008.

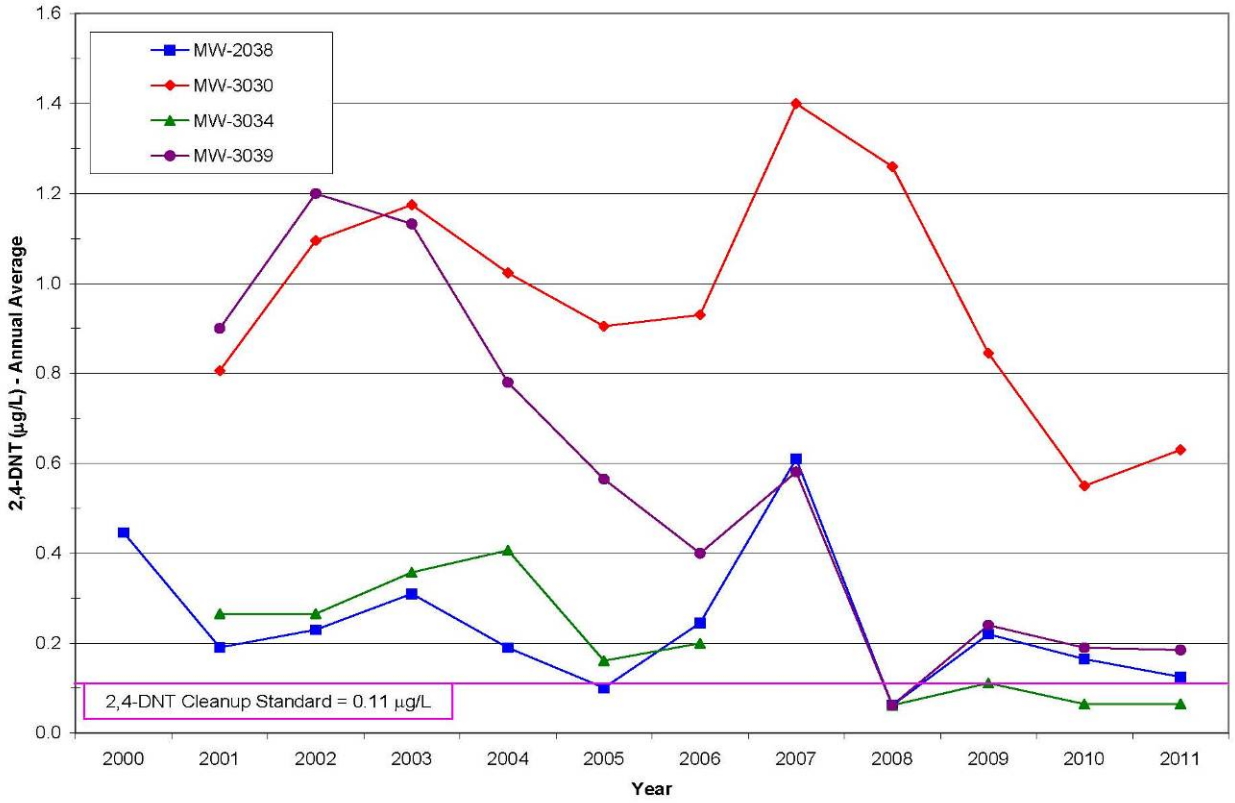

Figure 17. Annual Average 2,4-DNT Concentrations in Objective 2 Wells in the Former Raffinate Pits Area (1997–2011)

Trend analysis of data from 2007 through 2011 indicates that 2,4-DNT concentrations in the former Raffinate Pits area are decreasing, as indicated by negative slopes (Table 23). A statistically significant downward trend was calculated for well MW-3030. A review of the trend data suggests that concentrations of 2,4-DNT are relatively stable in the remainder of the Objective 2 wells, where slopes and confidence intervals are small. If the current overall decrease in 2,4-DNT concentrations continue in MW-3030, the cleanup standard of 0.11 µg/L could be reached by 2018, based on an estimate derived from an exponential curve model.

Table 23. Trending Analysis for 2,4-DNT in Objective 2 MNA Wells in the Raffinate Pits Area (2007–2011)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-2038	10	None	–0.03	–0.08	0.02
MW-3030	10	**Down**	–0.18	–0.38	–0.07
MW-3034	8	None	0	–0.03	0.02
MW-3039	10	None	–0.05	–0.06	0.05

µg/L/yr = microgram per liter per year

Overall, nitroaromatic compound impact in the former Raffinate Pits area is confined to the weathered unit of the Burlington-Keokuk Limestone. The concentrations of 2,4-DNT are decreasing. The cleanup standard for 2,4-DNT could be attained in MW-3030 by 2018 if decreases continue at the current rate.

3.1.1.6 Detection Monitoring Results for the GWOU

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 in the vicinity of 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 concentrations are monitored using 21 wells, 4 springs, and 1 surface water location situated along the fringes or downgradient of the areas of highest impact of the different contaminant plumes at the site. The monitoring well locations were sampled once in 2011, and the springs were sampled quarterly, unless otherwise noted.

Uranium

Data from the detection monitoring network indicate that uranium is migrating along the preferential flow pathways (paleochannels), as expected. Uranium levels exceeding the MCL of 20 pCi/L were reported in MW-4036 during the second bimonthly sampling period. The uranium levels in the remainder of the wells screened in either the weathered or unweathered unit are low and have been stable over time. A summary of the uranium values for samples collected in 2011 is presented in Table 24.

Uranium levels in Burgermeister Spring have been variable but within historical ranges and well below the trigger level of 150 pCi/L (Figure 18). Uranium levels increased in 2005 and have shown a general decline since that time. Periodic increases in uranium levels in Burgermeister Spring may be related to the infrequent increases that occur in groundwater in the Raffinate Pits area (see Section 3.1.1.7). Uranium levels in SP-6303 remain low and are consistent with historical data. No measureable flow was observed in SP-6303 during the second half of the year. The uranium levels in Burgermeister Spring and SP-6303 are not correlated and indicate that the source contribution to SP-6303 is less than the contribution to Burgermeister Spring. Uranium levels in Dardenne Creek have been low since monitoring resumed at locations SW-2007 in 2001.

Table 24. 2011 Uranium Data for GWOU Objective 3, 4, and 5 Locations

Sample ID	Unit/Location	Uranium (pCi/L)					
Weathered Unit							
MW-3031	Fringe	2.3			2.2		
MW-3037	Fringe	2.2			2.8		
MW-4026	Southeast Drainage (alluvium)	ND (<0.045)			ND (<0.045)		
MW-4036	Downgradient	2.0	**44.0**	5.2	3.0	2.1	2.4
MW-4041	Downgradient	1.5			1.6		
MWS-1	Downgradient	0.88			0.70		
MWS-4	Downgradient	0.37			0.37		
Unweathered Unit							
MW-3006	Fringe	0.37			0.47		
MW-4042	Downgradient	0.26			0.24		
MWD-2	Downgradient	0.21			0.24		
Springs and Surface Water							
SP-5303	Southeast Drainage	**64.0**		**41.2**	**63.0**		**77.9**
SP-5304	Southeast Drainage	**67.0**		**54.1**	**62.0**		**79.2**
SP-6301	Burgermeister Spring	8.1	**20.4**	**36.2**	**49.0**	**35.4**	**43.7**
SP-6303	Burgermeister Spring Branch	0.41	0.47	0.74	Dry	Dry	Dry
SW-2007	Dardenne Creek	0.59					

J = estimated value less than the reporting limit; pCi/L = picocurie(s) per liter
Values in **bold** exceed the MCL of 20 pCi/L

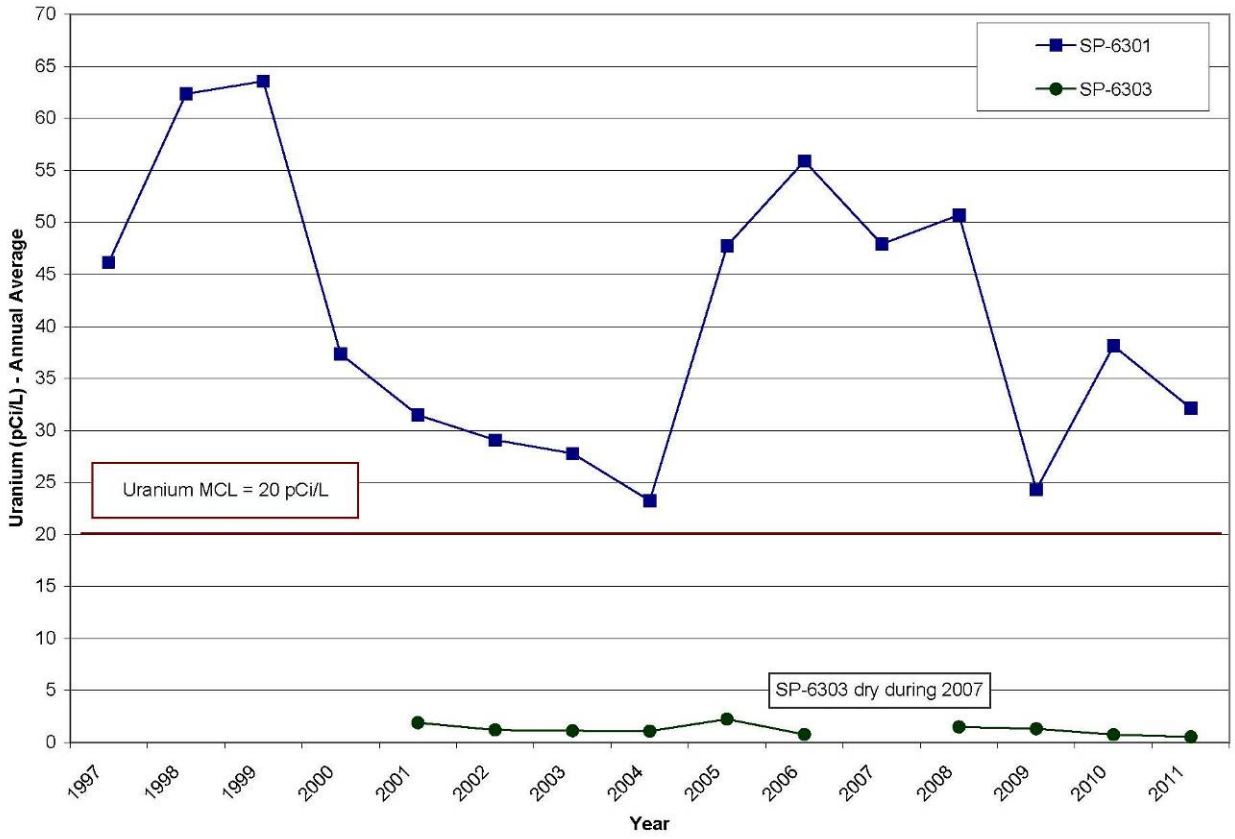

Figure 18. Annual Average Uranium Levels in Burgermeister Spring and SP-6303 (1997–2011)

Results of the trend analysis for Burgermeister Spring (SP-6301) and SP-6303 indicate that uranium levels are decreasing, as indicated by negative slopes (Table 25). Analysis of the data collected from 2007 through 2011 indicated no statistical trends, either upward or downward, for these two springs. Although a statistically significant downward trend was not indicated in Burgermeister Spring, if the current rate of decrease continues, the MCL of 20 pCi/L could be reached by 2024, based on an estimate derived from an exponential curve model.

Table 25. Trending Analysis for Uranium in SP-6301 and SP-6303 (2007−2011)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
SP-6301	27	None	–1.8	–8.9	5.9
SP-6303	13	None	–0.06	–0.32	0.11

pCi/L/yr = picocurie(s) per liter per year

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. The source of uranium in the two springs is residually contaminated sediments within the bedrock fracture system. The uranium levels in the two Southeast Drainage springs monitored under this program have been less variable in the past few years (Figure 19), and the behavior of uranium is similar in both

springs. Uranium levels in both springs exceed the MCL but are less than the trigger level of 150 pCi/L. Uranium levels in MW-4026, a monitoring well downgradient of the two springs, were within the range of background.

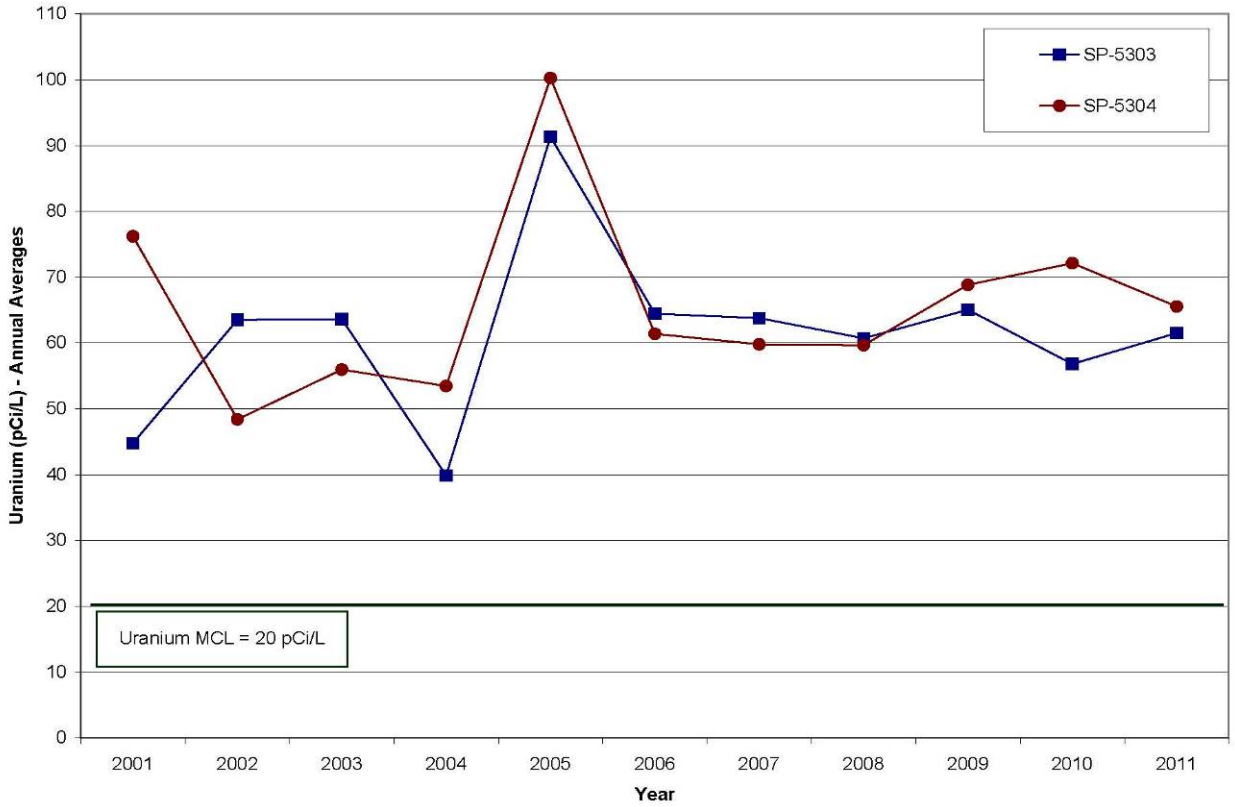

Figure 19. Annual Average Uranium Levels in Southeast Drainage Springs (2001–2011)

Results of the trend analysis for SP-5303 and SP-5304 indicate that uranium levels are slightly increasing, as indicated by positive slopes (Table 26). Analysis of the data collected from 2007 through 2011 indicated no statistical trends for these two springs. Data from these two springs have been relatively stable for the past 5 years as indicated by small slopes and confidence intervals.

Table 26. Trending Analysis for Uranium in SP-5303 and SP-5304 (2007−2011)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
SP-5303	17	None	0.22	–5.7	6.8
SP-5304	17	None	2.7	–2.3	8.0

pCi/L/yr = picocuries per liter per year

While uranium levels in the Raffinate Pits area have changed since implementation of the MNA remedy for uranium, overall, the remedy remains protective as indicated by data from the Objective 3, 4, and 5 monitoring locations. 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. Discharge from the impacted portion of the unweathered unit into the weathered unit is monitored at MW-4036. Uranium levels in Objective 3–far wells remain low, and levels in Burgermeister Spring, while variable, are declining.

Nitrate (as N)

The nitrate concentrations in the detection monitoring wells indicate that the movement of the area of impact is behaving as expected. The concentrations of nitrate in wells MW-4036 and MWS-1 exceeded the MCL for nitrate (as N). Data from MWS-1 were consistent with historical data and are less than the trigger level of 30 mg/L. The nitrate concentrations in the remainder of the wells screened in either the weathered or unweathered unit were low and have been stable. Nitrate data reported in the springs were consistent with historical data. A summary of the data is presented in Table 27.

Table 27. 2011 Nitrate (as N) Data for GWOU Objective 3, 4, and 5 Locations

Sample ID	Unit/Location	Nitrate (as N) (mg/L)			
Weathered Unit					
MW-4014	Fringe	6.1			
MW-4041	Downgradient	0.28			
MWS-1	Downgradient	**19.0**			
MWS-4	Downgradient	1.8			
Unweathered Unit					
MW-2021	Vertical Extent	ND (<0.02)			
MW-2022	Vertical Extent	ND (<0.02)			
MW-3006	Fringe	ND (<0.02)			
MW-4007	Downgradient	0.06			
MW-4042	Downgradient	ND (<0.02)		ND (<0.02)	
MWD-2	Downgradient	ND (< 0.02)			
Springs and Surface Water					
SP-6301	Burgermeister Spring	0.58	2.5	Note 1	1.3
SP-6303	Burgermeister Spring Branch	Note 1	0.25	dry	dry

Values in **bold** exceed the MCL of 10 mg/L.
J = estimated value less than the reporting limit; mg/L = milligram(s) per liter; ND = not detected above the reporting limit
Note 1: Data were rejected through verification/validation process.

The nitrate concentrations in Burgermeister Spring ranged between 0.58 mg/L and 2.5 mg/L, which are less than the MCL of 10 mg/L. The annual average nitrate concentrations in Burgermeister Spring have been less than the MCL since 2002 (Figure 20). Nitrate concentrations in SP-6303 have been less than the MCL since monitoring resumed in 2001.

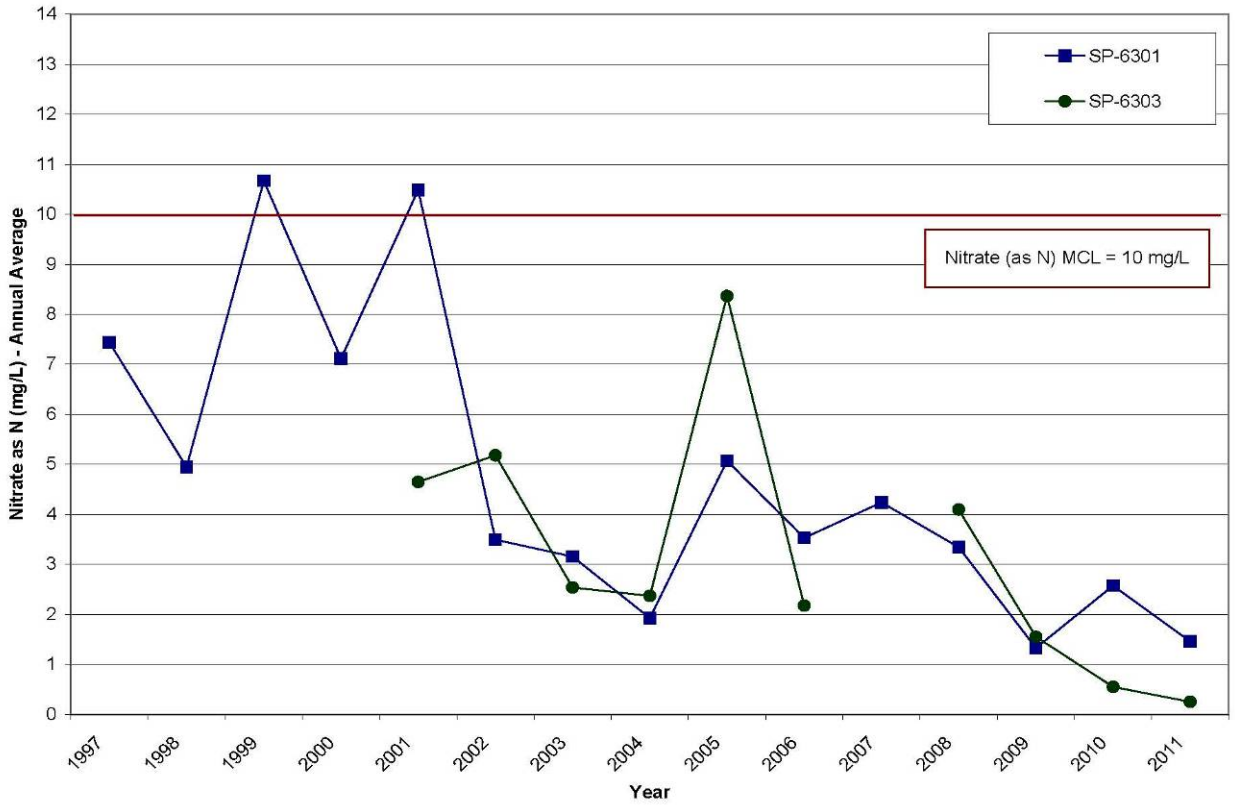

Figure 20. Annual Average Nitrate Concentrations in Burgermeister Spring and SP-6303 (1997–2011)

Results of the trend analysis for Burgermeister Spring (SP-6301) and SP-6303 indicate that nitrate concentrations are decreasing, as indicated by negative slopes (Table 28). Analysis of the data collected from 2007 through 2011 indicated no statistically significant trends for these two springs. Nitrate concentrations are considered relatively stable in these two springs, where slopes and confidence intervals are small.

Table 28. Trending Analysis for Nitrate (as N) in SP-6301 and SP-6303 (2007−2011)

Location	No. of Samples	Trend	Slope (mg/L/yr)	Confidence Intervals	
				Lower	Upper
SP-6301	23	None	–0.32	–1.0	0.18
SP-6303	11	None	–1.1	–2.8	0.12

mg/L/yr = milligrams per liter per year

Trichloroethene

Detections of TCE were not reported in the detection monitoring wells; however, estimated values less than 1 µg/L were reported in SP-6303 and are consistent with historical data. Estimated values are concentrations reported less than the quantification limit and may indicate the presence of TCE. The data from the past 5 years indicate that the area of TCE impact has not expanded, either laterally or vertically. No detectable concentrations of the breakdown products *cis*-1,2-DCE, *trans*-1,2-DCE, or vinyl chloride were reported in any of the detection monitoring locations. A summary of the TCE data is presented in Table 29.

Table 29. 2011 TCE Data for GWOU Objective 3, 4, and 5 Locations

Sample ID	Unit/Location	TCE (μg/L)			
Weathered Unit					
MW-3031	Fringe	ND (<1.0)			
MW-3037	Fringe	ND (<1.0)			
MW-4036	Downgradient	ND (<1.0)			
MW-4041	Downgradient	ND (<1.0)			
MWS-1	Downgradient	ND (<1.0)			
MWS-4	Downgradient	ND (<1.0)			
Unweathered Unit					
MW-3006	Fringe	ND (<1.0)			
MW-4007	Downgradient	ND (<1.0)			
MW-4040	Vertical Extent	ND (<1.0)			
Springs and Surface Water					
SP-6301	Burgermeister Spring	ND (<1.0)	ND (<1.0)	ND (<1.0)	ND (<1.0)
SP-6303	Burgermeister Spring Branch	ND (<1.0)	0.71 (J)	dry	dry

J = estimated value less than the reporting limit; μg/L = microgram per liter;
ND = not detected above the reporting limit

Nitroaromatic Compounds

Detection monitoring results for 1,3-DNB indicated that the impacted groundwater in the overlying weathered unit has not moved downward from the area of known impact within the weathered unit (Table 30). Fringe location MW-2051 had an estimated concentration of 1,3-DNB less than detection limit and is consistent with historical data. No detectable concentrations were reported in the springs.

Table 30. 2011 1,3-DNB Data for GWOU Objective 3, 4, and 5 Locations

Sample ID	Location	1,3-DNB (μg/L)			
Weathered Unit					
MW-2032	Fringe	ND (<0.014)			
MW-2051	Fringe	0.045 (J)			
MW-4014	Downgradient	ND (<0.014)			
MW-4039	Fringe	ND (<0.013)			
MW-4041	Downgradient—Far	ND (<0.013)			
Unweathered Unit					
MW-2022	Vertical Extent	ND (<0.014)			
MW-2023	Vertical Extent	ND (<0.013)			
MW-2056	Vertical Extent	ND (<0.014)			
Springs					
SP-6301	Burgermeister Spring	ND (<0.014)	ND (<0.014)	ND (<0.014)	ND (<0.014)
SP-6303	Burgermeister Spring Branch	ND (<0.014)	ND (<0.014)	dry	dry

J = estimated value less than reporting limit; μg/L = microgram per liter;
ND = nondetect above method detection limit indicated in parentheses

The concentrations of 2,4,6-TNT reported in the detection monitoring wells in the weathered unit indicate that affected groundwater has not migrated beyond the area of known impact (Table 31). Fringe location MW-2051 had an estimated concentrations of 2,4,6-TNT less than the detection limit; this concentration is consistent with historical data. No detectable concentrations of 2,4,6-TNT were reported in the wells in the unweathered unit or in Burgermeister Spring and SP-6303.

Detection monitoring results for 2,4-DNT impact in the Frog Pond area indicate that limited migration continued in the weathered unit (Table 32), and the concentrations reported in MW-2051, MW-4013, and MW-4015 did not exceed the trigger level set for the Objective 3 wells. The concentration of 2,4-DNT in MW-4015 did exceed the cleanup standard of 0.11 µg/L but is consistent with historical data. The data from the unweathered unit wells indicate that the impacted groundwater in the overlying weathered unit has not moved downward. No detectable concentrations were reported in Burgermeister Spring and SP-6303.

Detection monitoring results for 2,4-DNT impact in the Raffinate Pits area show that minimal migration from this area has continued (Table 32). The source of the estimated concentration of 2,4-DNT reported in MW-4036 may be the Chemical Plant site, the Army property, or both. This estimated concentration did not exceed the trigger level set for the Objective 3 wells. The data from the unweathered unit wells verified that the impacted groundwater in the overlying weathered unit has not migrated downward.

Table 31. 2011 2,4,6-TNT Data for GWOU Objective 3, 4, and 5 Locations

Sample ID	Location	2,4,6-TNT (µg/L)			
Weathered Unit					
MW-2032	Fringe	ND (<0.021)			
MW-2051	Fringe	0.076 (J)			
MW-4014	Downgradient	ND (<0.021)			
MW-4039	Fringe	ND (<0.021)			
MW-4041	Downgradient—Far	ND (<0.021)			
Unweathered Unit					
MW-2022	Vertical Extent	ND (<0.022)			
MW-2023	Vertical Extent	ND (<0.021)			
MW-2056	Vertical Extent	ND (<0.022)			
Springs					
SP-6301	Burgermeister Spring	ND (<0.022)	ND (<0.022)	ND (<0.022)	ND (<0.021)
SP-6303	Burgermeister Spring Branch	ND (<0.022)	ND (<0.022)	dry	Dry

J = estimated value less than reporting limit; µg/L = microgram per liter;
ND = nondetect above method detection limit indicated in parentheses

Table 32. 2011 2,4-DNT Data for GWOU Objective 3, 4, and 5 Locations

Sample ID	Location	2,4-DNT (μg/L)			
Weathered Unit					
MW-2032	Fringe—FP	ND (<0.018)			
MW-2051	Fringe—FP	0.059 (J)			
MW-3037	Fringe—RP	ND (<0.018)			
MW-4013	Downgradient—FP	0.092 (J)			
MW-4014	Downgradient—FP	ND (<0.018)			
MW-4015	Downgradient—FP	0.13			
MW-4036	Downgradient—RP	0.085 (J)			
MW-4039	Fringe—FP	ND (<0.018)			
MW-4041	Downgradient—Far	ND (<0.018)			
MWS-1	Downgradient—RP	ND (<0.019)			
Unweathered Unit					
MW-2023	Vertical Extent—FP	ND (<0.019)			
MW-2056	Vertical Extent—FP	ND (<0.018)			
MW-3006	Vertical Extent—RP	ND (<0.019)			
MW-4040	Vertical Extent—RP	ND (<0.018)			
Springs					
SP-6301	Burgermeister Spring	ND (<0.019)	ND (<0.019)	ND (<0.019)	0.018 (J)
SP-6303	Burgermeister Spring Branch	ND (<0.019)	ND (<0.019)	Dry	Dry

FP = Frog Pond area; J = estimated value less than reporting limit; μg/L = microgram per liter;
ND = nondetect above method detection limit indicated in parentheses; RP = Raffinate Pits area

Continued downgradient migration of 2,6-DNT impacted groundwater from the Frog Pond area is monitored by the Objective 3 wells (Table 33). Concentrations in these downgradient wells have decreased slightly during the review period. Concentrations are consistent with historical data. No detectable concentrations of 2,6-DNT were reported in the wells in the unweathered unit. However, an estimated detection was reported in MW-2023 in 2009. The concentrations reported in Burgermeister Spring and SP-6303 are low and consistent with historical data. None of the concentrations reported exceeded the triggers levels set for the Objective 3 or 4 wells or the Objective 5 springs.

The nitroaromatic compound NB has not been detected in any of the Objective 3, 4, or 5 monitoring locations since the MNA program began in 2004.

Table 33. 2011 2,6-DNT Data for GWOU Objective 3, 4, and 5 Locations

Sample ID	Location	2,6-DNT (μg/L)			
Weathered Unit					
MW-2032	Fringe	ND (<0.021)			
MW-2051	Fringe	0.033 (J)			
MW-4013	Downgradient	0.52			
MW-4014	Downgradient	0.15			
MW-4015	Downgradient	0.98			
MW-4039	Fringe	ND (<0.021)			
MW-4041	Downgradient—Far	ND (<0.021)			
Unweathered Unit					
MW-2023	Vertical Extent	ND (<0.021)			
MW-2056	Vertical Extent	ND (<0.022)			
Springs					
SP-6301	Burgermeister Spring	ND (<0.022)	0.078 (J)	0.093 (J)	0.048 (J)
SP-6303	Burgermeister Spring Branch	ND (<0.022)	ND (<0.022)	dry	dry

J = estimated value less than reporting limit; μg/L = microgram per liter;
ND = nondetect above method detection limit indicated in parentheses

3.1.1.7 GWOU Special Study—Elevated Uranium in the Unweathered Unit

In response to increased uranium levels measured in MW-3024 and MW-3040 and periodic high uranium levels in MW-4036, a special study was initiated in 2008. The analysis of the data collected from 2008 through 2010 is discussed in the annual Site Environmental Report for calendar year 2010 (DOE 2011). The following actions were undertaken to evaluate the possible changes in conditions and to better understand the mechanisms causing the increases in uranium levels:

- Quarterly sampling of MW-3024, MW-3040, and MW-4036 and other nearby wells for uranium was performed initially. Frequency was later increased to bimonthly in 2010.
- Sampling of SP-6201 on the neighboring Army property and Burgermeister Spring.
- Evaluation of groundwater levels and precipitation events.
- Installation of a well (MW-4043) screened in the unweathered unit adjacent to MW-4036.

Data from the wells and springs included in the special study are summarized in Table 34.

Table 34. Uranium Data from Special Study for MW-3024, MW-3040, and MW-4036

Date	Uranium Levels (pCi/L)					
	MW-3024	MW-3040	MW-4036	MW-4040	MW-4043	SP-6201
Unit	Unweathered	Unweathered	Weathered	Unweathered	Unweathered	Spring
Mar 2008		**94.1**		**313**		
Apr 2008	**125**					
May 2008		**95.5**	**79.9**	**378**		
Jul 2008	**109**	**107**	4.5	**360**		19.3
Aug 2008	**120**	**106**	2.8	**370**		19.2
Sep 2008			2.4			
Oct 2008	**100**	**98.2**	1.7	**347**		
Feb 2009	**99.5**	**98.8**	9.6	**332**		
Apr 2009	**110**	**105**	**27.7**			
May 2009				**296**		**27.9**
Aug 2009	**118**	**105**	1.3	**339**		9.8
Nov 2009	**200**	**167**	**71.1**	**530**		**20.4**
Feb 2010	**102**	**95.9**	**41.8**	**303**	**74.5**	
Mar 2010						17.7
April 2010	**108**	**88.0**	7.4	**305**	**67.7**	
May 2010						14.0
June 2010	**102**	**94.5**	3.0	**284**	**74.5**	11.0
August 2010	**108**	**102**	2.4	**291**	**88.0**	8.1
October 2010	**108**	**102**	2.0	**305**	**94.8**	7.4
December 2010	**115**	**109**	2.2	**311**	**94.1**	10.4
February 2011	**108**	**94.8**	2.0	**264**	**81.2**	6.6
April 2011	**124**	**108**	**44.0**	**300**	**90.7**	18.6
June 2011	**102**	**96.8**	5.2	**308**	**75.8**	10.2
August 2011	**115**	**102**	3.0	**311**	**88.0**	3.9
October 2011	**118**	**108**	2.1	**315**	**87.3**	6.3
December 2011	**127**	**110**	2.4	**331**	**90**	3.5

Values in **bold** exceed the MCL of 20 pCi/L.
pCi/L = picocuries per liter

Data collected in 2011 continue to indicate that the uranium levels are highest in the unweathered unit. Uranium levels are variable in weathered unit well MW-4036 and in the downgradient spring SP-6201. These data continue to support the following conclusions:

- The reduction in infiltration has limited dilution of the impacted groundwater in the unweathered unit and has resulted in little flushing of the system due to the low amount of recharge through the system. Increased uranium levels are the result of desorption of residual uranium from contaminated materials that were forced deeper into the bedrock by the hydraulic head of water in the Raffinate Pits. Since there is little infiltration to flush this impacted groundwater through the bedrock aquifer, changes will likely be slow.
- Groundwater with higher uranium levels in the unweathered unit periodically contributes uranium mass to the weathered unit near MW-4036 and downgradient SP-6201. However, the mechanism that causes the periodic contribution of uranium into the weathered unit has not been identified.

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 levels measured in MW-4043. 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). The presence of elevated uranium in a downgradient spring, SP-6201 also supports the conclusion of downgradient migration of uranium. Downgradient migration is expected, as the attenuation mechanisms for uranium are dilution and dispersion, which lead to some downgradient migration. Objective 3–near well triggers were set to take into account migration of contaminants in the paleochannels.

Periodic uranium increases in Burgermeister Spring may be related to the infrequent increases that occur in MW-4036. It appears that when uranium levels increase in MW-4036, a similar increase occurs during the same sampling period or slightly later in Burgermeister Spring. Concurrent increases are possible because groundwater travel times from the site to Burgermeister Spring are on the order of 2 to 9 days, as determined from dye tracing.

3.1.1.8 Chemical Plant Hydrogeologic Data Analysis

Hydrogeologic conditions at the site are being monitored using all the wells included in the MNA network (Objectives 1, 2, 3, and 4 wells) 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 selected remedy. The static groundwater levels of the monitoring network are measured to establish that groundwater flow is not changing significantly and resulting in shifts in contaminant migration.

The average groundwater elevations measured in 2011 were used to construct a potentiometric surface map of the shallow aquifer, using the available wells at the Chemical Plant (Figure 21). The configuration of the potentiometric surface has remained relatively unchanged. However, groundwater elevations have decreased in several portions of the site. Even though changes have occurred in the groundwater elevations, the groundwater flow direction continues to be generally to the north. A groundwater divide is present along the southern boundary of the Chemical Plant site. Troughs in the groundwater surface occur where paleochannels are located.

Groundwater elevations have shown a general decrease in the weathered unit of the Burlington-Keokuk Limestone (Figure 22). Groundwater elevations in the weathered unit in the Frog Pond area show influence of surface water infiltration. Groundwater elevations in the unweathered unit have decreased in the Raffinate Pits area (Figure 23). The decreases in both units are likely due to the removal of large surface water impoundments, such as the Raffinate Pits, during site remediation.

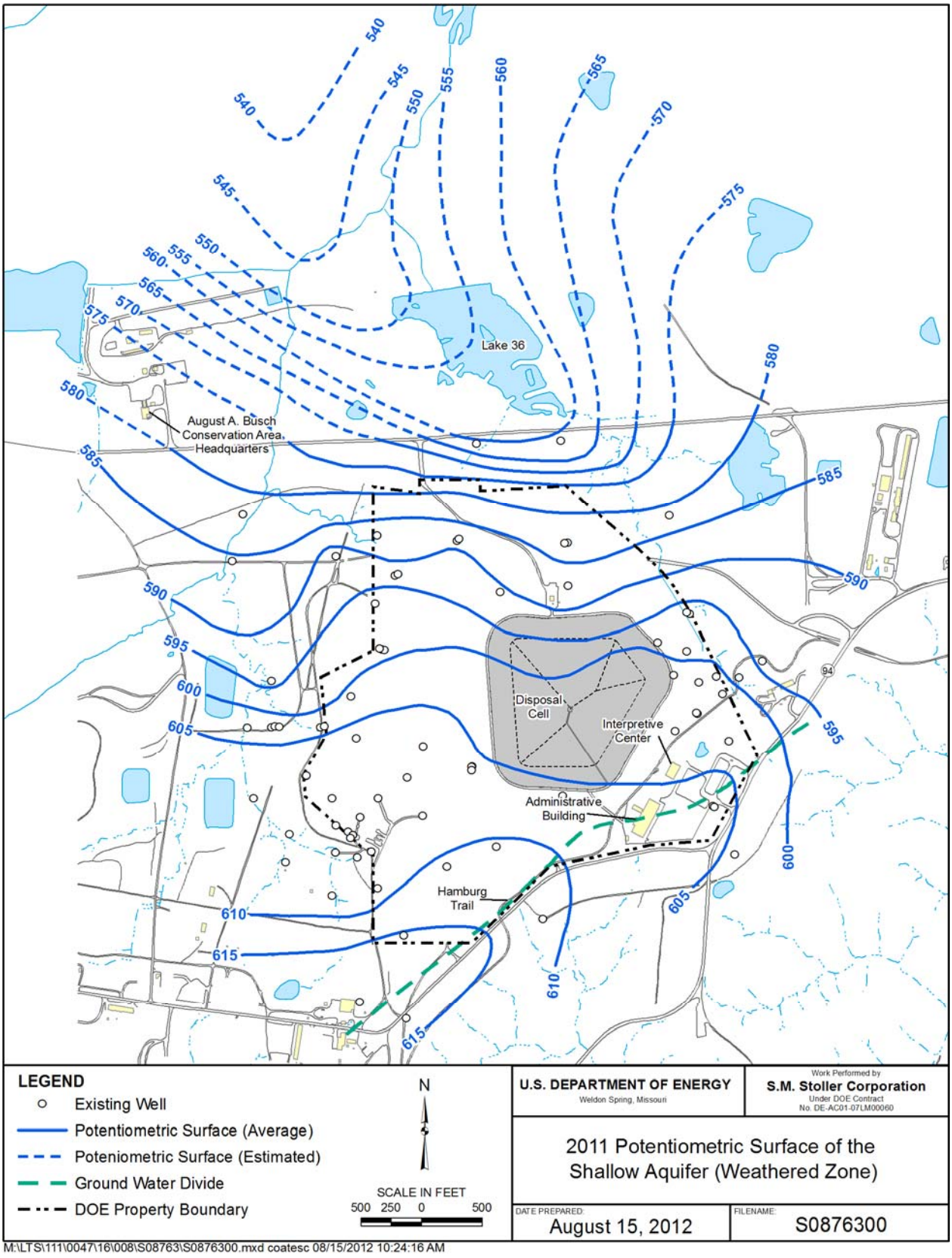

Figure 21. 2011 Potentiometric Surface of the Shallow Aquifer (Weathered Zone)

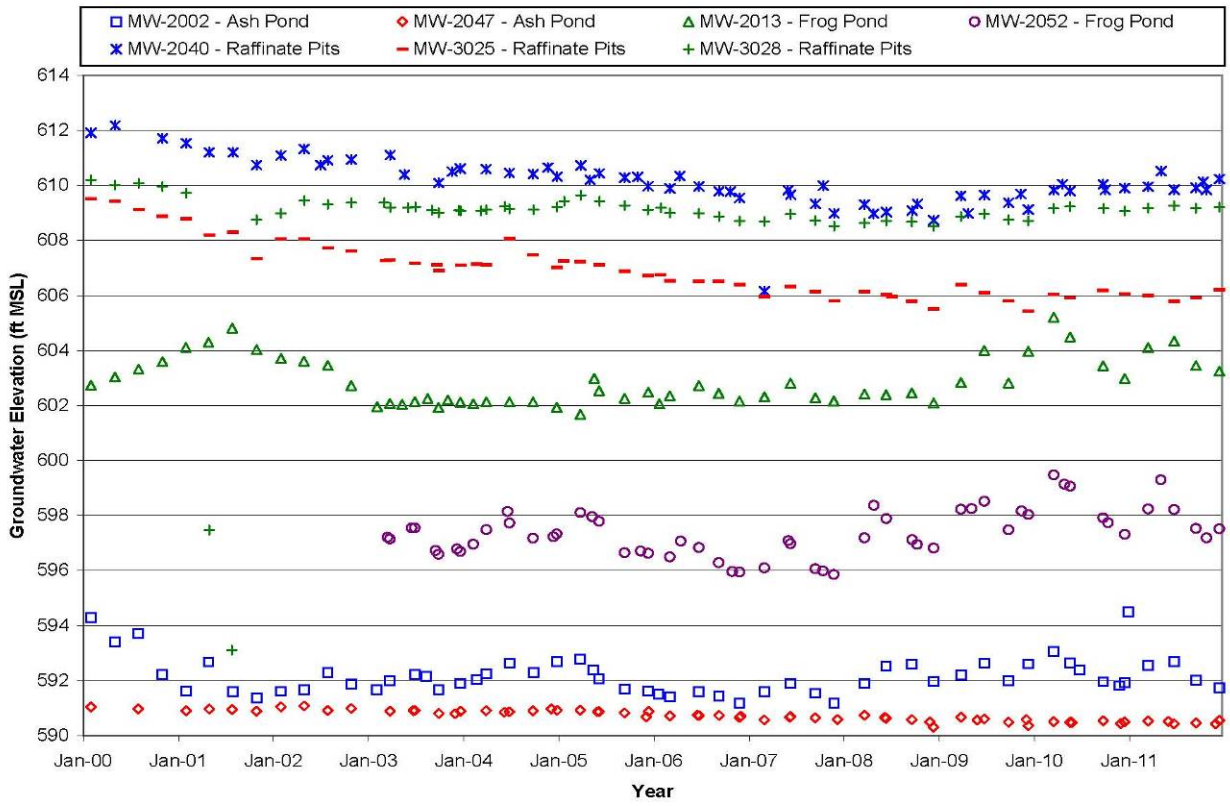

Figure 22. Groundwater Elevations in the Weathered Unit

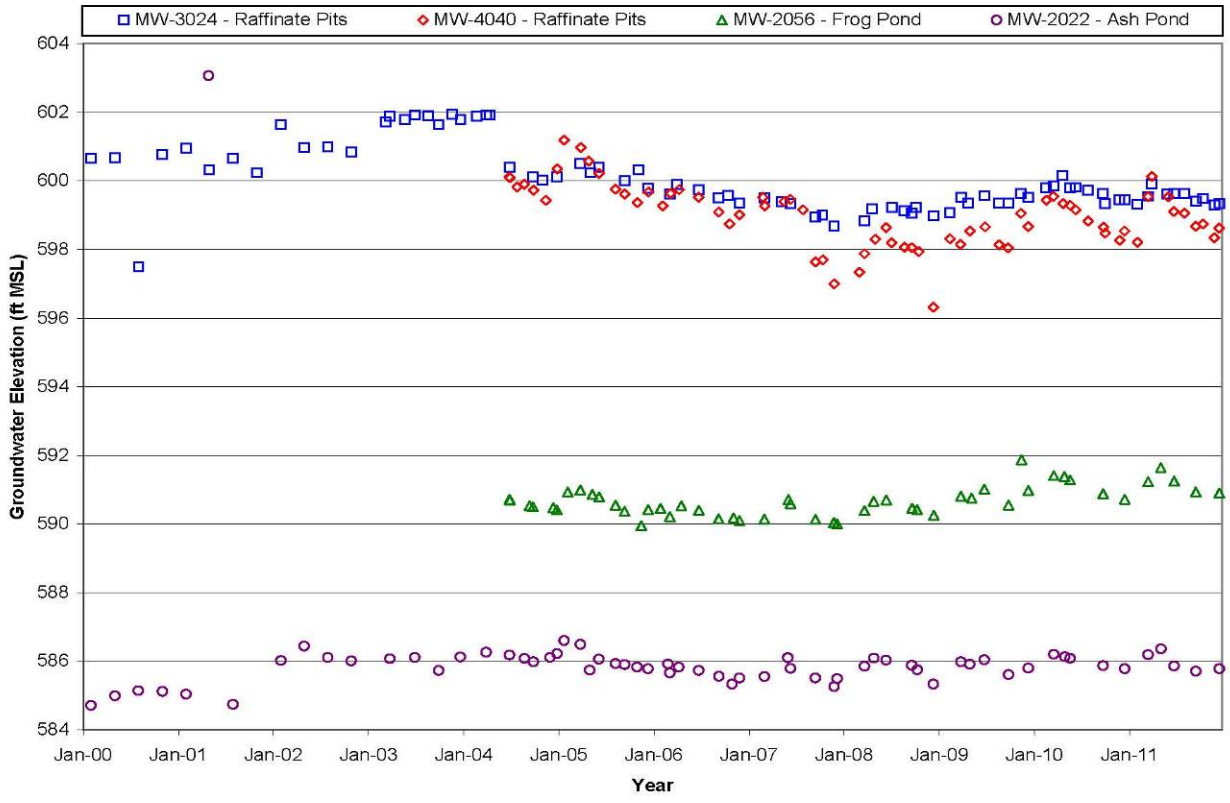

Figure 23. Groundwater Elevations in the Unweathered Unit

3.1.2 Weldon Spring Quarry

EPA signed the QROU ROD (DOE 1998a) on September 30, 1998. The QROU ROD specified long-term groundwater monitoring and institutional controls 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).

3.1.2.1 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 silty clay soil and loess deposits and is not saturated (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 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 the 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 the 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 infiltration of precipitation and overland runoff that recharges the bedrock aquifer.

Eight monitoring wells in the Darst Bottom area 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 35 (DOE 1998a).

Table 35. 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

[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).
pCi/L = picocurie(s) per liter; UCL_{95} = 95th percentile upper confident limit on the mean concentration

3.1.2.2 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 the removal of the wastes from the Quarry. The remaining source of groundwater contamination is 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 Decorah Formation that constitute the Quarry. The extent of uranium in groundwater was limited to the area north of the slough through precipitation by a naturally occurring chemical reduction process and adsorption onto aquifer materials.

Nitroaromatic compounds, primarily 2,4-DNT, in the groundwater system coincide with where these wastes were disposed of in the Quarry proper. Nitroaromatic compounds entered the shallow aquifer via migration through bedrock fractures of the Quarry. The mobility of nitroaromatic compounds in the bedrock aquifer is high because these compounds have little sorptive affinity for the bedrock materials. Some microorganism activity may be able to transform and degrade TNT and DNT in the alluvial materials north of the slough.

3.1.2.3 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).

To implement these two monitoring objectives, the wells were categorized into monitoring lines (Figure 24). 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.

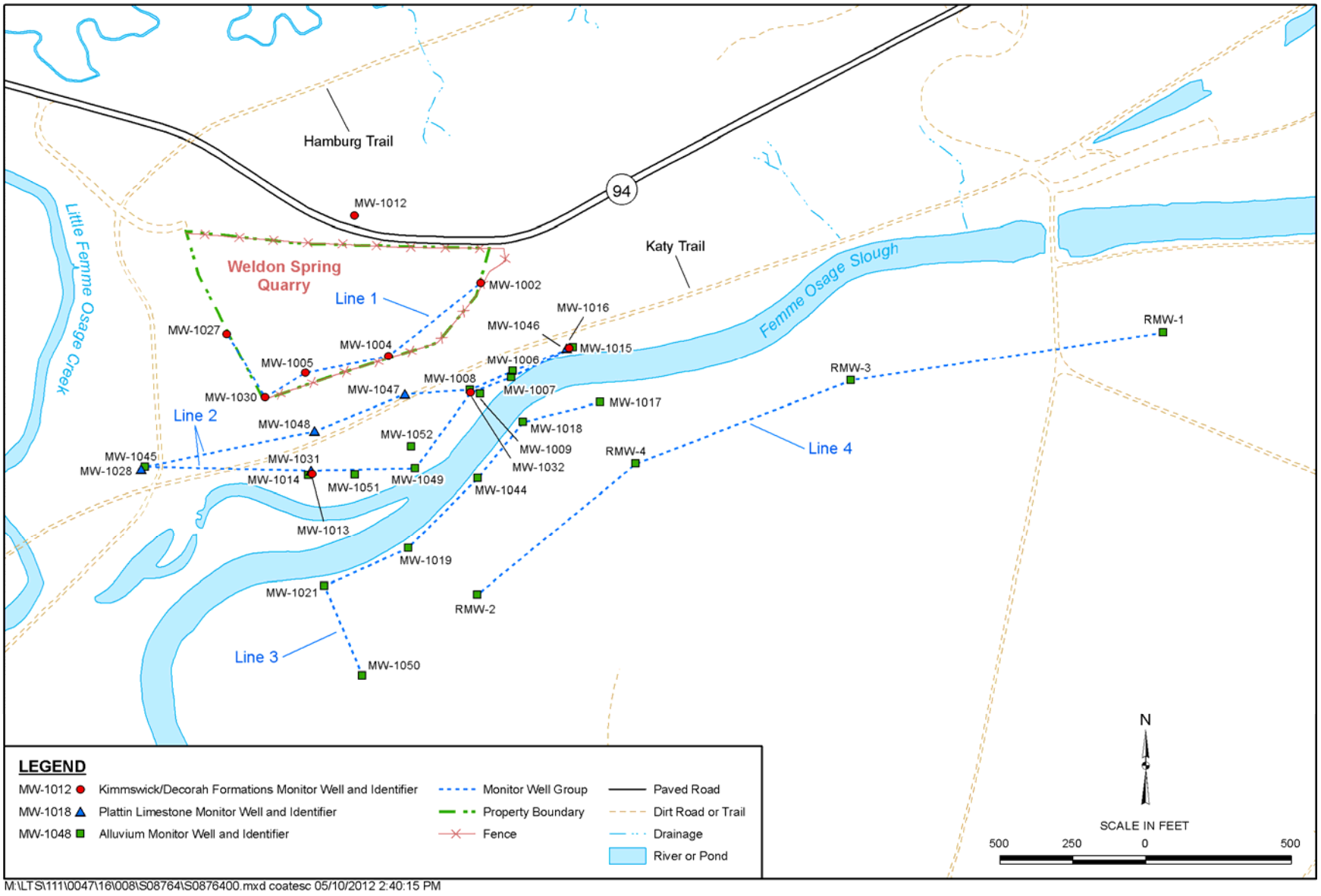

Figure 24. Groundwater Monitoring Well Locations at the Quarry Area of the Weldon Spring, Missouri, Site

- The second line of wells monitors the area of impact within alluvial materials and shallow bedrock 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 also sampled to establish trends in contaminant concentrations within the areas of higher impact and to monitor the oxidizing and reducing environments that are present within this area.
- 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 Public Water Supply District #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 potential occurrences of uranium outside the range of natural variation.

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

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 were sampled semiannually starting in 2009 due to declining uranium levels. Monitoring wells between the quarry and the Femme Osage Slough, the area of highest impact, are sampled quarterly. Locations south of the slough are sampled semiannually or annually. In 2011, all locations in the Quarry area were sampled for uranium, sulfate, and dissolved iron. A selected group of wells north of the slough was sampled for nitroaromatic compounds.

Testing for temporal trends using the Mann-Kendall test was performed for total uranium and 2,4-DNT data collected between 2007 and 2011. Results for the trending analysis are reported for wells in Lines 1 and 2 of the Quarry monitoring network, as these wells monitor the area of groundwater impact. Trending is used as a general indicator of changes in the groundwater quality in this area.

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

Contaminant concentrations are monitored using 24 wells screened in either the bedrock or alluvial materials in the area of uranium and 2,4-DNT impact, which is north of the Femme Osage Slough. The data are discussed in the following sections.

Uranium

Uranium is monitored in both the bedrock and the adjoining alluvial materials north of the Femme Osage Slough. These wells are monitored to determine when the area of groundwater impact north of the slough will have a negligible impact on the groundwater south of the slough.

Uranium levels in the Line 1 wells have shown a general decrease (Figure 25). In 2011, two locations had uranium levels that exceeded the target level of 300 pCi/L (Table 36). The annual average levels of uranium in MW-1002, MW-1027, and MW-1030 have been less than the target level of 300 pCi/L established for groundwater north of the Femme Osage Slough since 2006. Uranium levels in MW-1002 and MW-1030 have consistently been less than the MCL of 20 pCi/L since 2001.

Table 36. 2011 Total Uranium in QROU Line 1 Wells

Location	Line	Geologic Unit	Uranium (pCi/L)	
			S1	S2
MW-1002	1	Kimmswick-Decorah	2.9	2.7
MW-1004	1	Kimmswick-Decorah	**535**	**548**
MW-1005	1	Kimmswick-Decorah	**440**	**440**
MW-1012	1[a]	Kimmswick-Decorah	2.4	2.1
MW-1027	1	Kimmswick-Decorah	169	54
MW-1030	1	Kimmswick-Decorah	8.1	5.7

[a] Upgradient location
Concentrations in **bold** exceed the target level of 300 picocuries per liter
pCi/L = picocuries per liter

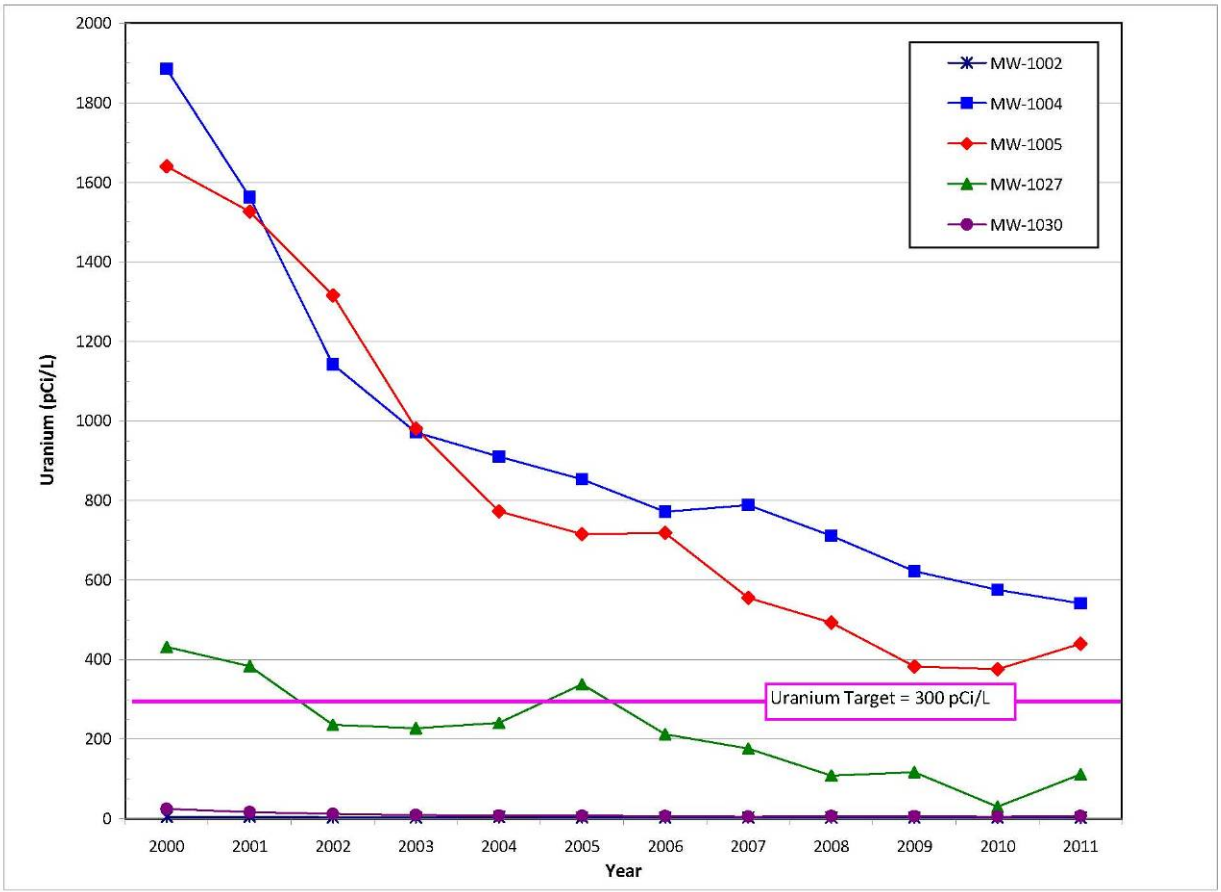

Figure 25. Average Uranium in Line 1 Monitoring Wells

The results of trend analysis for the Line 1 wells (Table 37) indicate that uranium levels in recent years have been decreasing in most of these wells, as indicated by negative slopes. Statistically significant downward trends have been calculated for MW-1002, MW-1004, and MW-1005. If the current overall decline in uranium levels continues in these wells, the target level of 300 pCi/L could be reached by 2014, based on an estimate derived from an exponential curve model. Uranium levels in MW-1030 are stable based on the small slope and confidence intervals.

Table 37. Trending Analysis for Uranium in Line 1 Groundwater Monitoring Wells (2007–2011)

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
MW-1002	14	**Down**	–0.23	–0.39	–0.09
MW-1004	14	**Down**	–68.2	–91.4	–43.5
MW-1005	14	**Down**	–39.1	–79.3	–9.2
MW-1027	14	None	–22.4	–55.9	2.0
MW-1030	14	None	0.33	–0.08	0.74

pCi/L/yr = picocurie(s) per liter per year

Several bedrock wells located between the Quarry rim and Femme Osage Slough (Line 2) continue to have elevated uranium levels (Table 38). However, only one Line 2 bedrock well had uranium levels that exceeded the target level of 300 pCi/L. Uranium levels in the Line 2 bedrock wells have generally decreased since 2000 (Figure 26). The highest levels of uranium are measured in MW-1032, which is screened beneath the area of highest uranium impact in the overlying alluvium. The average levels of uranium in MW-1015, MW-1028, MW-1031, MW-1046, MW-1047, and MW-1048 have been less than the target level of 300 pCi/L since 2009.

Table 38. 2011 Total Uranium in QROU Line 2 Bedrock Wells

Location	Line	Geologic Unit	Uranium (pCi/L)			
			Q1	Q2	Q3	Q4
MW-1013	2	Kimmswick-Decorah	198	230	202	181
MW-1015	2	Kimmswick-Decorah	162	115	113	107
MW-1028	2	Plattin	2.0	1.7	1.3	1.6
MW-1031	2	Plattin	9.8	10.0	9.7	10.0
MW-1032	2	Kimmswick-Decorah	**555**	**596**	**575**	**447**
MW-1046	2	Plattin	1.2	1.1	1.2	1.1
MW-1047	2	Plattin	0.71	0.74	0.71	0.72
MW-1048	2	Plattin	152	183	196	116

Concentrations in **bold** exceed the target level of 300 picocuries per liter.

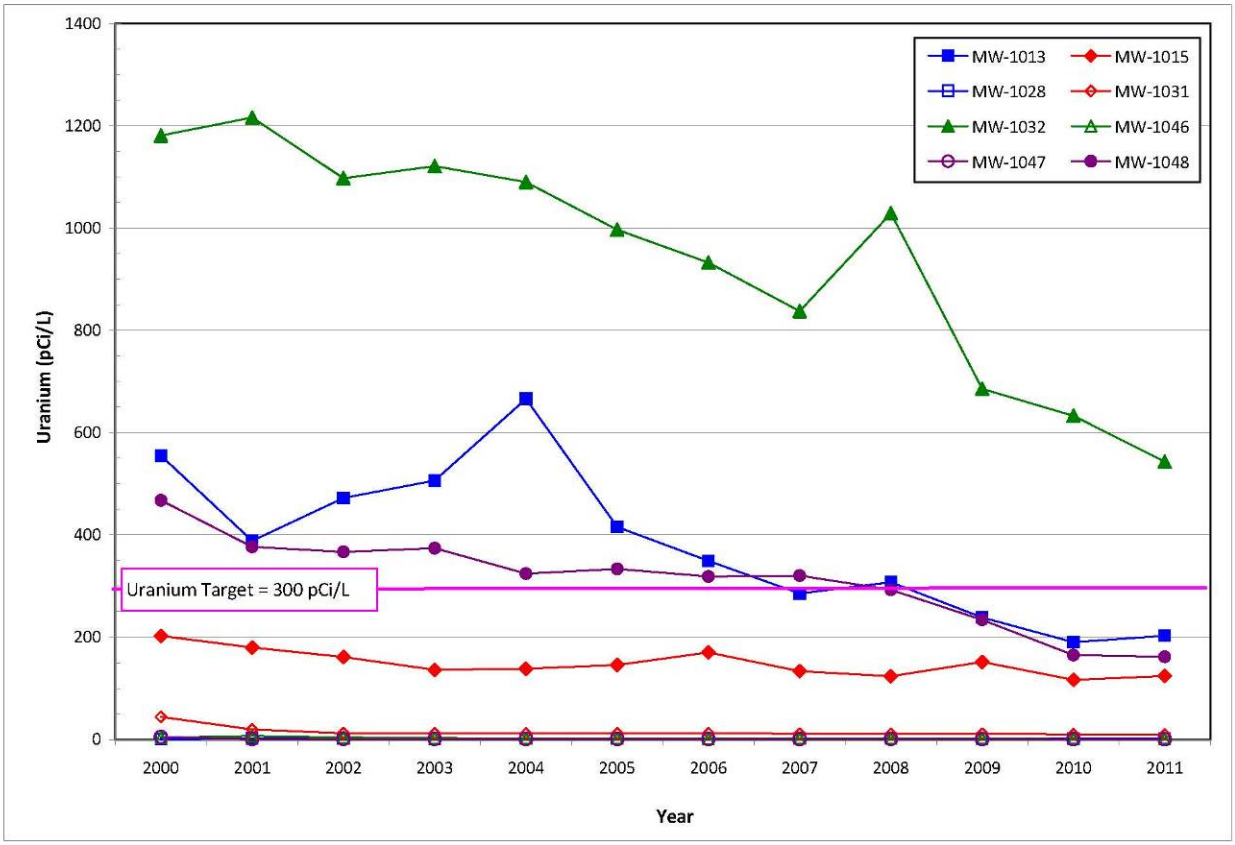

Figure 26. Average Uranium in Line 2 Bedrock Wells

Results continue to indicate that the highest levels of uranium in groundwater occur in the alluvial materials between the Quarry rim and Femme Osage Slough (Table 39). In 2011, five of these locations had uranium levels that exceeded the target level of 300 pCi/L. These wells are in the center of the area of uranium impact. The average levels of uranium in MW-1009, MW-1045, and MW-1049 have remained low during the review period and represent the limits of uranium impact in the groundwater. Uranium levels in the Line 2 alluvial wells rebounded after a significant decrease was observed in this area in 2006 (Figure 27). Since that time, levels have varied at most locations; however, levels have been similar to those measured in 2005.

Table 39. 2011 Total Uranium in QROU Line 2 Alluvial Wells

Location	Line	Geologic Unit	Uranium (pCi/L)			
			Q1	Q2	Q3	Q4
MW-1006	2	Alluvium	**1219**	**1016**	**372**	**880**
MW-1007	2	Alluvium	23.8	56.0	10.6	14.0
MW-1008	2	Alluvium	**2451**	**2776**	**2261**	**1029**
MW-1009	2	Alluvium	1.1	0.43	1.2	1.6
MW-1014	2	Alluvium	**1286**	**1286**	**765**	**1022**
MW-1016	2	Alluvium	154	129	120	118
MW-1045	2	Alluvium	1.4	1.4	1.5	1.4
MW-1049	2	Alluvium	0.05 (J)	ND (<0.014)	0.02 (J)	0.05 (J)
MW-1051	2	Alluvium	**1056**	**880**	**731**	**745**
MW-1052	2	Alluvium	**752**	**880**	**321**	**1070**

Concentrations in **bold** exceed the target level of 300 picocuries per liter.
J = estimated value less than the reporting limit; pCi/L = picocurie(s) per liter

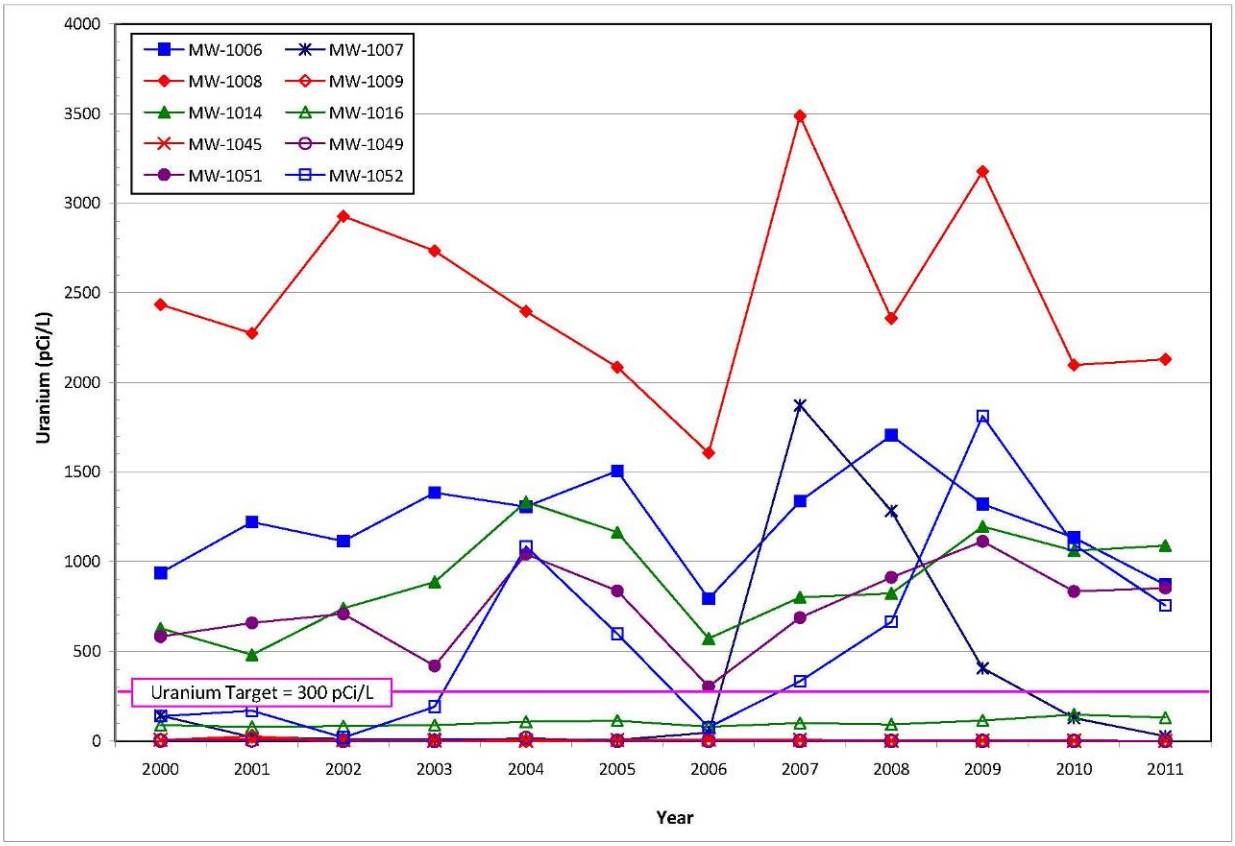

Figure 27. Average Uranium (pCi/L) in Line 2 Alluvial Wells

In previous reports, increasing uranium levels were reported in alluvial wells MW-1006, MW-1008, MW-1014, MW-1051, and MW-1052 starting in 2007. These alluvial wells monitor the area of highest uranium impact. Since 2007, uranium levels in MW-1006, MW-1008, and

MW-1052 have decreased, although the levels in MW-1008 and MW-1052 have been variable. Uranium levels in MW-1014 and MW-1051 increased until 2009 and then have remained stable.

A significant increase in uranium levels in alluvial well MW-1007, which is screened in the reduced portion of the groundwater north of the slough, was observed in 2007. Subsequent data have indicated a general decline in uranium levels. The geochemical data from MW-1007 do not support the presence of elevated uranium in groundwater. The geochemistry in this well exhibits high dissolved iron concentrations and low oxidation-reduction potential (ORP) values, indicators of a reducing environment. However, sulfate concentrations, which are typically low in reducing environments, area slightly elevated. The evaluation of filtered and unfiltered data indicated no significant difference between the filtered and unfiltered samples, even though the turbidity in the well had increased. Although elevated uranium levels are reported in MW-1007, which is along the northern boundary of the reduction zone, Line 3 data indicate no migration of uranium south of the Femme Osage Slough into the Missouri River alluvium.

Trending results for the Line 2 wells (Table 40), which are screened in the saturated alluvium or bedrock between the Quarry Rim and the Femme Osage Slough, show decreases in uranium levels in this area, as indicated by negative slopes in all but two of the 18 wells sampled. The data collected in 2007 through 2011 were evaluated for statistically significant trends. Statistically significant downward trends were identified in six of the eight bedrock wells in Line 2 and in six of the 10 alluvial wells. Well MW-1032 is the only bedrock well with uranium levels above the target level of 300 pCi/L, and if the current decreases continue, the target level could be reached by 2014 in the bedrock groundwater, based on an estimate derived from an exponential curve model. Alluvial wells MW-1006, MW-1008, MMW-1051, and MW-1052 have uranium levels greater than the target level of 300 pCi/L. Estimates derived from the exponential curve model indicate that uranium in these wells could reach the target level by 2017 if current decreases continue.

Table 40. Trending Analysis for Uranium in Line 2 Groundwater Monitoring Wells (2007–2011)

Location	Unit	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
					Lower	Upper
MW-1006	Alluvium	20	**Down**	–123	–214	–44.9
MW-1007	Alluvium	20	**Down**	–285	–471	–167
MW-1008	Alluvium	20	**Down**	–280	–678	–19.9
MW-1009	Alluvium	20	**Down**	–0.44	–0.69	–0.18
MW-1013	Bedrock	20	**Down**	–32.1	–50.0	–10.2
MW-1014	Alluvium	20	None	70.1	–37.8	187
MW-1015	Bedrock	20	**Down**	–7.2	–10.0	–1.6
MW-1016	Alluvium	20	Up	11.1	3.2	19.1
MW-1028	Bedrock	17	None	–0.04	–0.20	0.11
MW-1031	Bedrock	20	None	–0.48	–0.91	0.08
MW-1032	Bedrock	20	**Down**	–85.4	–109	–63.6
MW-1045	Alluvium	20	**Down**	–0.40	–0.84	–0.23
MW-1046	Bedrock	20	**Down**	–0.22	–0.30	–0.15
MW-1047	Bedrock	20	**Down**	–0.07	–0.14	–0.02
MW-1048	Bedrock	20	**Down**	–44.8	–56.2	–26.2
MW-1049	Alluvium	20	**Down**	–0.03	–0.04	–0.01
MW-1051	Alluvium	20	None	–31.2	–152	122
MW-1052	Alluvium	20	None	84.5	–157	292

pCi/L = picocurie(s) per liter

Increasing uranium levels are reported in alluvial wells MW-1014 and MW-1016, as indicated by positive slopes. A statistically upward trend was calculated for MW-1016. Uranium levels in MW-1016 are below the target level of 300 pCi/L. Levels in well MW-1014 also exceed the target level of 300 pCi/L; however, an upward trend was not indicated at this location.

The attainment objective for the long-term monitoring of 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 (DOE 2000b). The average uranium levels in eight wells north of the slough exceeded the target level in 2011. The 90th percentile associated with the data from the Line 1 and 2 wells was 1,153 pCi/L. This value is lower than those determined since 2007 (Figure 28). Looking at the 90th percentile for Lines 1 and 2 separately indicates that the metric is controlled by changes in the Line 2 wells, primarily the uranium levels measured in the Line 2 alluvial wells.

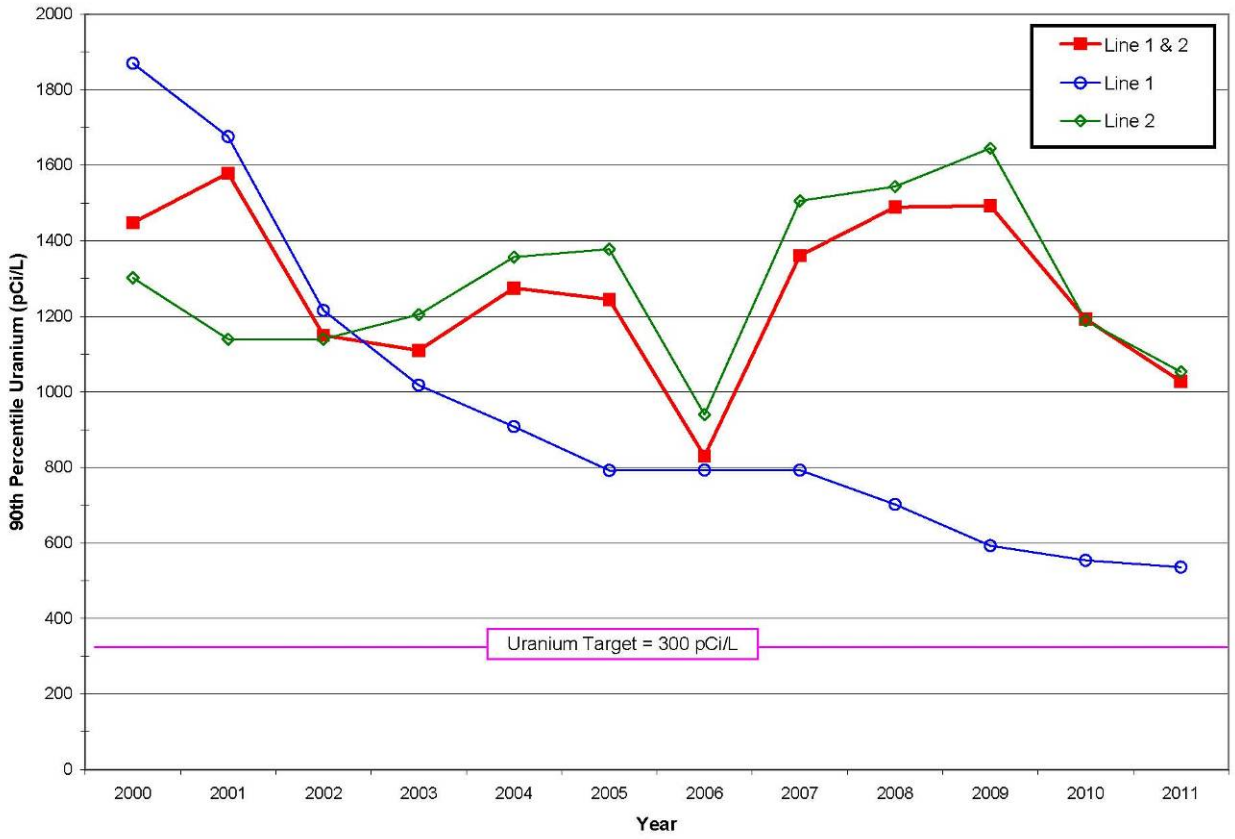

Figure 28. 90th Percentile of Uranium in Line 1 and 2 Wells (2000–2011)

Overall, the decreasing uranium levels 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 reduced and possibly prevented 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. Although uranium levels have

increased in some of the alluvial wells north of the slough, levels are far below historical highs. Monitoring in wells screened in the reducing portion of the area north of the slough indicates that uranium levels continue to remain low.

Nitroaromatic Compounds

In 2011, samples from eight monitoring wells were analyzed for the nitroaromatic compound 2,4-DNT (Table 41). These monitoring wells have historically been impacted by nitroaromatic compounds along the Quarry rim or between the Quarry and Femme Osage Slough. Concentration of 2,4-DNT in MW-1027 during the first half of 2011 was above the Missouri Water Quality Standard of 0.11 μg/L. MW-1027 is the only well in which 2,4-DNT levels have exceeded the target level of 0.11 μg/L since 2009.

Table 41. 2011 2,4-DNT Concentrations for the QROU Monitoring Locations

Location	Line	Geologic Unit	Average Concentration (μg/L)			
			S1		S2	
MW-1002	1	Kimmswick-Decorah	ND (<0.019)		ND (<0.018)	
MW-1004	1	Kimmswick-Decorah	ND (<0.018)		ND (<0.018)	
MW-1005	1	Kimmswick-Decorah	ND (<0.018)		ND (<0.018)	
MW-1006	2	Alluvium	0.023	ND (<0.018)	ND (<0.019)	ND (<0.019)
MW-1027	1	Kimmswick-Decorah	**3.5**		0.018 (J)	
MW-1032	2	Kimmswick-Decorah	ND (<0.018)	ND (<0.019)	ND (<0.018)	ND (<0.018)
MW-1045	2	Alluvium	ND (<0.019)	ND (<0.019)	ND (<0.019)	ND (<0.019)
MW-1049	2	Alluvium	ND (<0.021)	ND (<0.018)	ND (<0.018)	ND (<0.018)

Concentrations in **bold** exceed the Missouri Water Quality Standard of 0.11 μg/L for 2,4-DNT.
μg/L = microgram per liter; ND = analyte not detected above method detection limit indicated in parentheses.

The concentrations of 2,4-DNT in MW-1006 and MW-1027 have fluctuated since bulk waste removal was completed in the Quarry (Figure 29). Increased concentrations were observed in wells MW-1006 and MW-1027 starting in 2004, and the concentrations fluctuated significantly after that time. Concentrations less than the detection limit have historically been reported in MW-1045 and MW-1049, which are the farthest downgradient wells in the vicinity of wells MW-1006 and MW-1027.

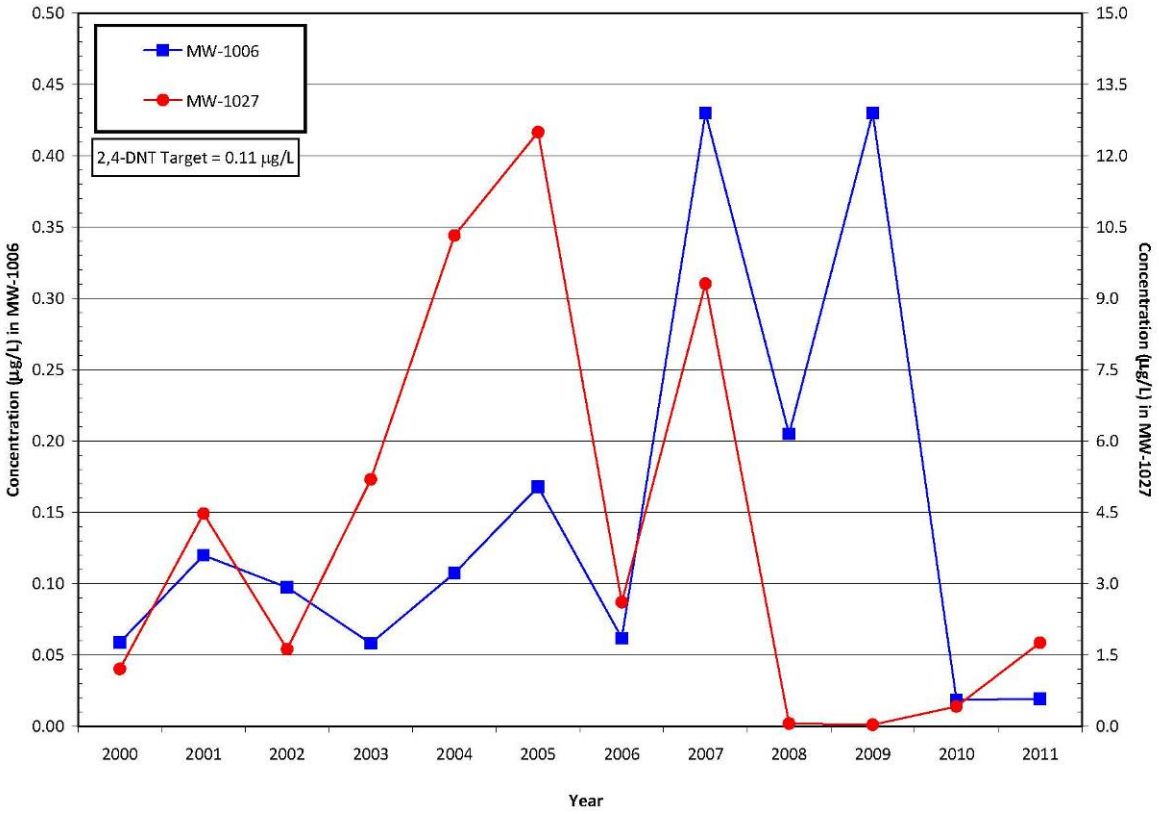

Figure 29. Average 2,4-DNT Concentrations in MW-1006 and MW-1027

Trend analyses for 2,4-DNT were performed for wells MW-1006 and MW-1027 (Table 42), as these are the only locations that had detectable concentrations in the last 5 years. Overall, the concentrations of 2,4-DNT are decreasing at these two locations, as indicated by negative slopes. A statistical downward trend was calculated for MW-1006, although concentrations of 2,4-DNT are already less than the target level of 0.11 µg/L. Data from 2007 through 2011 indicated no statistical trend for MW-1027.

Table 42. Trending Analysis for 2,4-DNT in Selected Quarry Groundwater Monitoring Wells (2007–2011)

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Upper
MW-1006	18	**Down**	–0.086	–0.14	–0.007
MW-1027	14	None	–0.099	–1.29	0

µg/L/yr = microgram(s) per liter per year

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 (DOE 2000b). The eight monitoring wells that were selected for continued long-term monitoring were used to calculate this metric. The 90th percentile associated with the data from the eight wells was 0.020 µg/L, based on data collected in 2011. This value is significantly lower

than those measured in previous years (Figure 30) and the second year that the value has been less than the target level of 0.11 µg/L.

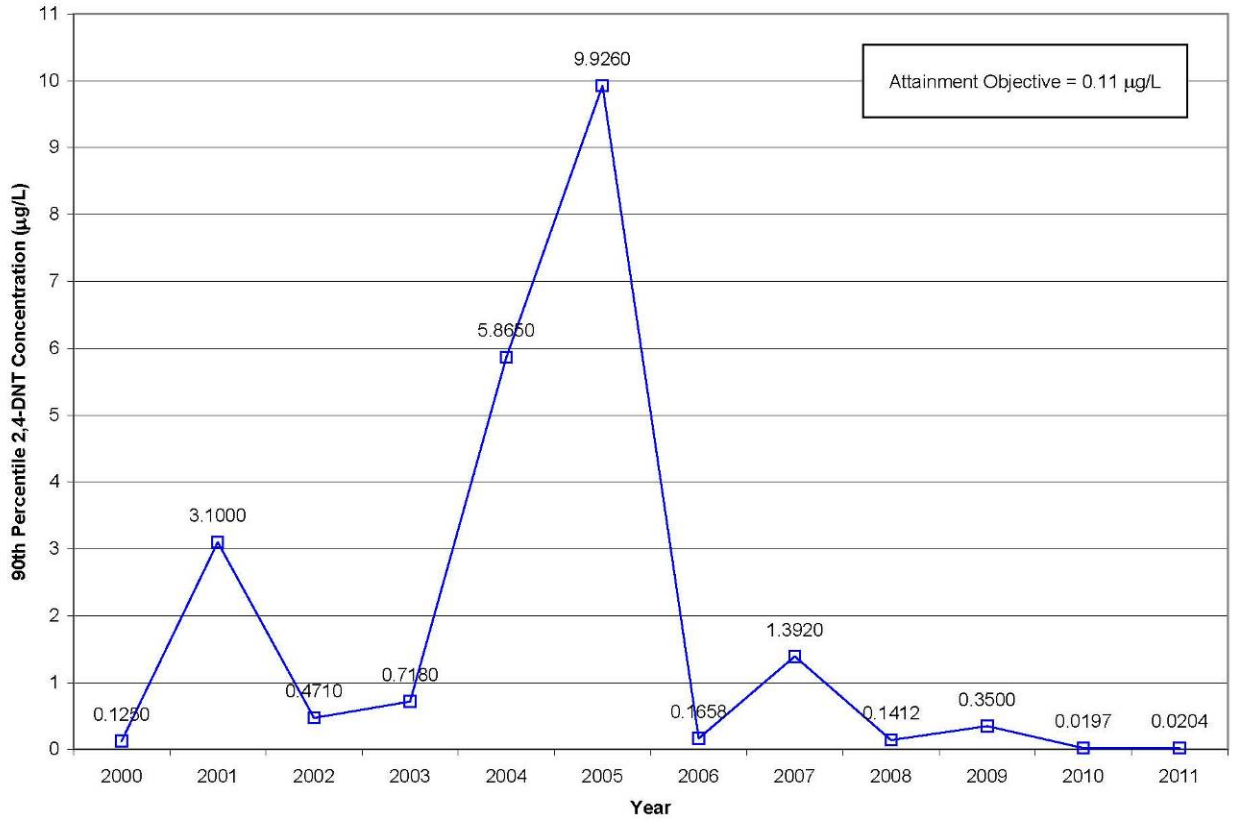

Figure 30. 90th Percentile of 2,4-DNT in Line 1 and 2 Wells (2000–2011)

Overall, 2,4-DNT impact in groundwater is located within two discrete areas. Concentrations, although variable, have generally decreased since the removal of the bulk wastes in the quarry. Present concentrations in groundwater pose little potential impact to the groundwater in the Missouri River alluvium.

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 oxidation potential (Eh). Sulfate is monitored as an indicator of redox conditions in the groundwater in the vicinity of the Quarry. Higher sulfate concentrations are generally observed in an oxidizing environment. Iron (total dissolved and ferrous) is also monitored as an indicator of redox conditions in the groundwater. Iron concentrations generally 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. A summary of the geochemical parameters for each monitoring location is presented in Table 43.

Table 43. Geochemical Parameter Data at the Weldon Spring Quarry in 2011

Location	Line	Geologic Unit	Average Values			
			Sulfate (mg/L)	Dissolved Iron (µg/L)	Ferrous Iron (µg/L)	ORP[a] (mV)
MW-1002	1	Kimmswick-Decorah	93.0	ND (<22.0)	10	223
MW-1004	1	Kimmswick-Decorah	102	385	270	80
MW-1005	1	Kimmswick-Decorah	91.5	376	0	91
MW-1012	1	Kimmswick-Decorah	39.6	ND (<30.0)	10	153
MW-1027	1	Kimmswick-Decorah	63.0	ND (<22.0)	10	178
MW-1030	1	Kimmswick-Decorah	119	11,160	1,980	–21
MW-1006	2	Alluvium	47.4	1,980	1,890	–19
MW-1007	2	Alluvium	14.1	51,975	23,415	–142
MW-1008	2	Alluvium	70.6	ND (<30.0)	42.5	69
MW-1009	2	Alluvium	14.9	26,225	11,510	–116
MW-1013	2	Kimmswick-Decorah	61.5	3,628	2,635	–41
MW-1014	2	Alluvium	96.6	602	440	33
MW-1015	2	Kimmswick-Decorah	68.2	48.4	20	76
MW-1016	2	Alluvium	77.8	ND (<30.0)	10	129
MW-1028	2	Plattin	28.7	ND (<30.0)	10	82
MW-1031	2	Alluvium	30.0	35.1	7.5	100
MW-1032	2	Kimmswick-Decorah	98.0	167	207	51
MW-1045	2	Alluvium	23.0	54.0	80	90
MW-1046	2	Plattin	59.0	ND (<30.0)	7.5	143
MW-1047	2	Plattin	73.0	ND (<30.0)	10	84
MW-1048	2	Plattin	58.0	884	602	9
MW-1049	2	Alluvium	0.76 (J)	46,750	24,700	–169
MW-1051	2	Alluvium	84.8	104	55	45
MW-1052	2	Alluvium	42.8	8,192	4,815	–64

[a] Convert oxidation-reduction potential to Eh by adding 200 mV to the ORP value.
J = estimated value less than the reporting limit; mg/L = milligrams per liter; mV = millivolts;
µg/L = micrograms per liter; ND = analyte not detected above method detection limit included in parentheses;
ORP = oxidation-reduction potential

A review of the 2011 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 for 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 has been consistent, and the attenuation of uranium in this area continues.

3.1.2.5 Monitoring Results for the Missouri River Alluvium

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

Uranium

The six monitoring wells immediately south of the slough (Line 3) and the four RMW-series wells (Line 4) were sampled for uranium during 2011 (Table 44) to verify that levels remain within the range of its natural variation in Missouri River alluvium. The results indicate that uranium levels were less than the statistical background value in the alluvium (Table 35).

None of the locations south of the slough have uranium levels that exceed the drinking water standard of 20 pCi/L.

Table 44. 2011 Total Uranium Levels in the Missouri River Alluvial Aquifer

Location	Line	Uranium (pCi/L)			
MW-1017	3	0.074		ND (<0.045)	
MW-1018	3	ND (<0.045)	0.056 (J)	ND (<0.045)	0.062
MW-1019	3	ND (<0.045)		< 0.045	
MW-1021	3	ND (<0.045)		ND (<0.045)	
MW-1044	3	ND (<0.045)	<0.095	ND (<0.045)	ND (<0.045)
MW-1050	3	ND (<0.045)		ND (<0.045)	
RMW-1	4	1.1			
RMW-2	4	2.8			
RMW-3	4	0.68			
RMW-4	4	0.50			

J = estimate value less than the reporting limit; ND = analyte not detected above method detection limit indicated in parentheses; pCi/L = picocurie(s) per liter

Geochemical Parameters

The monitoring wells south of the slough were sampled for sulfate, dissolved iron, and ORP to assess redox conditions in the Missouri River alluvium downgradient of the area of uranium impact (Table 45). 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 the migration of uranium if it were to pass beyond the reduction zone north of the slough. Data from the review period were consistent for all locations except MW-1044.

Increased sulfate concentrations were reported in MW-1044 beginning in 2008 and have continued through 2011. A slight increase in sulfate was also measured in nearby MW-1018. High iron concentrations and low ORP values continued to support the interpretation that a reducing environment is prevalent in this area. Uranium levels remain low at the locations along the southern edge of the Femme Osage Slough.

Table 45. 2011 Geochemical Parameter Data in the Missouri River Alluvial Aquifer

Location	Average Values			
	Sulfate (mg/L)	Dissolved Iron (µg/L)	Ferrous Iron (µg/L)	ORP[a] (mV)
MW-1017	1.0	20,200	1,785	–169
MW-1018	17.8	37,000	13,690	–173
MW-1019	0.76	13,750	4,640	–135
MW-1021	0.72	14,900	7,850	–141
MW-1044	214	37,000	6,720	–186
MW-1050	8.4	14,900	5,700	–148
RMW-1	27.0	5,500	2,340	–19
RMW-2	14.0	7,700	1,300	–113
RMW-3	11.0	14,000	10,300	–124
RMW-4	4.5	18,000	2,575	–130

[a] Convert oxidation-reduction potential to Eh by adding 200 millivolts to the oxidation-reduction value.
mg/L = milligram(s) per liter; mV = millivolts; µg/L = micrograms per liter; ORP = oxidation-reduction potential
J = estimated values less than the reporting limit

3.1.2.6 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 and resulted in shifts in potential contaminant migration. The average groundwater elevations measured in 2010 were used to construct a groundwater surface map of the shallow bedrock and alluvium at the Quarry (Figure 31). Groundwater flow is parallel to the bedrock bluff of the Quarry as it moves south beneath the Femme Osage Slough. The configuration of the shallow groundwater surface has remained relatively unchanged from previous years.

Groundwater elevations in the quarry area fluctuate significantly (Figure 32), 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 than the wells screened in the Missouri River alluvium (Lines 2, 3 and 4). In 2006, water levels were extremely low due to drought conditions in the Quarry area that continued into early 2008. Water levels have generally increased in the Quarry area since that time.

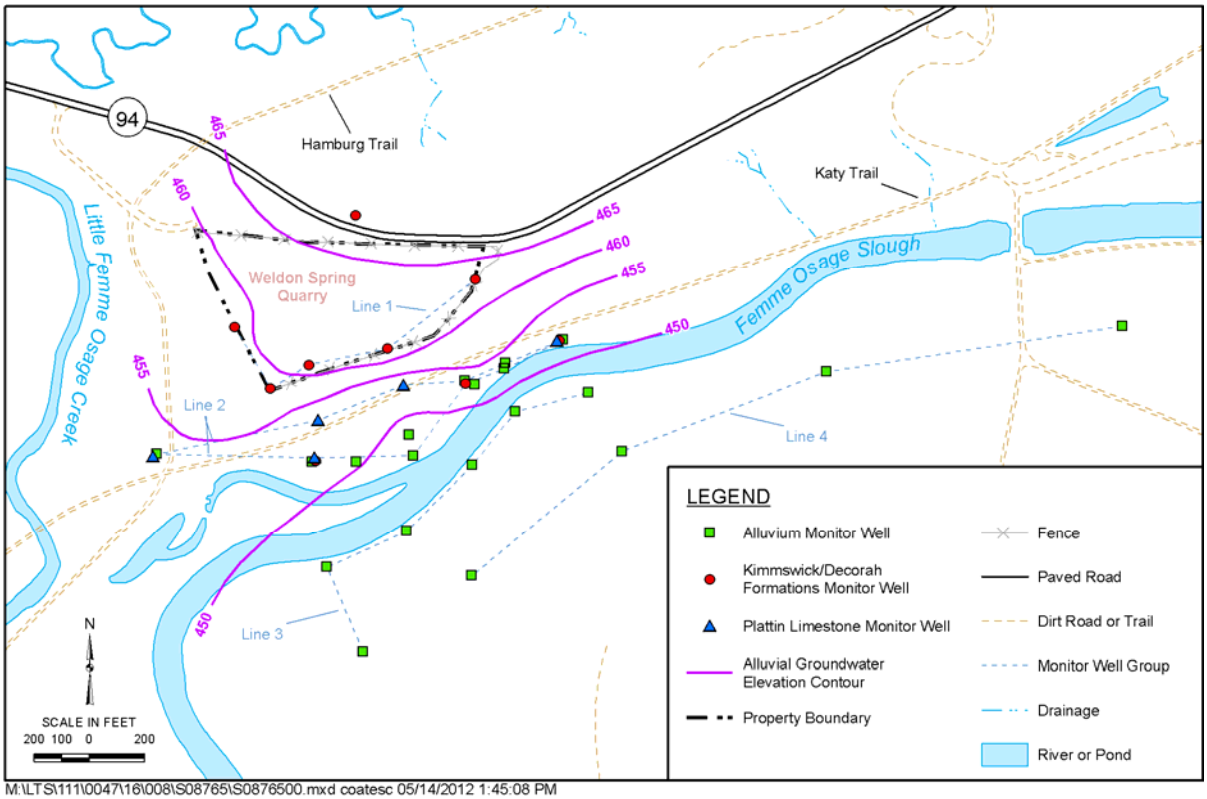

Figure 31. Groundwater Surface at the Weldon Spring Quarry

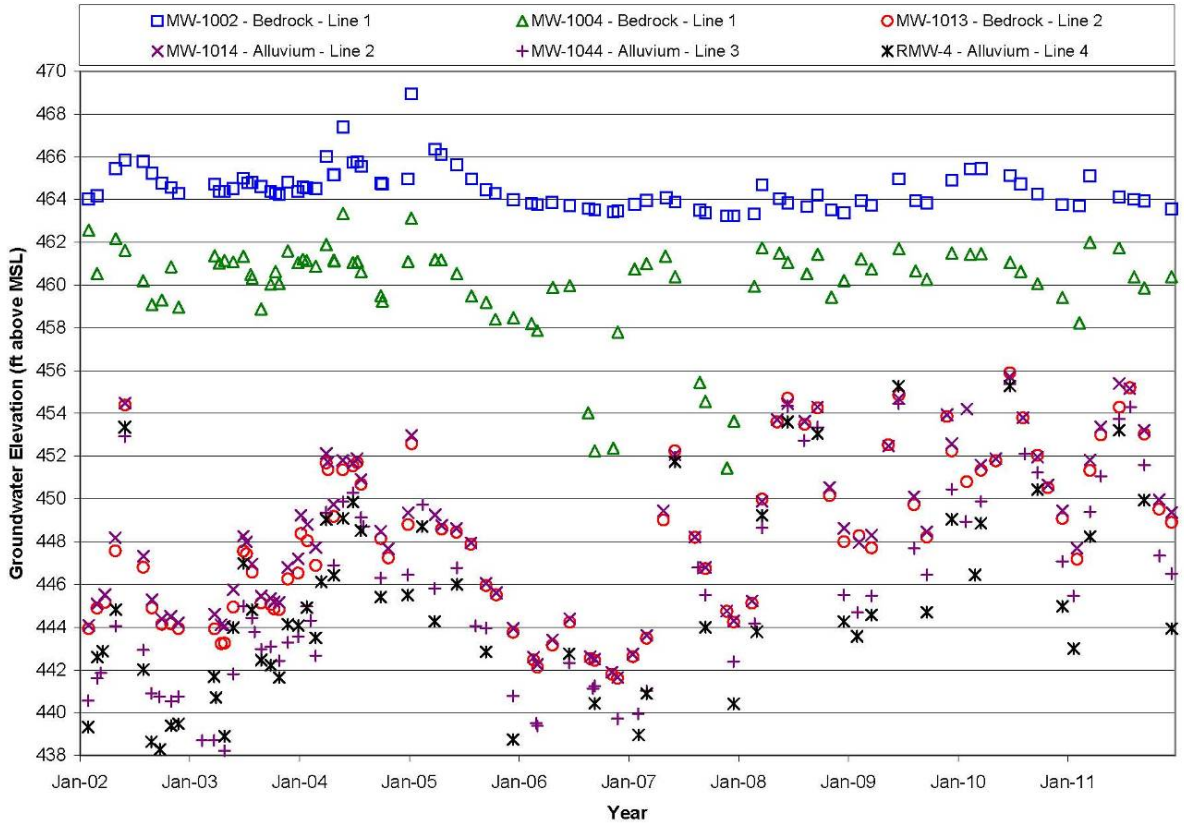

Figure 32. Groundwater Elevations in the Quarry Area

3.1.3 Disposal Cell Monitoring

Five groundwater monitoring wells, one spring, and disposal cell leachate were sampled during 2011 as part of the detection monitoring program for the permanent disposal cell. This monitoring is performed to meet the substantive requirements of 40 CFR 264 Subpart F; 10 CSR 25-7.264(2)(F), and 10 CSR 80-3.010(8). These federal and state hazardous- or solid-waste regulations were identified as ARARs for the selected remedy in the *Record of Decision for the Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1993). These wells, the spring, and the leachate were monitored in accordance with Appendix K of the LTS&M Plan (DOE 2008).

3.1.3.1 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 (Figure 4). Semiannual detection monitoring began in mid-1998, after cell construction and waste placement activities had begun.

The monitoring program for the disposal cell consisted of semiannual sampling of the monitoring wells, spring, and leachate. Groundwater and surface water samples were analyzed for the list of analytes in Table 46. Leachate was analyzed for the list of analytes in Table 47. Sampling was performed as specified in Appendix K of the LTS&M Plan (DOE 2008).

Table 46. Disposal Cell Detection Monitoring—Groundwater and Surface Water 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

PAHs = polycyclic aromatic hydrocarbons; PCBs = polychlorinated biphenyls

Table 47. 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 (as N) 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

COD = chemical oxygen demand; PAHs = polycyclic aromatic hydrocarbons; PCBs = polychlorinated biphenyls; TDS = total dissolved solids; TOC = total organic carbon

Under the monitoring program, signature parameter (barium and uranium) data from each monitoring event are compared to the baseline tolerance limits (BTLs) to trace general changes in groundwater quality and determine whether statistically significant evidence of contamination due to cell leakage exists. Tolerance limits for signature parameters have been calculated using the data set from 1997 through 2002, using 95 percent confidence limits.

The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if there are changes in the groundwater system. Data are compared to the 3 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 three times the standard deviation for a given location.

Wells with data showing statistically significant increases or decreases are re-sampled to confirm the exceedance. If the results of the re-sampling 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 contaminant of concern for the GWOU, this information is evaluated under the monitoring program for that operable unit.

3.1.3.2 Disposal Cell Monitoring Results

The 2011 monitoring results for the signature parameters are presented in Table 48 along with applicable BTLs. The results were less than the applicable BTLs, which indicates that there is no statistical evidence of leakage of leachate into the groundwater beneath the disposal cell. Data indicating general groundwater quality in the detection monitoring wells and springs during this period were consistent with historical data.

Table 48. 2011 Signature Parameter Results and Associated BTLs at Disposal Cell Monitoring Locations

Parameter	Location	BTL	Results	
			June 2011	December 2011
Barium (µg/L)	MW-2032	337	148	182
	MW-2046	277	215	198
	MW-2047	471	397	338
	MW-2051	285	250	238
	MW-2055	98	18.7	16.9
	SP-6301	180	138	115
Uranium (pCi/L)	MW-2032	6.4	2.4	2.2
	MW-2046	1.8	1.1	1.2
	MW-2047	2.7	1.1	1.2
	MW-2051	4.5	1.2	1.3
	MW-2055	7.5	1.8	1.9
	SP-6301	159	36.2	43.7

µg/L = micrograms per liter; pCi/L = picocuries per liter

The disposal cell leachate 2011 monitoring results are presented in Table 49. The LCRS is sampled semiannually, and the data are used for comparison with 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 iron, manganese, and uranium. Concentrations of these three constituents have shown a general decline.

Table 49. 2011 Disposal Cell Leachate Monitoring Data

Parameter	Concentrations	
	June 2011	**December 2011**
Chloride (mg/L)	51.7	53.3
Fluoride (mg/L)	0.24 (J)	0.26 (J)
Nitrate-N (mg/L)	1.5	0.20 (J)
Sulfate (mg/L)	64.7	51.0
Arsenic (µg/L)	5.0	ND (<2.0)
Barium (µg/L)	743	673
Chromium (µg/L)	ND (<2.0)	ND (<2.0)
Cobalt (µg/L)	4.3	5.2
Iron (µg/L)	5,240	2,160
Lead (µg/L)	ND (<0.5)	ND (<0.5)
Manganese (µg/L)	896	660
Nickel (µg/L)	11.5	7.8
Selenium (µg/L)	7.1	3.6
Thallium (µg/L)	ND (<0.4)	0.58
COD (mg/L)	39.6	31.1
TDS (mg/L)	762	714
TOC (mg/L)	12.0	14.0
1,3,5-TNB (µg/L)	ND (<0.017)	ND (<0.017)
1,3-DNB (µg/L)	ND (<0.014)	ND (<0.014)
2,4,6-TNT (µg/L)	ND (<0.022)	ND (<0.022)
2,4-DNT (µg/L)	ND (<0.019)	ND (<0.019)
2,6-DNT (µg/L)	ND (<0.022)	ND (<0.022)
NB (µg/L)	ND (<0.033)	ND (<0.033)
Radium-226 (pCi/L)	0.64 (J)	ND (<0.40)
Radium-228 (pCi/L)	0.76 (J)	ND (<0.76)
Thorium-228 (pCi/L)	ND (<0.26)	ND (<0.23)
Thorium-230 (pCi/L)	0.31 (J)	0.33 (J)
Thorium-232 (pCi/L)	ND (<0.17)	ND (<0.22)
Uranium (pCi/L)	21.1	22.7
PCBs/PAHs (µg/L)	ND (<0.50)	ND (<0.50)
DO (mg/L)	2.3	2.5
ORP (mV)	–54	99
pH (s.u.)	7.2	7.3
SC (µmhos/cm)	1131	1210
Temperature (°C)	17.2	13.5
Turbidity (NTU)	20.3	23.6

COD = chemical oxygen demand; DNB = dinitrobenzene; DO = dissolved oxygen;
µmhos/cm = micromhos per centimeter; J = estimated value less than the reporting limit;
ND = analyte not detected above method detection limit indicated in parentheses;
NTU = nephelometric turbidity units; ORP = oxidation-reduction potential; PAHs = polycyclic aromatic hydrocarbons;
PCBs = polychlorinated biphenyls; R = data point rejected during validation process; SC = specific conductance;
s.u. = standard units; TDS = total dissolved solids; TOC = total organic carbon

3.1.3.3 Groundwater Flow

Groundwater flow rate and direction are evaluated annually as specified in Appendix K of the LTS&M Plan (DOE 2008). The groundwater flow direction was determined by constructing a potentiometric surface map of the shallow aquifer, using the available wells at the Chemical Plant (Figure 21). The configuration of the potentiometric surface has remained relatively

unchanged since the construction of the disposal cell. The groundwater flow direction is generally to the north. A groundwater divide is present along the southern boundary of the site.

The average groundwater flow rate (average linear velocity) is calculated using the following equation:

$$v = -Ki/n_e$$

Where: v = velocity
K = average hydraulic conductivity
i = hydraulic gradient
n_e = effective porosity

The average hydraulic conductivity (K), using data from the cell monitoring wells, is 7×10^{-3} centimeters per second. An effective porosity (n_e) of 0.10 was selected to estimate the maximum groundwater flow rate in this area. The hydraulic gradient (i) in the disposal cell area is 0.011 ft/ft and is based on data from MW-2032 and MW-2055, located 2,100 ft apart. This approach is consistent with the calculations presented in Appendix K of the LTS&M Plan (DOE 2008). The average flow rate for 2011 was 2.2 ft per day, which is the same as the average flow rate calculated since 2005.

3.2 Surface Water

3.2.1 Chemical Plant Surface Water

The surface water locations at Schote Creek, Dardenne Creek, and Busch Lakes 34, 35, and 36 (Figure 5) were sampled once during 2011 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.

The results for the Chemical Plant surface water sampling are presented in Table 50 along with the recent 5-year high for each location, for comparison. The uranium levels at Busch Lake 34 continue to be higher compared to the remainder of the locations; however, uranium levels at the Busch Lake outlets have shown an overall decline since remediation at the Chemical Plant site. The Schote Creek and Dardenne Creek locations are downstream of the lakes and have always shown relatively low levels because the Chemical Plant portion of the watershed is much smaller than the total watershed area. These results are consistent with data from previous years.

Table 50. 2011 Total Uranium at Weldon Spring Chemical Plant Area Surface Water Locations

Location	Uranium (pCi/L)	Recent High[a]
SW-2004 (Busch Lake 34)	3.9	8.1 (2007)
SW-2005 (Busch Lake 36)	3.2	3.4 (2007)
SW-2012 (Busch Lake 35)	1.0	2.4 (2007)
SW-2016 (Dardenne Creek)	1.1	1.4 (2009)
SW-2024 (Schote Creek)	1.8	2.4 (2009)

[a] 2007−2011
pCi/L = picocuries per liter

3.2.2 Quarry Surface Water

Four locations within Femme Osage Slough (Figure 33) were sampled quarterly in 2011 to assess the water quality in the slough and the potential impact from groundwater north of the slough (Table 51). These sampling sites are in the upper section of the slough, which is adjacent to the area of groundwater impact. Occasionally, groundwater north of the slough will discharge into the slough when the water table is high.

Table 51. 2011 Total Uranium in the Femme Osage Slough near the Quarry

Location	Uranium (pCi/L)			
	Q1	Q2	Q3	Q4
SW-1003	30.0	60.0	17.3	32.6
SW-1004	47.0	64.0	17.7	34.1
SW-1005	14.0	43.0	16.0	27.5
SW-1010	25.0	51.0	20.0	34.3

pCi/L = picocuries per liter; Q1, Q2, Q3, Q4 = quarterly sampling periods

Elevated uranium levels were identified for the four surface water monitoring locations along the Femme Osage Slough in May 2008, and a special study was initiated to evaluate the changes in condition and to identify mechanisms causing the increase in uranium levels. Prior to the May 2008 sampling event, the slough had been completely dewatered for several months, and sampling was performed a short period after water had begun to pond within the slough.

From the special study, it was concluded that after periods when the slough was dry or very low and portions of the slough bottom became exposed, elevated uranium values are reported in the samples collected soon after the slough refilled and inundated. Sorption of uranium onto the sediments is not permanent and can be reversed. Desorption from organics likely occurs when the areas are re-saturated with surface water runoff and river water after the sediments have dried out. The reversal of precipitated uranium may occur to a minor extent. The period that uranium is released from sediments is not long, and levels measured in the surface water return to typical values when the water covers the bottom of the slough.

Uranium levels in the Femme Osage Slough (Figure 34) have been elevated since this water body has been partially or completely dewatered starting in late 2006. Elevated uranium levels are reported during periods when the slough levels are low, as reflected in the second quarter values. Average uranium values are lower than those reported in 2009 and 2010. Quarterly sampling of the slough will continue in 2012.

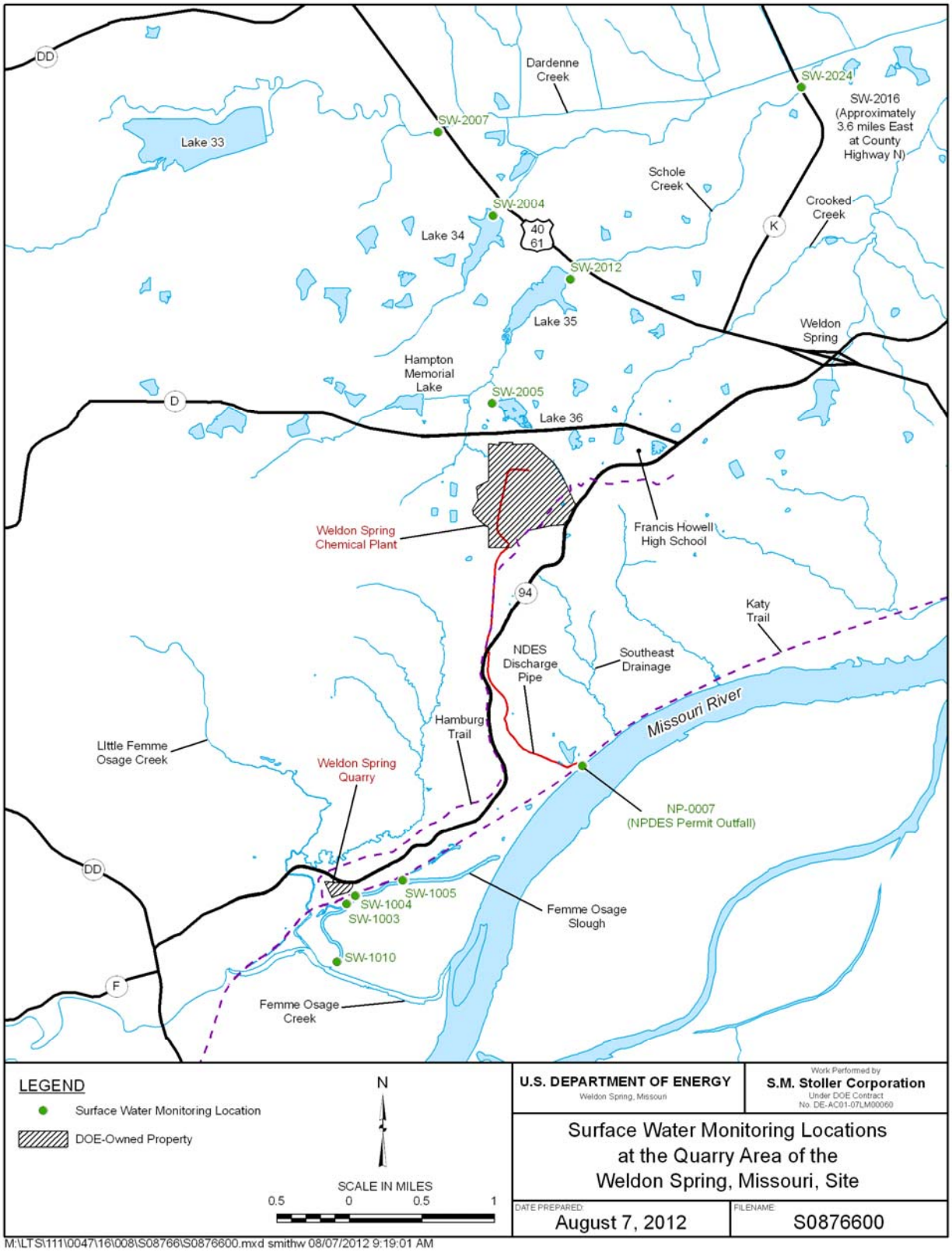

Figure 33. Surface Water Monitoring Locations at the Quarry Area of the Weldon Spring, Missouri, Site

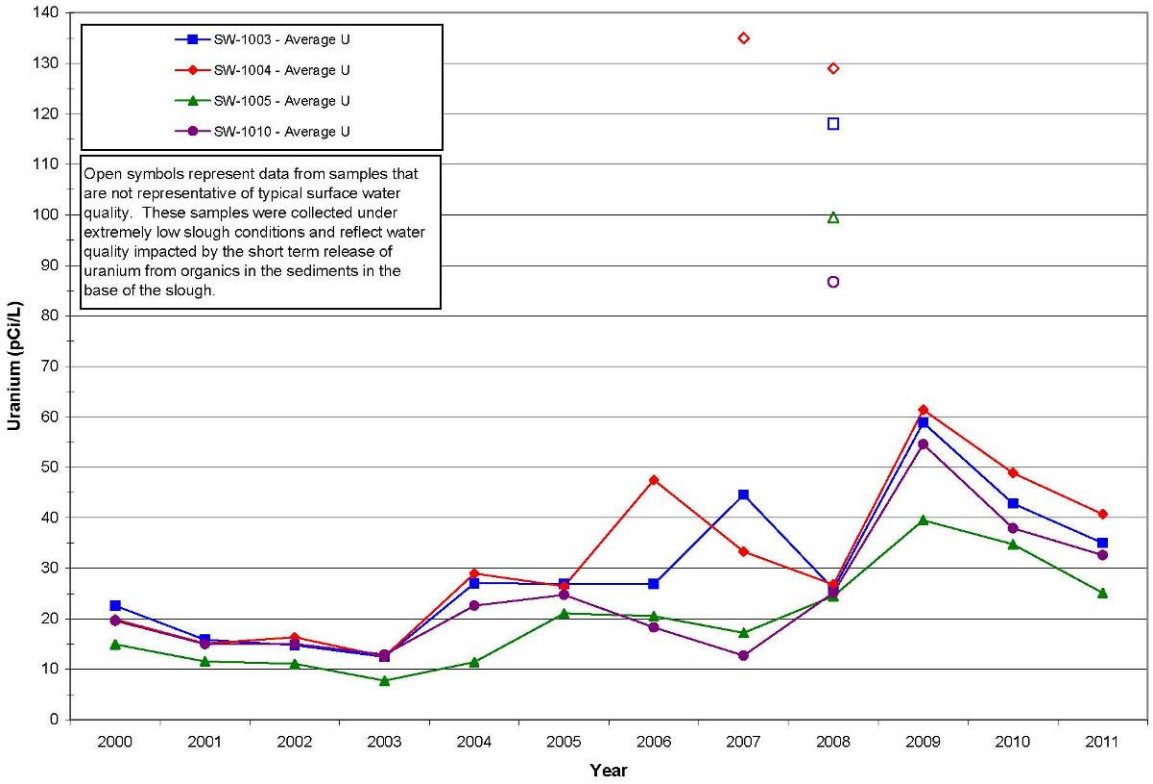

Figure 34. Uranium Levels in the Femme Osage Slough

3.3 Leachate Collection and Removal System

The LCRS collects leachate from the disposal cell. The leachate continued to be sampled in accordance with the Disposal Cell Groundwater Monitoring Plan in Appendix K of the LTS&M Plan (DOE 2008). The leachate analytical data for 2011 were discussed previously in Section 3.1.3.2 and are shown in Table 49.

As needed, the leachate is pumped from the sump, pretreated, and then transported to MSD for final treatment in their Bissell Point Plant wastewater treatment facility. A sample of leachate is collected and analyzed in accordance with MSD requirements for each hauling event. MSD requirements for the leachate are discussed in Section 2.1.3.3.

Uranium concentrations in untreated leachate during 2011 averaged approximately 19.2 pCi/L. The uranium concentrations data have increased slightly since 2010, when uranium levels were near 16 pCi/L. A high uranium concentration of 22.8 pCi/L was observed in December 2011. The actual uranium concentrations in the untreated leachate are shown in Figure 35.

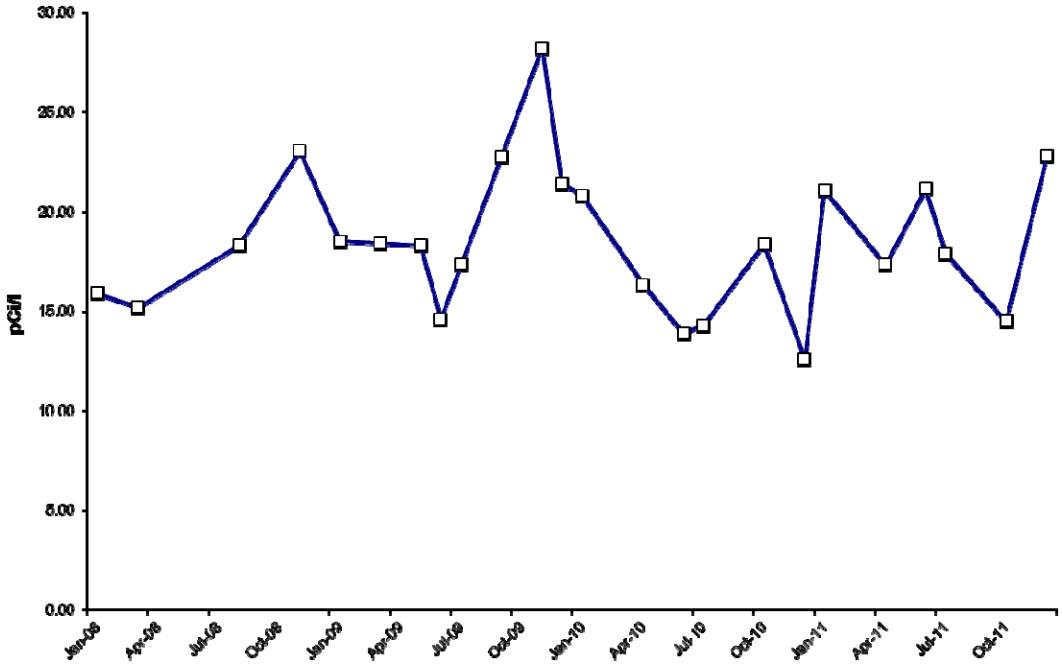

Figure 35. Actual Uranium Concentrations in the Primary Leachate

Every 2 weeks, the leachate flow rates from the disposal cell are verified and monitored, and the LCRS is inspected. The leachate levels were recorded on a data logger and downloaded remotely at least once per day. The regulations in 40 CFR 264.303(c) only require monthly recording and, if the levels are stable, quarterly flow recording thereafter. Leachate flow rates are reported in units of gallons per day and compared to the action leakage rate of 100 gallons per acre per day established for the secondary (or lower) leachate collection system.

During 2010 and 2011, discharge from the primary leachate collection system generated approximately 88 gallons per day and 83 gallons per day, respectively. The daily averages for the primary leachate flow rates are shown in Figure 36. The combined leachate flow rate from the secondary leachate collection system averaged approximately 10.5 gallons per day during 2010 and 10.2 gallons per day in 2011. On a per-acre basis, the average leakage rate for the secondary leachate collection system in 2010 and 2011 was approximately 0.44 and 0.42 gallon per acre per day, respectively. This rate continues to be significantly less than 1 percent of the action leakage rate of 100 gallons per acre per day.

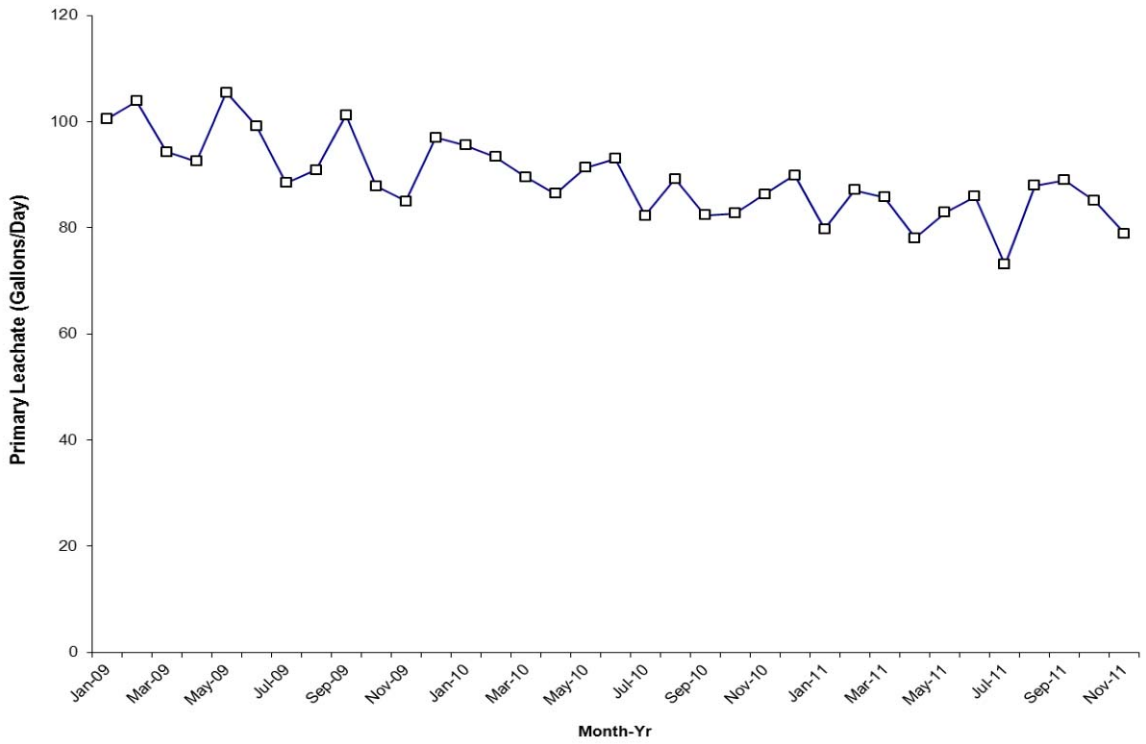

Figure 36. Daily Averages of the Primary Leachate Flow

3.4 Air

In the past, during active site remediation, the Weldon Spring Site operated an extensive environmental airborne monitoring and surveillance program in accordance with DOE orders, EPA and National Emission Standards for Hazardous Air Pollutants regulations, and the WSSRAP *Environmental Monitoring Plan* (DOE 2003a). Throughout the remediation of contaminated soils and materials, the potential for airborne releases and atmospheric migration of radioactive contaminants was closely monitored by measuring gamma exposure rates and concentrations of radon, airborne radioactive particulates, airborne asbestos, and fine particulate matter at various site perimeter and offsite locations. The potential for the airborne release of radionuclides was eliminated with the final emplacement of contaminated materials in the permanent disposal cell. No air monitoring has been conducted since 2001 (DOE 2001).

3.5 Radiation Dose Analysis

This section evaluates the potential effects of remaining surface water and groundwater discharges of radiological contaminants from the Weldon Spring Site in 2011. The total effective dose (TED) has been calculated for 2011 based on the applicable exposure pathway. Doses resulting from airborne emissions are no longer calculated, since the potential for the airborne release of radiological contaminants has been eliminated, and, therefore, the regulations of 40 CFR 61 Subpart H, "National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities," are no longer relevant. Similarly, doses resulting

from external gamma radiation are no longer calculated since the radon sources have been remediated and are contained within the permanent disposal cell. The cell cover effectively mitigates radon releases to levels comparable to those at background locations.

For this report, the potential exposure in terms of dose to an individual who consumes spring water contaminated with uranium is calculated. Because this calculation uses data from the spring with the highest uranium concentration (SP-5304 in the Southeast Drainage, where the 2011 uranium concentration was 79.2 pCi/L), the calculated dose represents the dose for the reasonable maximally exposed individual. The estimated TED to this maximally exposed individual is about 0.17 mrem. This result is compared to DOE limits established in DOE Order 458.1 to demonstrate compliance with regulatory requirements.

3.5.1 Pathway Analysis and Exposure Scenario

In developing specific elements of the Weldon Spring Site environmental monitoring program, potential exposure pathways and health effects of the radioactive and chemical materials present onsite are evaluated to determine if potential pathways of exposure exist. Under current site conditions, the only potential pathway to consider is that of a recreational visitor to the Weldon Spring Conservation Area possibly coming into contact with spring water specifically at SP-5304 in the Southeast Drainage. A dose calculation for a population within 49.6 miles of the site is not estimated, since the airborne release of radioactive contaminants is not a factor.

Consumption of contaminated groundwater at both the Chemical Plant/former Raffinate Pits and the Quarry areas is not currently a pathway of concern, as no drinking water wells are located near the contaminated groundwater in the Chemical Plant and Raffinate Pits area, and there is no access to the impacted groundwater at the Quarry area. Concentrations of uranium in the production wells near the Weldon Spring Quarry are comparable to background concentrations.

The inhalation of airborne particulates, inhalation of radon gas, and external gamma irradiation are also no longer pathways of concern, since the contaminated soils and other materials have been remediated and placed in the onsite cell. Hence, these pathways were not included in the dose estimates for 2011.

The radiological public dose guideline in DOE Order 458.1 is applicable for comparing potential doses at the Weldon Spring Site. This guideline provides for an annual limit of 100 mrem TED, accounting for all exposure pathways (excluding background).

3.5.2 Total Effective Dose Estimates

The TED estimate for the exposure scenario was calculated using 2011 environmental monitoring data. The annual dose is well below the standards set by DOE for public exposure.

This section discusses the estimated TED to a hypothetical individual assumed to frequent the Southeast Drainage of the Weldon Spring Conservation Area. No private residences are adjacent to the Southeast Drainage, which is situated on land currently managed by MDC. Therefore, the calculation of dose equivalent is based on a recreational user of the Conservation Area who drank from SP-5304 20 times per year during 2011.

Exposure scenario assumptions particular to this dose calculation include the following:

- The maximally exposed individual drank 1 cup (0.2 liter [L]) of water from the spring 20 times per year (equivalent to 1.05 gallons [4.0 L] of water for the year).
- The maximum uranium concentration in water samples taken from spring locations during 2011 was at SP-5304 in the Southeast Drainage (79.2 pCi/L). This concentration was assumed to be present in all of the water ingested by the maximally exposed individual.

On the basis of the natural uranium activity ratios of 49.1 percent for U-234, 2.3 percent for U-235, and 48.6 percent for U-238, the dose conversion factors (DCFs) for ingestion for U-238 and U-234 were used for calculating the dose. These DCFs are 2.69×10^{-4} mrem/pCi and 2.83×10^{-4} mrem/pCi for U-238 and U-234, respectively (Eckerman et al. 1988).

The TED is calculated as shown below:

TED (ingestion of contaminated water for uranium) = Concentration (pCi/L) × Volume of Water Ingested (L) × DCF (U-238 + U-234) (mrem/pCi).

TED (total uranium) = 79.2 pCi/L × 4 L × (2.69×10^{-4} mrem/pCi + 2.83×10^{-4} mrem/pCi) = 0.17 mrem.

This value represents less than 0.17 percent of the DOE standard of 100 mrem TED above background. In comparison, the annual average exposure to natural background radiation in the United States results in a TED of approximately 300 mrem (BEIR 1990).

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4.0 Environmental Quality

4.1 Highlights of the Quality Assurance Program

Quality assurance for 2011 sampling activities followed the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PLN/S04351).

- Average relative percent differences were calculated for duplicate samples of groundwater, surface water, and springs.
- Trip and equipment blanks were assessed and summarized.
- The data validation program accepted 99.9 percent of the all data in 2011 (including field data).

4.2 Program Overview

The environmental quality assurance program includes management of the plans and procedures governing environmental monitoring activities at the Weldon Spring site and at the subcontracted offsite laboratories. This section discusses the environmental monitoring standards at the Weldon Spring site and the goals for these programs, plans, and procedures.

The environmental quality assurance program provides the Weldon Spring site with reliable, accurate, and precise monitoring data. The program furnishes guidance and directives to detect and prevent quality problems from the time a sample is collected until the associated data are evaluated and utilized. Key elements in achieving the goals of this program are compliance with the quality assurance program and environmental quality assurance program procedures; the use of quality control samples; complete documentation of field activities and laboratory analyses; and reviews of data documentation for precision, accuracy, and completeness (data validation).

The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* summarizes the data quality requirements for collecting and analyzing environmental data. The LTS&M Plan (DOE 2008) lists the sampling locations and provides site-specific detail for quality control samples. These plans describe administrative procedures for environmental data management, data validation, database administration, and data archiving.

Analytical data are received from subcontracted analytical laboratories. Uncensored data have been used for reporting and calculating annual averages (when available). When there was no instrument response, nondetect data were used in calculations of averages at a value of one-half the detection limit.

4.2.1 Applicable Standards

Applicable standards for environmental quality assurance include (1) use of the approved analytical and field measurement methods; (2) collection and evaluation of quality control samples; (3) accurate, precise, and complete evaluations; and (4) preservation and security of all applicable documents and records pertinent to the environmental monitoring program.

4.2.2 Analytical and Field Measurement Methods

Analytical and field measurement methods used at the Weldon Spring Site comply with applicable standards required by DOE, EPA, and the American Public Health Association. Analytical methods used by subcontracted laboratories for environmental monitoring primarily follow the EPA SW-846 requirements and the EPA drinking water and radiochemical methods. Field measurement methods typically follow the American Public Health Association's *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association1992).

4.3 Quality Control Samples

Quality control samples for environmental monitoring are collected in accordance with the required sampling plan, which specifies how frequently quality control samples should be collected. Table 52 describes the quality control samples collected at the Weldon Spring Site.

Table 52. Quality Control Sample Description

Type of Quality Control Sample	Description
Equipment Rinsate Blank	Monitors the effectiveness of decontamination procedures used on nondedicated sampling equipment. Equipment blanks include rinsate and filter blanks.
Trip Blank	Monitors volatile organic compounds that may be introduced during transportation or handling at the laboratory. Trip blanks are collected with distilled water in the Weldon Spring Site laboratory.
Field Duplicate	Monitors field conditions that may affect the reproducibility of samples collected from a given location. Field duplicates are collected in the field at the same location.
Matrix Spike[a]	Assesses the matrix and accuracy of laboratory measurements for a given matrix type. The results of this analysis and the routine sample are used to compute the percent recovery for each parameter.
Matrix Duplicate[a]	Assesses the matrix and precision of laboratory measurements for inorganic parameters in a given matrix type. The results of the matrix duplicate and the routine sample are used to compute the relative percent difference for each parameter.
Matrix Spike Duplicate[a]	Assesses the matrix and precision of laboratory measurements for organic compounds. The matrix spike duplicate is spiked in the same manner as the matrix spike sample. The results of the matrix spike and matrix spike duplicate are used to determine the relative percent difference for organic parameters.

[a] A laboratory sample is split from the parent sample.

The quality control program is assessed by analyzing the results of quality control samples and comparing them to the actual samples, using the method discussed in Sections 4.3.1 and 4.3.2.

4.3.1 Duplicate Results Evaluation

Field duplicate analyses were evaluated in 2011. The matrix duplicate analyses were performed at subcontracted laboratories from aliquots of original samples collected at the Weldon Spring Site and are not summarized in this document. Matrix duplicates were used to assess the precision of analyses and also to aid in evaluating the homogeneity of samples or analytical interference of sample matrixes. Matrix duplicates were assessed during the data validation process for each sample group.

Generally, field duplicate samples were analyzed for the same parameters as the original samples and were collected at the rate of approximately one for every 10 samples. In 2011, 23 field duplicates were collected from 264 locations sampled (8.7 percent). Typically, duplicate samples were analyzed for the common parameters (e.g., uranium, inorganic anions, metals).

When field duplicate samples were available, the average relative percent difference (RPD) was calculated. This difference represents an estimate of precision. The equation used was:

$$RPD = \frac{|S - D|}{\left(\frac{S + D}{2}\right)} \times 100$$

Where: S = analytical result of the original sample, and
D = analytical result of the duplicate sample.

Table 53 summarizes the calculated RPD for field duplicate samples for groundwater, springs, and surface water matrixes. Parameters that were not commonly analyzed for or that were not contaminants of concern were not evaluated. The RPD was calculated only for samples whose analytical results exceeded 5 times the detection limit and did not have any quality control problems (e.g., blank contamination).

Table 53. Summary of Calculated RPDs

Parameter	Number of Samples	Average RPD
Uranium	15	4.8
Iron	6	4.7
Cobalt	2	17.4
Barium	2	12.9
Nitrate (as N)	5	6.3
Sulfate	10	2.2
Volatile organic compounds	7	15.6
Nitroaromatic compounds	5	8.2
Manganese	2	8.5
Nickel	2	19.6

The results in Table 53 demonstrate that average RPDs calculated were within the 20 percent criterion. Also, several individual parameters exceeded the 20 percent criterion and were assessed and discussed in the individual data validation reports. As a result, the average field duplicate sample analyses assessed in 2011 were considered to be of acceptable quality.

4.3.2 Blank Sample Results

Various types of blanks are collected to assess the conditions or contaminants that may be introduced during sample collection and transportation. These conditions and contaminants are monitored by collecting blank samples to ensure that environmental samples are not being contaminated. Blank samples evaluate:

- The environmental conditions under which the samples (i.e., for analysis of volatile organic compounds) were shipped (trip blanks).
- The ambient conditions in the field that may affect a sample during collection (trip blanks).
- The effectiveness of the decontamination procedure for sampling equipment used to collect samples (equipment rinsate blanks).

Sections 4.3.2.1 and 4.3.2.2 discuss the sample blank analyses and the potential impact of blank contamination upon the associated samples.

4.3.2.1 Trip Blank Evaluation

Trip blanks are collected to assess the impact of sample collection and shipment on groundwater and surface water samples analyzed for volatile organic compounds. Trip blanks are sent to the laboratory with each shipment of volatile organic samples.

In 2011, seven trip blanks were analyzed for volatile organic compounds. No reported compounds were detected in the trip blanks, and therefore, no volatile organic contamination was associated with the handling of these samples and their shipment to the laboratory.

4.3.2.2 Equipment Rinsate Blank Evaluation

Equipment rinsate blanks are samples that are collected by rinsing decontaminated equipment with distilled or deionized water. The collected rinse water is then analyzed for selected constituents. This procedure is used to determine the effectiveness of the decontamination process. At the Weldon Spring site, most of the groundwater samples are collected from dedicated equipment (e.g., pumps, dedicated bailers), and spring water is collected by placing the sample directly into a sample container. Therefore, no equipment blanks are required for groundwater or spring locations.

Surface water is collected using a dip cup, using a stainless-steel bucket, or directly into the sampling container. When the dip cup or stainless-steel bucket is used, an equipment rinsate blank is collected to assess the cleanliness of the equipment. One equipment rinsate blank was collected in 2011 to assess the stainless-steel bucket used for surface water sampling. The sample was analyzed for only total uranium. Uranium was not detected in the blank. There was no concern of cross contamination in the bucket in 2011.

4.4 Data Validation Program Summary

The data validation program at the Weldon Spring site follows the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites*. This program involves reviewing and qualifying 100 percent of the data collected during a calendar year. The data points represent the number of parameters analyzed (e.g., trichloroethene), not the number of physical analyses performed (e.g., volatile organics analyses).

Table 54 identifies the number of quarterly and total data points that were validated in 2011 and indicates the percentage of those selected that were complete. Data points in this table include all sample types (including field parameters).

Table 54. Validation Summary for Calendar Year 2011

Calendar Quarter	No. of Data Points Validated	No. of Validated Data Points Rejected	Completeness[a]
Quarter 1	541	0	100
Quarter 2	1,410	1	99.9
Quarter 3	540	2	99.6
Quarter 4	1167	1	99.9
2011 Total	3658	4	99.9

[a] Completeness is a measure of acceptable data. The value is determined by the following equation:

$$\text{Completeness} = \frac{(\#\text{ validated} - \#\text{ rejected})}{\#\text{ validated}}$$

Reflects all validatable data for the calendar year.

Table 55 identifies validation qualifiers assigned to the selected data points as a result of data validation. The Weldon Spring Site validation technical review was performed in accordance with the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites*. For calendar year 2011, 100 percent of data validation was completed. Data points in this table include samples of groundwater, leachate, surface water, and spring water.

Table 55. Validation Qualifier Summary for Calendar Year 2011

	Number of Data Points								
	Field	Anions	Metals	Misc.	Nitro-aromatics	Radio-Chemical	Semi-volatiles	Volatiles	Total
Accepted	792	135	639	864	576	94	368	186	3654
Rejected	0	0	0	4	0	0	0	0	4
Not Validatable	0	0	0	0	0	0	0	0	0
Total	792	135	639	868	576	94	368	186	3658
Percentages									
Accepted	100%	100%	100%	99.5%	100%	100%	100%	100%	99.9%
Rejected	0%	0%	0%	0.5%	0%	0%	0%	0%	0.1%
Not Validatable	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

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5.0 Long-Term Surveillance and Maintenance

The site has entered the LTS&M phase of the project. This section of the report discusses the status of LTS&M activities that took place during 2011.

5.1 LTS&M Plan

The LTS&M Plan was revised and finalized in December 2008 after review by EPA, MDNR, and the public, in accordance with the FFA. Revisions to the LTS&M Plan included changes to the monitoring programs at the Chemical Plant and the Quarry, the addition of the Special Use Area Well Drillers Rule as a final institutional control, the addition of language regarding potential discovery of contamination on MDNR-Parks property in areas that fall under the proposed institutional control easement areas, and minor edits to the text and appendixes.

5.2 Institutional Controls

The LTS&M Plan includes Section 3.0, "Institutional Controls Implementation Plan for the Weldon Spring Site," which summarizes information pertinent to the implementation of institutional controls to meet the objectives of the use restrictions described in the Explanation of Significant Differences (ESD) (DOE 2005a) issued in February 2005. Section 3.0 of the LTS&M Plan includes current site conditions and the risk-basis for why restrictions are needed, the objectives of the use restrictions, specific institutional controls already in place, and additional mechanisms identified for implementation. The status of implementing the additional institutional controls is discussed below.

- **Special Use Area designation under the State Well Drillers' Act:** The "Special Use Area" under the Missouri well code was finalized in the Missouri regulations and became effective August 2007 (10 CSR 23-3.100[8]). This is a special regulation that DOE and the Army pursued and that designated DOE's and the Army's groundwater restricted areas as special areas that require additional drilling protocols and construction specifications to be imposed by MDNR on any future domestic wells. This institutional control is complete.
- **Memorandum of Understanding (MOU) with the Army:** The Army and DOE signed the MOU in September and October 2009, respectively. This institutional control is complete.
- **Easements with surrounding affected State agency landowners (MDC, MDNR-Parks, Missouri Department of Transportation [MoDOT]) for implementing the use restrictions required on State properties:** DOE is seeking easements that would restrict use of the contaminated groundwater and the hydraulic buffer zone, and would also restrict land use in the Southeast Drainage and at the Quarry reduction zone. DOE issued draft easements and offered letters to the State agencies in 2006. During 2008, DOE corresponded with MDC, MDNR-Parks, and MoDOT regarding the easements, and in October 2008, DOE met with all three agencies to work toward negotiating the easements' final wording. DOE and MDNR-Parks finalized and signed the easement regarding the MDNR-Parks property in September 2009. The easement with MDC was signed by MDC on June 24, 2011, and by DOE on July 25, 2011. DOE is currently working closely with MoDOT regarding the easement on the MoDOT property. It is anticipated that the easement will be finalized in 2012.

5.3 Interpretive Center

5.3.1 Interpretive Center Operations

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 present:

- 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, as well as their manufacturing wastes.
- The events and community efforts to clean up the site, and the people who made it happen.
- A summary of LM's mission.
- An overview of LTS&M activities at the site.
- Information pertaining to the site's natural environment, such as soil and groundwater conditions and the prairie.
- Information about LM's renewable energy initiatives.

These exhibits may be changed as appropriate due to changing conditions or emerging issues at and near the site. An exhibit upgrade was completed in 2010; it included updating information in several exhibits, adding interactive and multimedia components, creating several new exhibits that address site-related topics, and improving the flow of foot traffic through the Center.

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

- Monday through Friday: 9:00 a.m. to 5:00 p.m.
- Saturday: 10:00 a.m. to 4:00 p.m. (10:00 a.m. to 2 p.m. November 1 through March 31).
- Sunday: 12:00 p.m. to 4:00 p.m.

The Interpretive Center is closed on federal holidays.

Attendance is tracked through the following types of public activities:

- Individuals that walk into the Interpretive Center from the street 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 room to conduct business meetings.
- Scheduled groups who are unable to visit the site but are recipients of Interpretive Center outreach presentations.

A significant number of individuals also use site amenities (e.g., Hamburg Trail, disposal cell perimeter road for prairie viewing, disposal cell viewing platform, native plant 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. It is estimated that between 5,000 and 15,000 individuals per year make use of site amenities in this way.

Attendance at the Interpretive Center in 2011 was 26,445 (Table 56), an increase of 1,489 from 2010. The kindergarten through grade 12 educational community continues 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. For a few school districts that have limited funding for field trips, outreach activities are scheduled, and Interpretive Center personnel give educational presentations at the school. Outreach activities usually involve several classes or the entire grade level of students.

Table 56. 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	1,786
2004	52	61	166	182	104	324	192	353	379	850	556	354	3,573
2005	123	605	1,056	2,048	1,888	1,408	1,370	1,091	1,511	1,663	1,739	903	15,405
2006	542	1,136	1,595	1,874	1,685	1226	1,465	1,431	1,176	2,215	1,735	692	16,772
2007	1,157	1,022	2,786	2,479	2,192	1,960	1,703	1,129	1,843	2,811	1,569	882	21,524
2008	1,132	1,445	2,261	3,086	2,489	1,734	1,556	1,395	2,412	2,624	1,705	1,142	22,981
2009	1,418	1,987	3,183	2,181	2,036	1,928	1,299	1,492	2,591	2,857	1,522	1,106	23,600
2010	1,440	1,441	2,485	2,378	2,968	2,002	1,904	1,117	2,615	2,696	2,396	1,534	24,956
2011	1,631	1,958	2,593	3,036	2,938	2,182	1,441	1,165	2,455	2,848	2,087	2,111	26,445
													157,833

Interpretive Center marketing efforts continue to be a critical component of making the public aware of Interpretive Center programs. In 2011, several new educational programs were developed based on teacher requests and Missouri curriculum requirements.

5.3.2 Howell Prairie and 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 prior to European settlement. Howell Prairie is one of the largest plantings of its kind in the St. Louis metropolitan area.

A variety of prairie maintenance activities were completed throughout 2011. Control of volunteer saplings and noxious weeds such as *Sericea lespedeza* and *Robinia pseudoacacia* continued. Individual trees and plants were spot-sprayed with herbicide as part of ongoing efforts to keep them from spreading throughout the prairie area. Although control efforts have resulted in significantly fewer numbers of plants in previous years, a slightly increased population was noted this year. It is thought that past and present prescribed burning activities stimulated the germination of dormant seed. Due to the limited quantity of dormant seed in the soil, the increased weed population is expected to be a short-term issue and will not likely be present in 2012.

Due to ample precipitation and maturing plant populations, 2010 was an effective growing season, producing a significant amount of plant litter that remained on the ground in the spring of 2011. Prescribed burning in the spring tends to boost plant growth, curtail woody species, and return nutrients to the soil, and improvement in plant density and species diversity was observed in burned areas several years ago. However, due to a very limited burning timeframe and wet conditions in the spring of 2011, no prescribed burn occurred in 2011. Future prescribed burns will be performed when conditions are favorable for controlled fires.

In the 2006 annual inspection, erosion areas in the prairie were identified as needing to be monitored and evaluated to ensure that channels were not encroaching into the disposal cell buffer zone. In August 2007, Stoller site-reclamation specialists, representatives from MDNR, and other local prairie experts performed an erosion evaluation. The site prairie establishment history was discussed, and erosion channels were observed. This evaluation showed that erosion was typical for a newly reclaimed site and that vegetation was successfully establishing within the channels, which would allow erosion areas to repair naturally. In response to this evaluation, a Stoller Geographic Information System specialist prepared a detailed map of all erosion areas by walking the site with a Global Positioning System (GPS) unit. A similar map was produced each year to track the progress of erosion repair. An erosion map is also scheduled to be prepared in 2012 to continue this tracking effort.

In June 2008, representatives from MDNR began prairie vegetation density and cover surveys to provide a baseline for determining the success of prairie management and treatment techniques. As stated in a draft December 2008 report, the initial results show that density and cover can be easily quantified in areas of the prairie to monitor the success of the maintenance practices, including treatments applied. In 2009 and 2010, the study continued, and results suggest successful prairie establishment despite pressure from a wide variety of exotic species.

In November and December 2011, seeds harvested from the native plant garden were overseeded in selected areas of the prairie. Again this year, areas with the most significant erosion were targeted.

The native plant garden, which consists entirely of plants native to Missouri, was designed and planted during 2004. Named the Native Plant Educational Garden, it contains extensive plantings of species from Howell Prairie, as well as other perennials, shrubs, and trees. Walking paths, benches, and markers to identify the various plants are located throughout the garden. Maintenance, consisting of manual weeding, occasional irrigation, and mulching, was performed throughout the growing season. In September, October, and November of the past 3 years, dried seed heads from grasses and forbs were harvested from the garden to be utilized for hand overseeding on the prairie area of the site. Volunteers continued to perform garden maintenance activities throughout 2011.

Howell Prairie, the Native Plant Educational Garden, and the Interpretive Center were designed to serve as institutional controls. These areas will attract visitors to the Weldon Spring Site, help to educate the community about the remediation project, and enhance the site's educational mission.

5.4 Inspections

The annual LTS&M inspection took place at the Weldon Spring Site from October 25 through 27, 2011. The inspection was conducted in accordance with the LTS&M Plan (DOE 2008) and the associated inspection checklist. Representatives from EPA, MDNR, MDC, and MoDOT participated in the inspection.

The main areas inspected at the site were areas where future institutional controls will be established, the Quarry, the disposal cell, the LCRS, monitoring wells, and assorted general features.

The institutional control areas were inspected to ensure that pending restrictions, such as excavating soil, groundwater withdrawal, and residential use, were not being violated. Each area was inspected, and no indications of violations of future restrictions were observed.

The disposal cell was inspected by walking 10 transects over the cell and around the cell perimeter. Handheld GPS equipment was used to navigate the 10 transects. Five areas of the cell, which had been marked and located by GPS survey equipment during the 2003 annual inspection, were located and observed for any signs of rock degradation. The LCRS was also inspected and found to be in good condition. Sixty-three of the 107 groundwater monitoring wells were inspected and found to be in good condition. Other site features, including the prairie, site markers, and roads, were also inspected. The inspection included contacting stakeholders and institutional control contacts.

The eighth annual public meeting required by the LTS&M Plan (DOE 2008) was held on June 1, 2011. This meeting was held to discuss the 2010 annual inspection, which took place in October 2010. Also discussed were a summary of environmental data, the status of institutional controls, and Interpretive Center and prairie activities.

5.5 Culvert Removal

As described in Appendix A of the LTS&M Plan, soil containing elevated concentrations of uranium-238 was left under twin culverts in the Highway D right-of-way within the Frog Pond Outlet located north of the Chemical Plant. The inside surfaces of the corrugated metal culverts contained fixed residual radioactivity that exceeded the DOE Order 5400.5 generic surface contamination guidelines for natural uranium, uranium-238, and associated decay products. A supplemental limit was approved by the DOE Oak Ridge Operations Office, Oak Ridge, Tennessee. The culverts were included on the annual inspection checklist, and each year DOE contacted MoDOT representatives to request that they contact DOE if any maintenance is scheduled in the area. MoDOT personnel notified DOE in 2010 of plans to widen the shoulders of Highway D, an undertaking that would require removing and replacing the culverts. DOE agreed to work with MoDOT during the removal project, which took place in August 2011. Radioactivity in soil surrounding the culverts did not exceed the cleanup criteria, and the soil was left in place. The culverts were relocated to a temporary storage area on DOE property and subsequently disposed of at a low-level radiological disposal facility. Therefore, no radiological issues exist at this location and this area will not be part of future annual inspections.

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6.0 References

40 CFR 61, Subpart H. U.S. Environmental Protection Agency, "National Emission Standards for Emissions of Radionuclides other than Radon From Department of Energy Facilities," *Code of Federal Regulations*, July 1, 2011.

40 CFR 141. U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations," *Code of Federal Regulations*, July 1, 2011.

40 CFR 264. U.S. Environmental Protection Agency, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*, July 1, 2011.

48 CFR 970.5223-1. U.S. Department of Energy, "Integration of Environment, Safety and Health into Work Planning and Execution," *Code of Federal Regulations*, October 1, 2004.

10 CSR 20-7.031. Missouri *Code of State Regulations*, Title 10, "Department of Natural Resources," Division 20, "Clean Water Commission," Chapter 7.031, "Water Quality Standards."

10 CSR 23-3. Missouri *Code of State Regulations*, Title 10, "Department of Natural Resources," Division 23, "Division of Geology and Land Survey," Chapter 3, "Well Construction Code."

10 CSR 25-7.264. Missouri *Code of State Regulations*, Title 10, "Department of Natural Resources," Division 25, "Hazardous Waste Management Commission," Chapter 7.264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities."

10 CSR 80-3.010. Missouri *Code of State Regulations*, Title 10, "Department of Natural Resources," Division 80, "Solid Waste Management," Chapter 3.010, Design and Operation."

American Public Health Association, 1992. *Standard Methods for the Examination of Water and Wastewater*, 18th ed., American Public Health Association, American Water Works Association, Water Environment Federation, Washington, DC.

BEIR V (Committee on the Biological Effects of Ionizing Radiation), National Research Council. *Health Effects of Exposure to Low Levels of Ionizing Radiation*. Washington, DC: National Academy Press, 1990.

DOE Orders:

231.1B	*Environment, Safety and Health Reporting*, June 27, 2011.
436.1	*Departmental Sustainability*, May 2, 2011.
458.1 Chg 2	*Radiation Protection of the Public and the Environment*, June 6, 2011.

DOE (U.S. Department of Energy), 1989. *Remedial Investigation for Quarry Bulk Wastes*, Rev. 1, DOE/OR/21548-066, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, December.

DOE (U.S. Department of Energy), 1990a. *Feasibility Study for Management of the Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri*, DOE/OR/21548-104, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, February.

DOE (U.S. Department of Energy), 1990b. *Record of Decision for the Management of the Bulk Wastes at the Weldon Spring Quarry*, DOE/OR/21548-317, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 1992a. *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Sites*, Rev. 0, DOE/OR/21548-074, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, November.

DOE (U.S. Department of Energy), 1992b. *Agricultural Sampling Plan*, Rev. 1, DOE/OR/21548-229. Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, December.

DOE (U.S. Department of Energy), 1993. *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site*, DOE/OR/21548-376, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 1996. *Engineering Evaluation/Cost Analysis for the Proposed Removal Action at the Southeast Drainage near the Weldon Spring Site, Weldon Spring, Missouri*, DOE/OR/21548-584, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, August.

DOE (U.S. Department of Energy), 1997. *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri*, DOE/OR/21548–571, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 1998a. *Record of Decision for the Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri*, DOE/OR/21548–725, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 1998b. *Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri*, DOE/OR/21548–587, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, February.

DOE (U.S. Department of Energy), 1999. *Southeast Drainage Closeout Report Vicinity Properties DA4 and MDC7*, Rev. 0, DOE/OR/21548-772, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 2000a. *Interim Record of Decision for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site*, DOE/OR/21548-798, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, September.

DOE (U.S. Department of Energy), 2000b. *Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit*, DOE/OR/21548-787, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2001. *Completion Report for Radon Flux Monitoring of the WSSRAP Disposal Facility*, DOE/OR/21548-876, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2003a. *Environmental Monitoring Plan*, Rev. 11, DOE/OR/21548–424, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2003b. *Quarry Residuals Operable Unit Remedial Action Report*, DOE/OR/21548–927, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, November.

DOE (U.S. Department of Energy), 2004a. *Chemical Plant Operable Unit Remedial Action Report*, DOE/GJ/79491−909, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2004b. *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, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

DOE (U.S. Department of Energy), 2004c. *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site*, DOE/GJ/79491−943, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, July.

DOE (U.S. Department of Energy), 2005a. *Explanation of Significant Differences, Weldon Spring Site*, Office of Legacy Management, February.

DOE (U.S. Department of Energy), 2005b. *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site*, DOE/GJ/79491-952, Office of Legacy Management, March.

DOE (U.S. Department of Energy), 2008. *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri, Site*, LMS/WEL/S0079-1.0, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, December.

DOE (U.S. Department of Energy), 2011. *Weldon Spring Site Environmental Report for Calendar Year 2010*, LMS/WEL/S07817, Office of Legacy Management, August.

Eckerman, K.F., A.B. Wolbarst, and A.C.B. Richardson, 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal Guidance Report No. 11, prepared for U.S. Environmental Protection Agency by Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

Environmental Management System Description, LMS/POL/S04346, continually updated, prepared by the S.M. Stoller Corporation for the U.S. Department of Energy Office of Legacy Management, Grand Junction Colorado.

Environmental Management System Programs Manual, LMS/POL/S04388, continually updated, prepared by the S.M. Stoller Corporation for the U.S. Department of Energy Office of Legacy Management, Grand Junction Colorado.

Environmental Protection Manual, LMS/POL/S04329, continually updated, prepared by the S.M. Stoller Corporation for the U.S. Department of Energy Office of Legacy Management, Grand Junction Colorado

Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, Executive Office of the President, January 24, 2007.

Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, Executive Office of the President, October 5, 2009.

Integrated Safety Management System with Embedded Worker Safety and Health Program, LMS/POL/S04328, continually updated, prepared by the S.M. Stoller Corporation for the U.S. Department of Energy Office of Legacy Management, Grand Junction Colorado.

ISO (International Organization for Standardization), 2004: *Environmental Management Systems—Requirements with Guidance for Use*, ISO 14001:2004(E).

Kleeschulte, M.J., L.F. Emmett, and J.H. Barks, 1986. *Hydrologic Data for the Weldon Spring Radioactive Waste-Disposal Sites, St. Charles, County, Missouri—1984–1986*, U.S. Geologic Survey Open-File Report 86-488, Rolla, Missouri.

NOAA (National Oceanic and Atmospheric Administration), 2005. *The Climatology of the St. Louis Area*, http://www.weather.gov/climate/index.php?wfo=lsx, accessed 10 May 2012.

Ruffner, J.A. and F.E. Bair, 1987. *Weather of U.S. Cities, City Reports, Alabama–Missouri*, vol. 1, 3rd ed., Gale Research Company, Detroit, Michigan.

Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites, LMS/PLN/S04351, continually updated, prepared by the S.M. Stoller Corporation for the U.S. Department of Energy Office of Legacy Management, Grand Junction Colorado.