GWOU ADMINISTRATIVE RECORD
SECTION TITLE:
GW-400-401-1.15

DOE/GJ/79491-936a

Record of Decision for the Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site

January 2004

prepared by

U.S. Department of Energy
Office of Legacy Management
Weldon Spring Site Remedial Action Project
Weldon Spring, Missouri

DECLARATION STATEMENT

Site Name and Location

Weldon Spring Quarry/Plant/Pits (commonly known as Weldon Spring Chemical Plant and Quarry)
Chemical Plant Area Groundwater Operable Unit
St. Charles County, Missouri
CERCLIS Identification Number: MO3210090004

Statement of Basis and Purpose

This Record of Decision (ROD) presents the selected remedy for the final remedial action for the groundwater operable unit (GWOU) of the U.S. Department of Energy's (DOE's) Weldon Spring Site in St. Charles County, Missouri. This remedy was selected in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). National Environmental Policy Act (NEPA) issues related to the Chemical Plant have also been addressed and have been integrated into the CERCLA decision-making process for the GWOU to the extent practicable, in accordance with DOE's policy on NEPA.

The selected remedy addresses cleanup of all contaminants of concern (COCs) in groundwater and springwater at the Chemical Plant area and is based on the Administrative Record (AR) for the GWOU. Major documents in the AR include the (1) Remedial Investigation/Feasibility Study (RI/FS) Work Plan, (2) RI and Baseline Risk Assessment (BRA) Reports, (3) Feasibility Study (FS) Report and Supplemental Feasibility Study, (4) Supporting Evaluation Report, and (5) Proposed Plan (PP). Public comments received during the review period for the PP were considered in the development of this ROD. Responses to significant public comments are provided in the Responsiveness Summary.

The State of Missouri does not concur with the selected remedy (see also Section 10.8 of the Decision Summary).

Assessment of the Site

The response action presented in this ROD is necessary to protect the public health or welfare or the environment from releases of hazardous substances into the environment at the site that have not been previously addressed.

Description of the Selected Final Remedy

The Groundwater Operable Unit (GWOU) addresses residual contamination of the shallow groundwater system in the Chemical Plant area. The selected remedy is monitored natural attenuation (MNA) with institutional controls (ICs) to limit groundwater use during the period of

remediation. MNA involves the collection of monitoring data to verify the effectiveness of naturally occurring processes to reduce contaminant concentrations over time. This ROD establishes remedial goals and performance standards for MNA. It also establishes expectations for groundwater use restrictions and identifies the instruments DOE expects to use to limit use.

The GWOU is the second of two operable units established for the Chemical Plant area of the Weldon Spring Site. The first operable unit, referred to as the Chemical Plant Operable Unit, addressed cleanup of the source materials including all principal threat wastes at the site. The ROD for this operable unit was signed in September 1993 and the remediation was completed in 1998. As a result, there is no longer a source for ongoing groundwater contamination.

The selected remedy in this ROD also serves as a change to the September 2000 Interim ROD for the GWOU addressing the TCE groundwater contamination. In-situ treatment of TCE did not perform adequately in the field and MNA is now considered the appropriate final remedy for TCE as well as the other groundwater contaminants.

The remedy selected in this ROD is the final remedy for the Chemical Plant GWOU and the final planned response action for Weldon Spring Site.

The ROD Data Certification Checklist at the end of this declaration lists the locations within this ROD where the reader can find key information supporting the selected remedy.

Statutory Determinations

The selected remedy is protective of human health and the environment, complies with federal and state requirements that are applicable or relevant and appropriate, is cost effective, and utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable.

The remedy in this GWOU does not satisfy the statutory preference for treatment as a principal element because extensive field testing has indicated that groundwater extraction methods and in-situ treatment technologies could not be effectively deployed on a large scale.

This remedy will ultimately result in hazardous substances, pollutants, or contaminants remaining on the site at levels that allow for unlimited use and unrestricted exposure, but it will take more than 5 years to achieve these conditions (i.e., remedial action objectives and cleanup levels). A policy review will be conducted in conjunction with the statutory review required for other operable units.

Director of Policy and Site Transition (LM-40)
Office of Legacy Management
U.S. Department of Energy

1/29/04
Date

Superfund Division Director
U.S. Environmental Protection Agency Region VII

Date

Groundwater Operable Unit ROD Data Certification Checklist

The following information is included in this ROD. Additional information can be found in the AR for this operable unit of the Weldon Spring Site.

Site Data	Chapter
COCs and their concentrations	5
Baseline risk represented by the contaminants	7
Cleanup levels established and the basis for the levels	8
Methods of addressing how source materials constitute principal threats	11
Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of groundwater used in the BRA and ROD	6
Potential land and groundwater use that will be available at the site as a result of the selected remedy	6
Estimated capital, annual operations and maintenance (O&M), and total present net-worth costs	9 and 10
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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document.

GENERAL

AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
CSR	*Code of State Regulation*
DA	U.S. Department of the Army
DHSS	Missouri Department of Health and Senior Services
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FFA	federal facility agreement
FHHS	Francis Howell High School
FS	feasibility study
GWOU	Groundwater Operable Unit
IC	institutional control
ICO	in-situ chemical oxidation
IROD	Interim Record of Decision
LOAEL	lowest observed adverse effect level
LTS&MP	Long-Term Surveillance and Maintenance Plan
MCL	maximum contaminant level
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
MDOH	Missouri Department of Health
MoDOT	Missouri Department of Transportation
MNA	monitored natural attenuation
MOA	memorandum of agreement
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NPL	National Priorities List
NOAEL	no observed adverse effect level
O&M	operations and maintenance
PP	Proposed Plan
RA	remedial action
RAO	remedial action objective
RBC	risk-based concentration
RD	remedial design
RfD	reference dose

GENERAL (Cont.)

RI	remedial investigation
ROD	Record of Decision
RPD	relative percent difference
SARA	Superfund Amendments and Reauthorization Act
UCL95	upper confidence limit at 95%
WSTA	Weldon Spring Training Area

CHEMICALS

1,3-DNB	1,3-dinitrobenzene
DNT	dinitrotoluene
2,4-DNT	2,4-dinitrotoluene
2,6-DNT	2,6-dinitrotoluene
NB	nitrobenzene
TCE	trichloroethylene
TNT	trinitrotoluene
2,4,6-TNT	2,4,6-trinitrotoluene

UNITS OF MEASURE

cm	centimeter(s)
cm^2	square centimeter(s)
d	day(s)
ft	foot (feet)
gal	gallon
h	hour(s)
ha	hectare(s)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
m	meter(s)
m^3	cubic meter(s)
mg	milligram(s)
mi	mile(s)
mL	milliliter(s)
pCi	picocurie(s)
yr	year(s)
µg	microgram(s)

DECISION SUMMARY

1 SITE NAME, LOCATION, AND DESCRIPTION

Name and Location: Weldon Spring Quarry/Plant/Pits (commonly known as Weldon Spring Chemical Plant and Quarry)
Chemical Plant Area Groundwater Operable Unit
St. Charles County, Missouri

U.S. Environmental Protection Agency (EPA) CERCLIS Database ID: MO3210090004

Lead Agency: U.S. Department of Energy (DOE)

Site Type: Federal Facility – Former Uranium Processing Plant

Site Description Abstract: The Groundwater Operable Unit GWOU) addresses groundwater contamination from uranium processing and trinitrotoluene (TNT) production in the vicinity of the former Chemical Plant. The former Chemical Plant area is located at DOE's Weldon Spring Site in St. Charles County, Missouri, about 30 miles west of St. Louis. The groundwater contamination also impacts the adjacent U.S. Department of Army training area, and wildlife conservation areas managed by the Missouri Department of Conservation (MDC).

2 SITE HISTORY AND ENFORCEMENT ACTIVITIES

The Weldon Spring Site consists of two noncontiguous areas: the Chemical Plant and the Quarry. Both properties are located in St. Charles County, Missouri, about 48 km (30 mi) west of St. Louis (Figure 2.1). The 88-ha (217-acre) Chemical Plant lies within the boundaries of the former Ordnance Works (Figure 2.2).

The Chemical Plant area was used for TNT production from 1941 to 1945 and later as a uranium-processing facility from 1957 to 1966. The Quarry was used to dispose of uranium and thorium residues (drummed and uncontained), radioactively contaminated building rubble and process equipment, and TNT and dinitrotoluene (DNT) residues from cleanup of the former Ordnance Works.

The sources of contamination at the Chemical Plant from uranium processes are those shown in the original layout of the Chemical Plant (Figure 2.3). These consisted of approximately 40 buildings, four waste retention ponds (referred to as Raffinate Pits), two ponds (Ash Pond and Frog Pond), and two former dumps (north and south). Remediation of these source areas has been completed. Burgermeister Spring, which is hydrologically connected to the Chemical Plant groundwater, is in the August A. Busch Memorial Conservation Area.

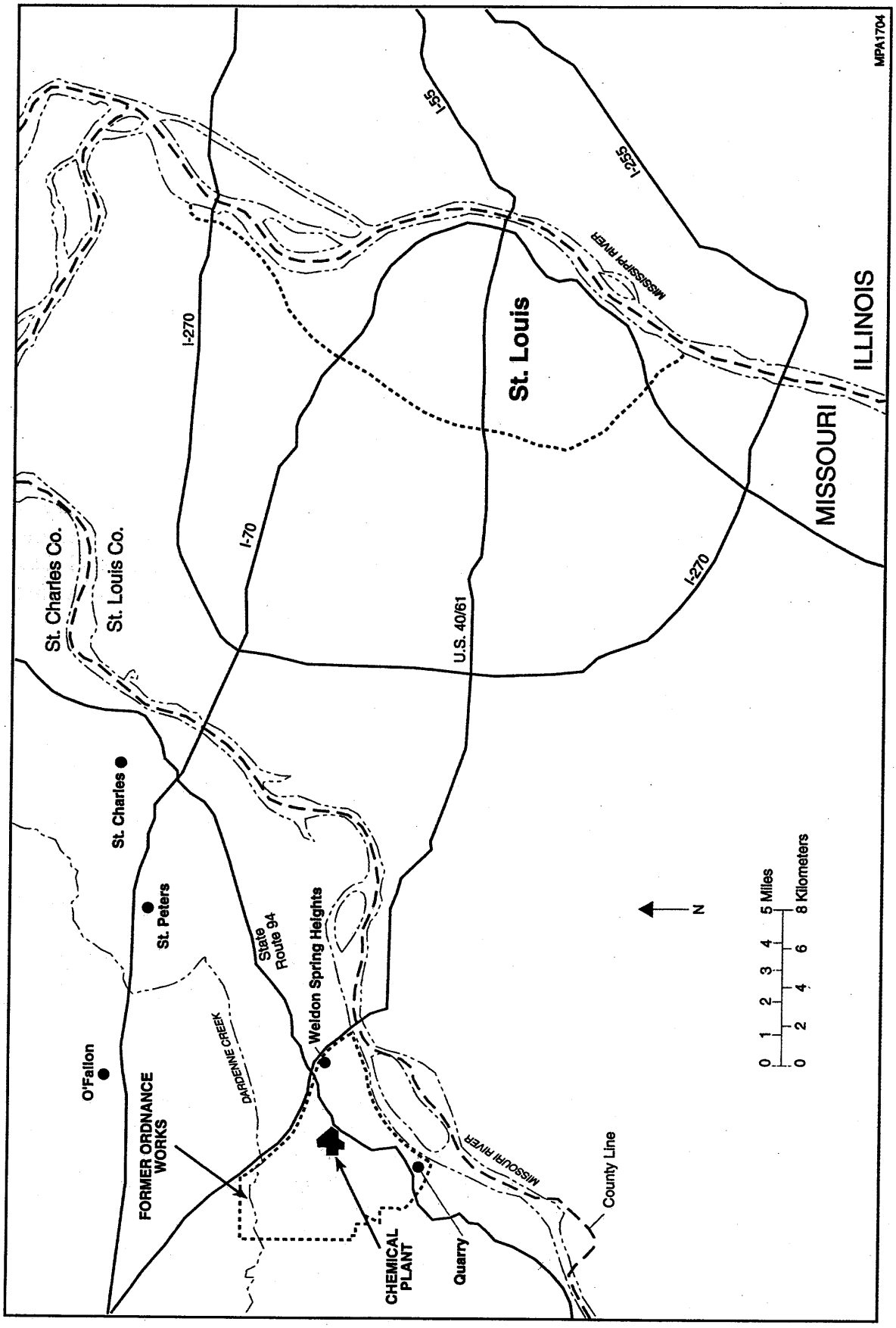


FIGURE 2.1 Location of the Weldon Spring Site

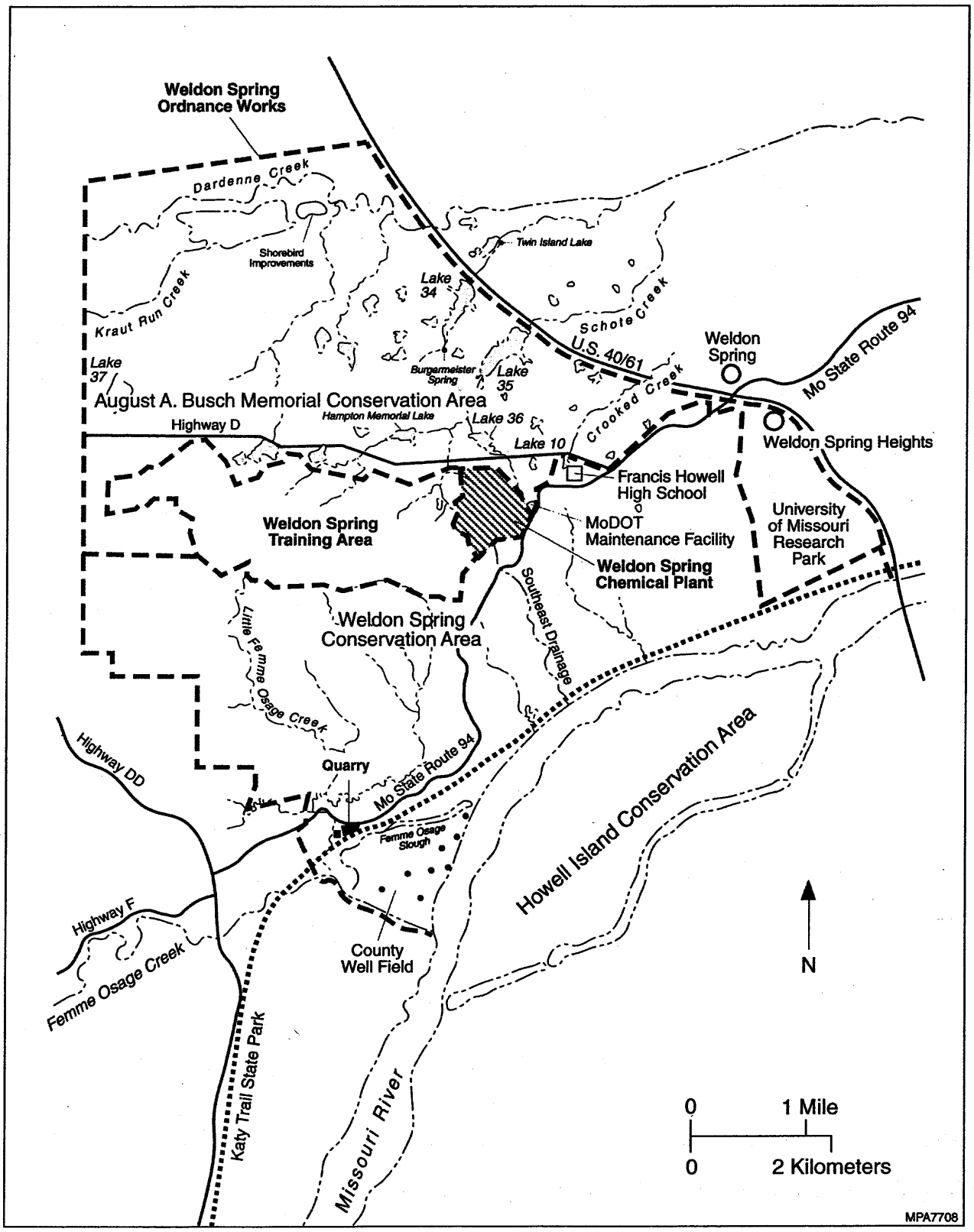


FIGURE 2.2 Map of the Chemical Plant Area and Immediate Vicinity

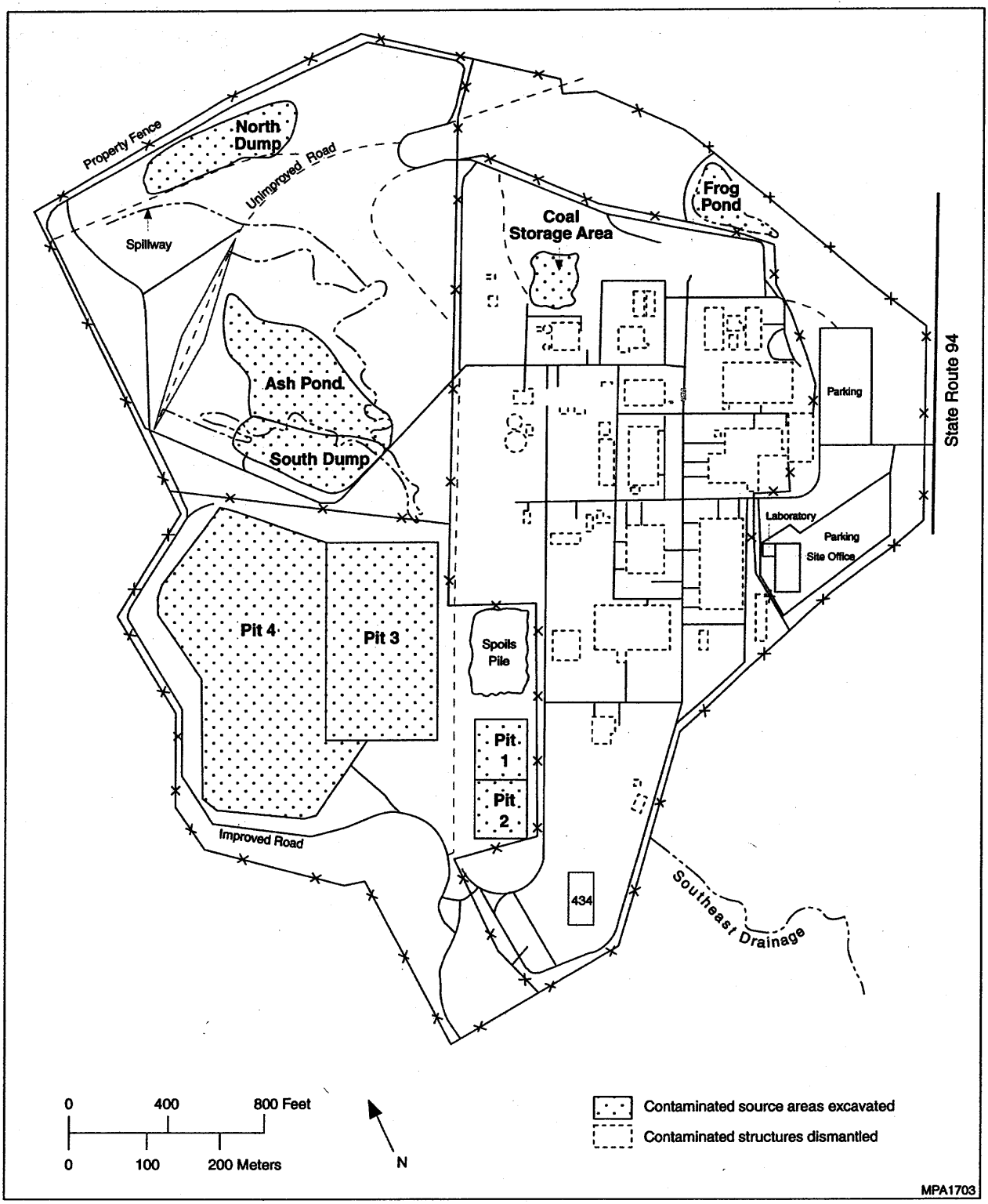


FIGURE 2.3 Original Layout of the Chemical Plant

In 1986, the EPA and DOE entered into a federal facility agreement (FFA) (EPA 1992b). The EPA listed the Quarry on the National Priorities List (NPL) in 1987. The Chemical Plant was added in 1989. The FFA was amended in 1992 and complies with Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The amended FFA includes agreements to ensure that the environmental impacts associated with past and present activities at the Weldon Spring Site are thoroughly investigated and that appropriate remedial action is taken, as necessary, to protect public health and the environment. It contains procedures for resolving disputes, assigning penalties for nonconformance, and ensuring public participation in the remedial action decision-making process. In addition, the amended FFA also facilitates the exchange of information between DOE and the State of Missouri by providing primary and secondary documents to the state for its review.

In 2000, DOE published the Interim Record of Decision (IROD) for the remediation of trichloroethylene (TCE). The remedial action presented in that IROD was in-situ chemical oxidation (ICO). This present Record of Decision (ROD) for remediation of the GWOU includes remediation of TCE by using a method that differs from the remedy selected in the 2000 IROD. A fundamental change to the IROD remedy for TCE is therefore being presented in this ROD (see Section 4).

3 COMMUNITY PARTICIPATION

The Proposed Plan (PP) and its supporting documentation (remedial investigation/ feasibility study [RI/FS] and other related reports) for the GWOU were made available to the public in August 2003. These reports can be found in the Administrative Record (AR) located at the site. The notice of availability of the PP was published August 3, 2003, in the *St. Louis Post-Dispatch* and the *St. Charles County Journal.* A public comment period was held from August 4 to September 3, 2003. A public meeting was held on August 13, 2003, to present the PP. At the meeting, DOE provided an overview of the preferred alternative and explained the process that led to its selection. Representatives from the Missouri Department of Natural Resources (MDNR), MDC, and EPA expressed the positions of their respective agencies regarding the proposal. Comments from several members of the public who attended the meeting were also received. A transcript of the meeting is available in the AR. Responses to comments received at the meeting and to comments received during the comment period are provided in the Responsiveness Summary, which is part of this ROD.

4 SCOPE AND ROLE OF THE GROUNDWATER OPERABLE UNIT

DOE has addressed the Weldon Spring Site cleanup through a series of response actions in order to more effectively manage the complex variety of problems (Figure 4.1). The work was organized as follows:

- Removal Actions: Priority actions undertaken to address immediate risks and stabilize site conditions

- Operable Unit 1: Quarry Bulk Waste
- Operable Unit 2: Chemical Plant
- Operable Unit 3: Quarry Residuals
- Operable Unit 4: Groundwater

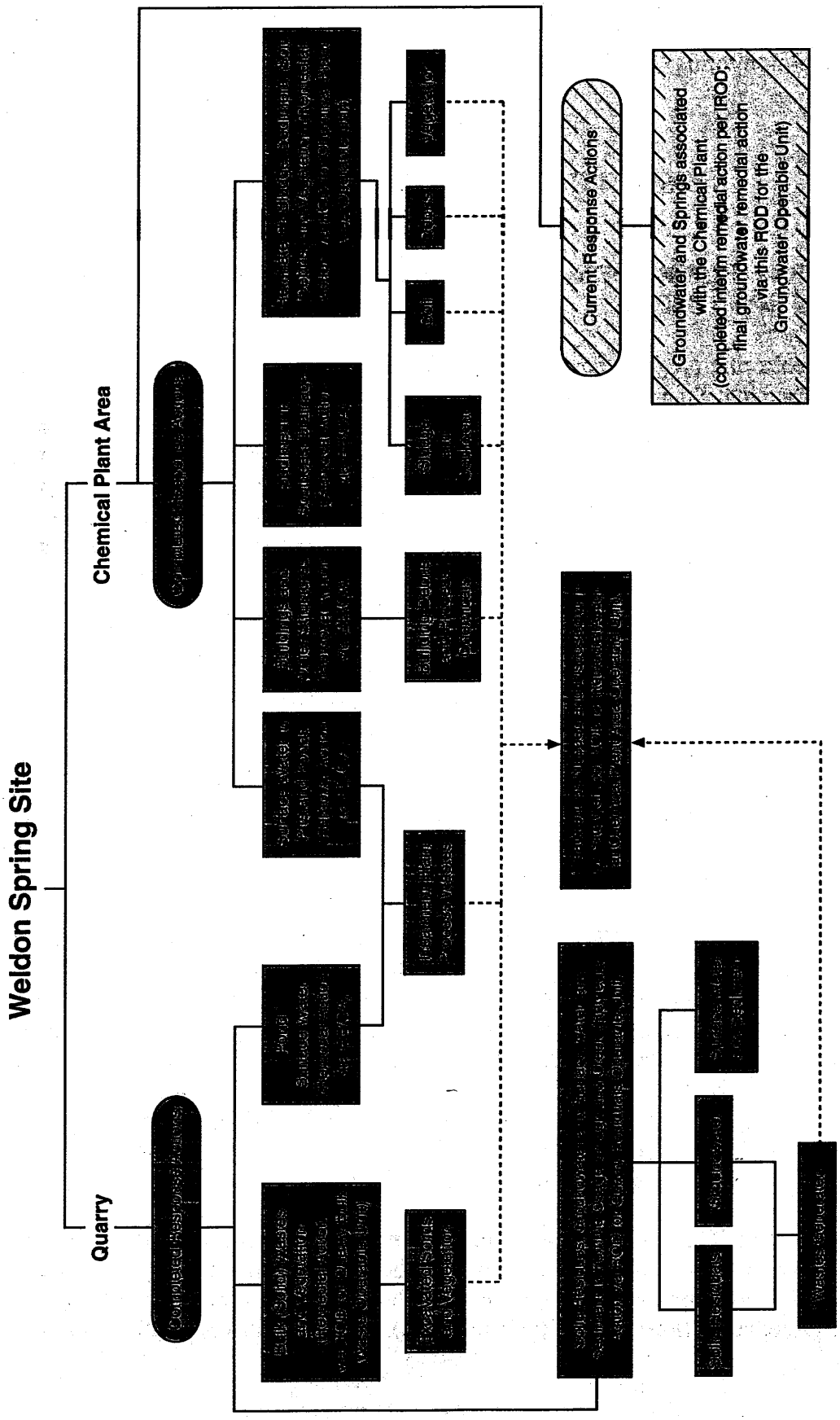
From 1988 through 1995, numerous response actions were completed under removal action authority to address obvious risks and stabilize site conditions. The actions included decontamination, demolition, and storage of the Chemical Plant buildings and structures; storage and treatment of containerized chemicals; asbestos abatement; storm water run-off controls; and construction and operation of water treatment plants.

Under the Quarry Bulk Waste interim ROD (March 1991), approximately 120,000 yd^3 of contaminated soil, metal, rubble, equipment, and debris were transported to the chemical plant area and placed in temporary storage. This activity was completed in 1995.

The ROD for the Chemical Plant Operable Unit was signed in September of 1993. Remediation activities undertaken for this operable unit included the removal of contaminated soil, demolition and removal of remaining concrete pads and foundations that supported the 44 structures and buildings, removal and treatment of the Raffinate Pits wastes, and permanent disposal of site wastes in an on-site engineered disposal facility. This resulted in the treatment and/or isolation of all source materials, including all principal threat wastes.

The Quarry Residuals Operable Unit ROD (September 1998) provides for long-term monitoring and institutional control of the contaminated groundwater in the Quarry area. Activities also included the backfilling and restoration of the Quarry pit and the construction and operation of a groundwater interceptor trench. The interceptor trench proved ineffective at recovering contaminated groundwater because of low flow conditions, and it was ultimately decommissioned. A contingency plan was established to protect against the unlikely event that contaminant migration would impact the county well field, which is located near the Quarry.

The Groundwater Operable Unit (GWOU), which is the subject of this ROD, addresses the residual contamination of the shallow groundwater aquifer in the vicinity of the former Chemical Plant. This ROD presents the selected remedy for the groundwater and is the final planned remedy for the Weldon Spring Site. A prior remedy for the GWOU was selected in a September 2000 IROD. The IROD focused on the TCE plume and selected ICO as the appropriate remedy. The maximum contaminant level (MCL) for TCE (5 µg/L) was determined to be an applicable or relevant and appropriate requirement (ARAR) and identified as the cleanup standard. The other contaminants were not addressed. Pilot-phase ICO was performed in April and May 2002. The treatment did not perform adequately under actual field conditions and was not implemented in full scale. The treatment method that will be used to address cleanup of TCE has been reevaluated. The selected remedy in this ROD will serve to change the remedy selected in the IROD.



Note: The boxes represent contaminated media addressed by the project's cleanup actions for the chemical plant and the quarry; they are connected by solid lines to the appropriate phase of site cleanup. Dashed lines identify wastes generated as a result of the completed response actions and that were treated and disposed of in the on-site cell at the chemical plant. Boxes with cross-hatching constitute contaminated media that are being addressed as part of the GWOU and this ROD. The GWOU is the final of four operable units for the Weldon Spring site.

FIGURE 4.1 Remediation Components for the Weldon Spring Site

This ROD will be followed by a remedial design/remedial action (RD/RA) Work Plan. The site Long-Term Surveillance and Maintenance Plan (LTS&MP) (DOE 2003a) will incorporate long-term (monitoring) activities stipulated in this final ROD and the RD/RA Work Plan.

5 SITE CHARACTERISTICS

5.1 CONTAMINATION UNDER CURRENT GROUNDWATER AND SPRINGWATER CONDITIONS

The current monitoring program consists of 86 wells (including 5 wells that monitor the performance of the Chemical Plant disposal cell) and 5 springs. Approximately 60 additional monitoring wells that had also been constructed and sampled since 1987 were abandoned because of (1) construction of the on-site disposal cell; (2) remedial action excavation activities; (3) damage or deterioration, usually accompanied by the drilling of a replacement well; and/or (4) long-term data collection that showed no impact from site contamination. Wells abandoned for this latter reason provide another line of evidence supporting the conclusion that groundwater contamination is not expanding beyond the existing areas of impact. The current network of wells and current network of springs monitored at the Chemical Plant area are shown in Figures 5.1 and 5.2, respectively. The contaminants of concern (COCs) in groundwater are TCE, nitrate, uranium, and nitroaromatic compounds. The nitroaromatic compounds of concern include 2,4-DNT, 2,6-DNT, 2,4,6-TNT, 1,3-dinitrobenzene (1,3-DNB), and nitrobenzene (NB). Contaminant contour maps are presented in Figures 5.3 through 5.8 for TCE, nitrate, uranium, 2,4-DNT, 2,6-DNT, and 2,4,6-TNT, respectively. 1,3-DNB and NB levels were exceeded in only one well, and contour maps for these have not been included in this report.

5.1.1 TCE

The MCL for TCE is 5 μg/L. TCE contamination exceeding that limit is found primarily within the Chemical Plant boundary (in the vicinity of the former Raffinate Pits) extending just beyond the DOE boundary onto the adjacent Army site. Contamination is primarily limited to the weathered portion of the shallow aquifer. The source of TCE contamination was drums discarded in Raffinate Pit 4, which were removed as part of the Chemical Plant Operable Unit. Since 1996, decreasing TCE trends have been observed. Data collected in 2002 showed TCE concentrations ranging from 1.6 to 580 μg/L, with the maximum reported for MW-4029 (a monitoring well located within the Chemical Plant boundary near the Raffinate Pits). Concentrations of TCE have been detected only in one spring, SP 6303, at approximately 1 μg/L.

In 2001, pilot-phase ICO of TCE was performed in an optimal location. It appears to have achieved only temporary reduction of TCE within the area of influence (approximately 100 ft [30 m] from the injection point). Dispersion of the oxidant favored a downgradient direction toward a preferential flow feature (paleochannel), and uniform distribution was not

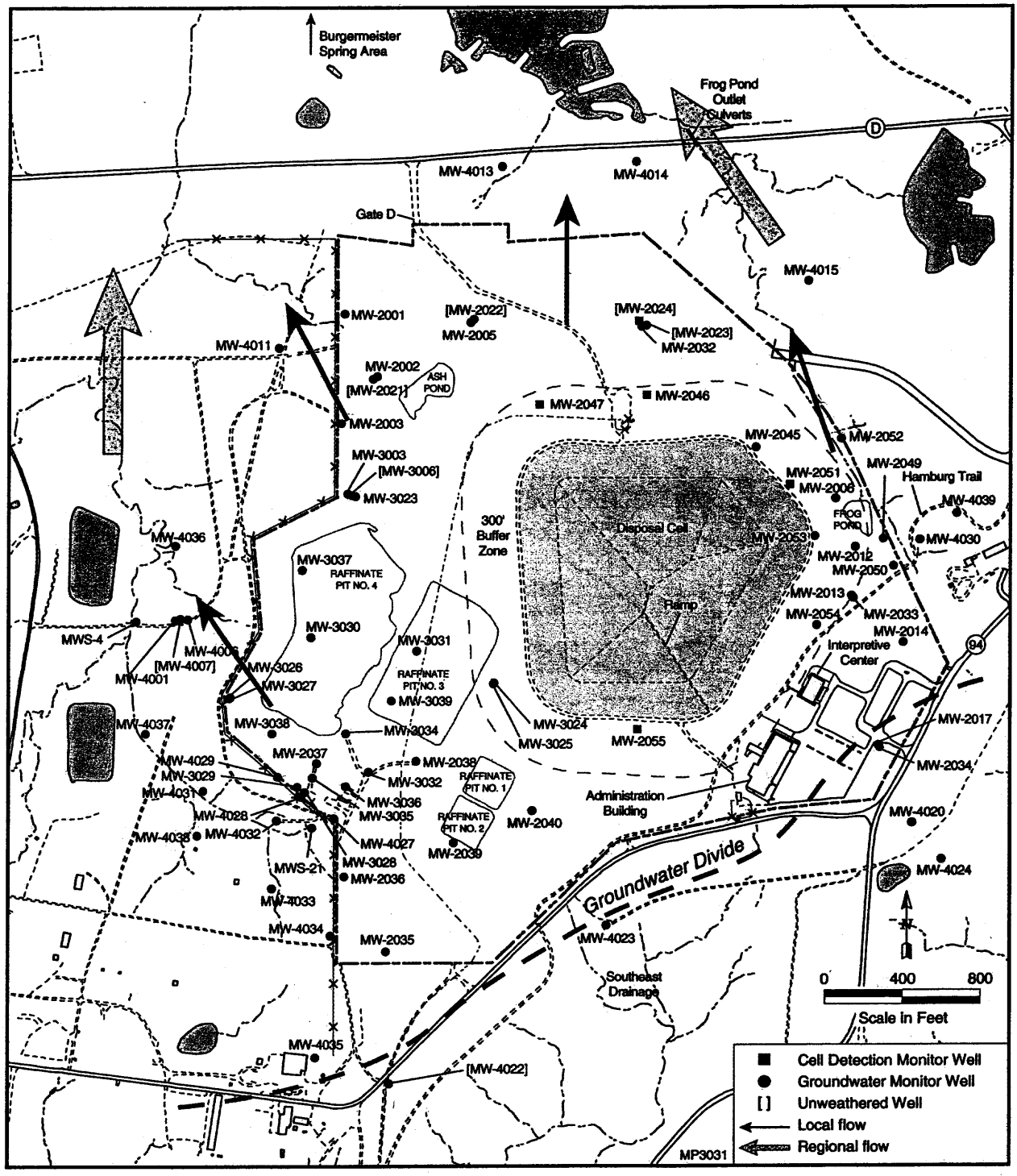


FIGURE 5.1 Locations of Wells in the Chemical Plant Area

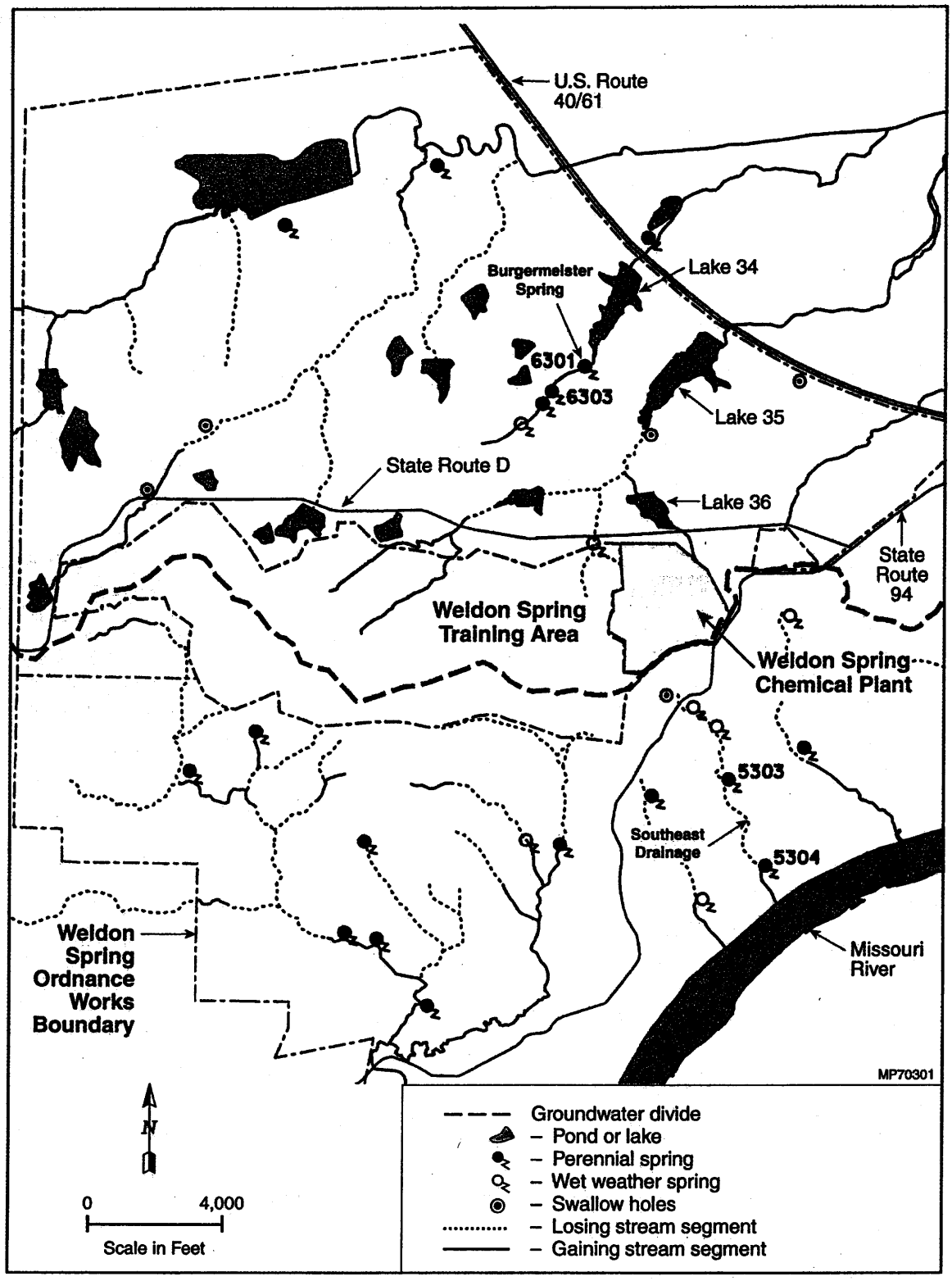


FIGURE 5.2 Locations of Springs and Drainage Areas in the Chemical Plant Area

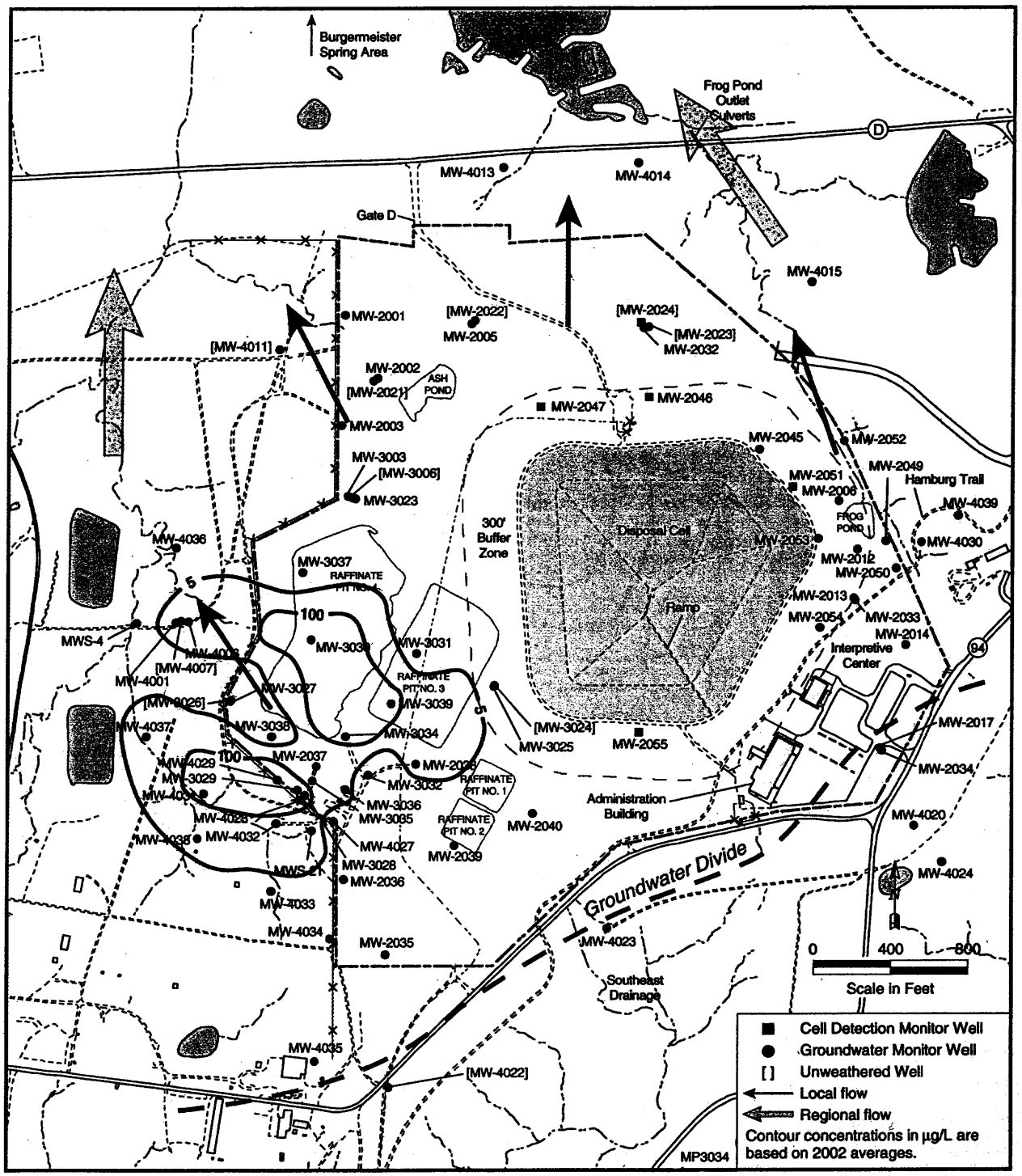


FIGURE 5.3 TCE Contamination Contour Based on Average Concentrations in 2002 at the Chemical Plant Area

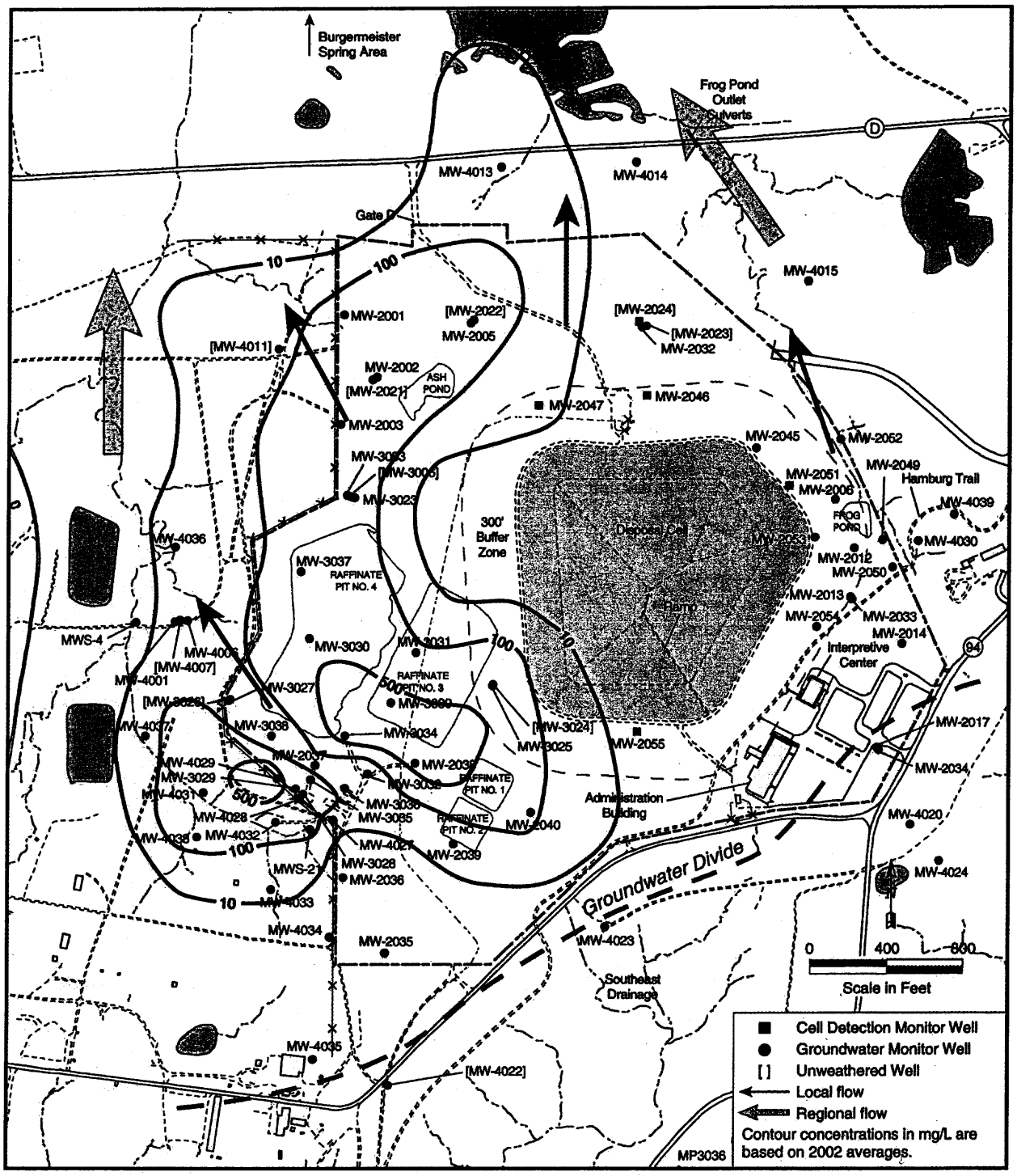


FIGURE 5.4 Nitrate Contamination Contour Based on Average Concentrations in 2002 at the Chemical Plant Area

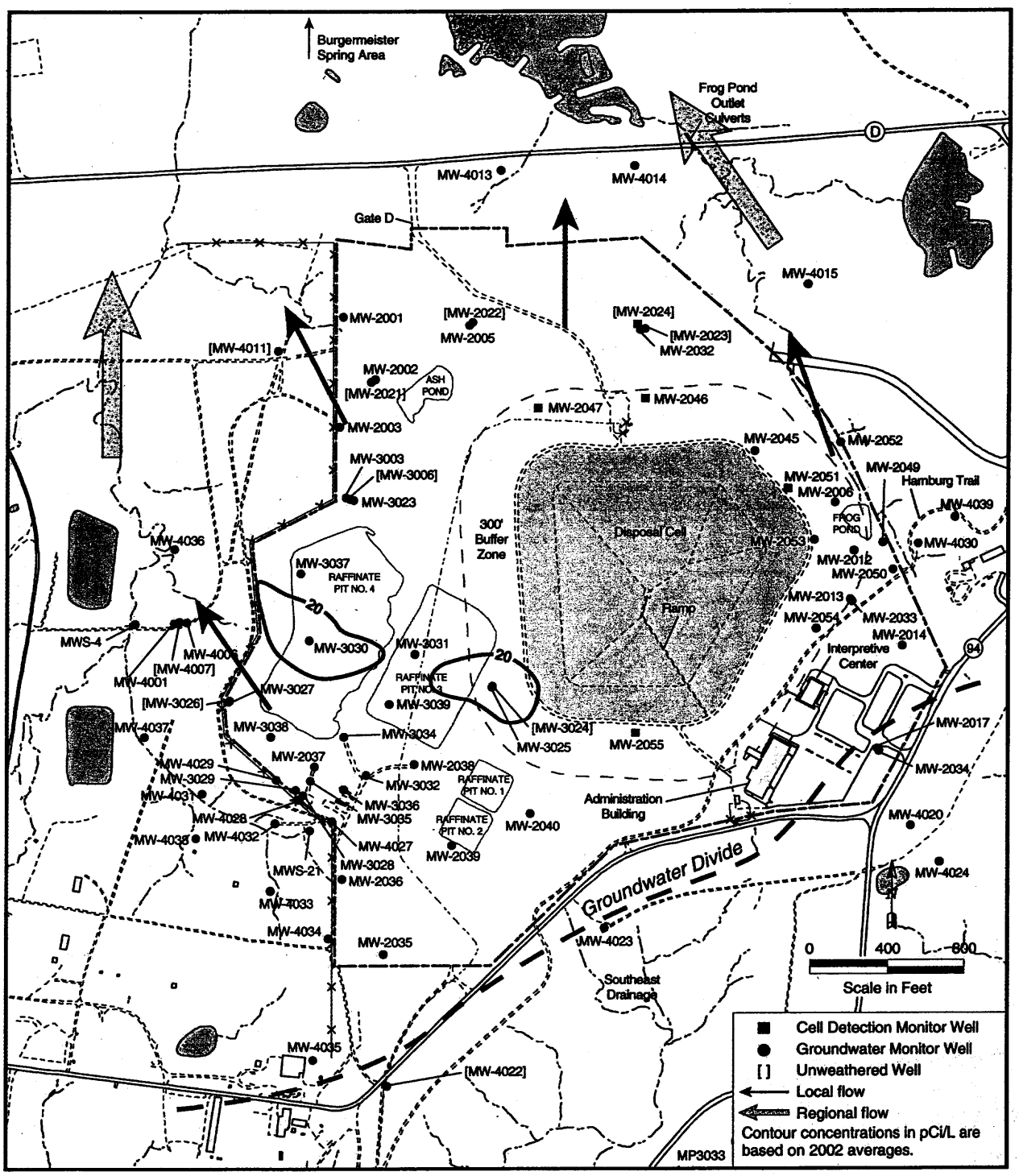


FIGURE 5.5 Uranium Contamination Contour Based on Average Concentrations in 2002 at the Chemical Plant Area

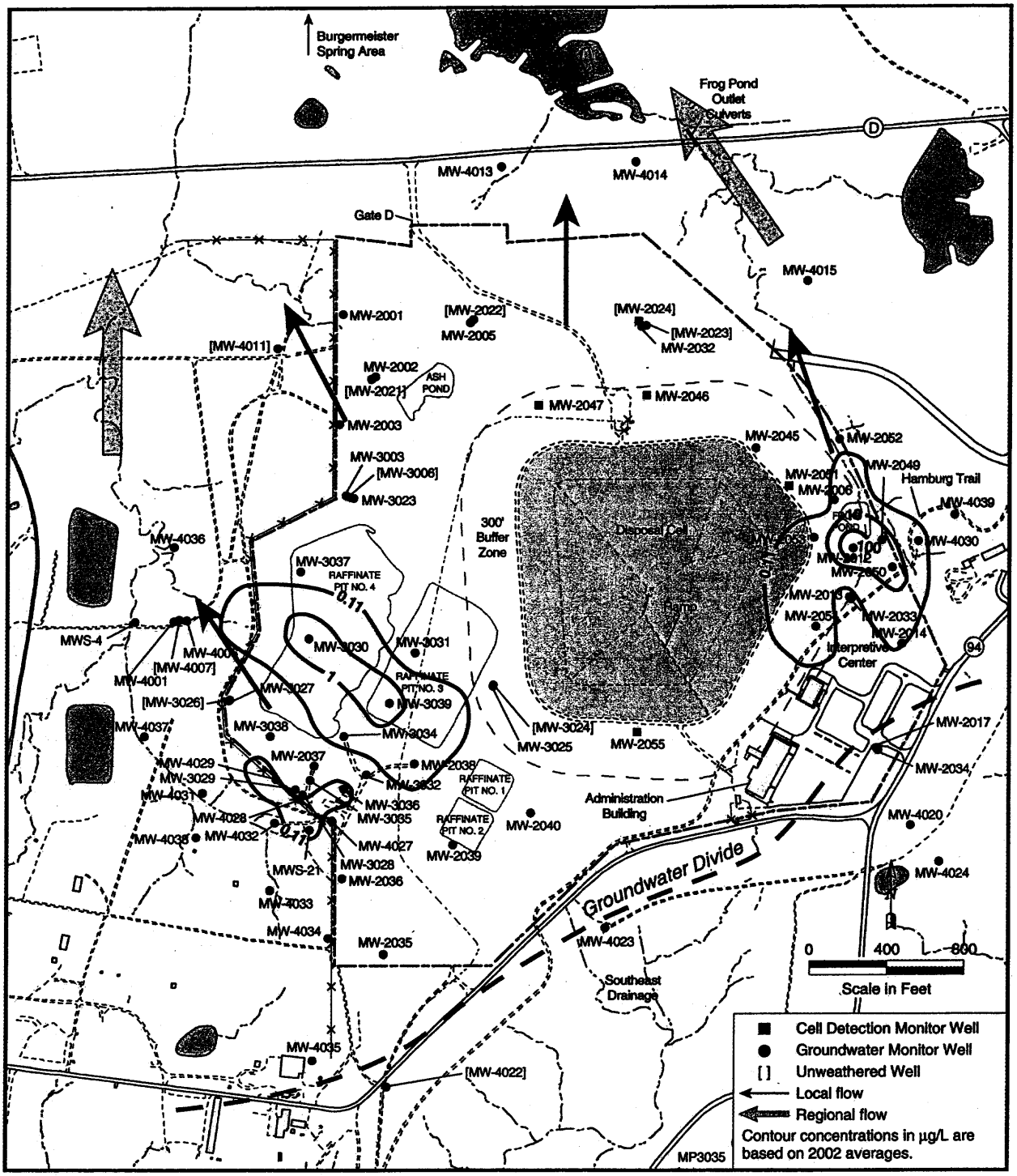


FIGURE 5.6 2,4-DNT Contamination Contour Based on Average Concentrations in 2002 at the Chemical Plant Area

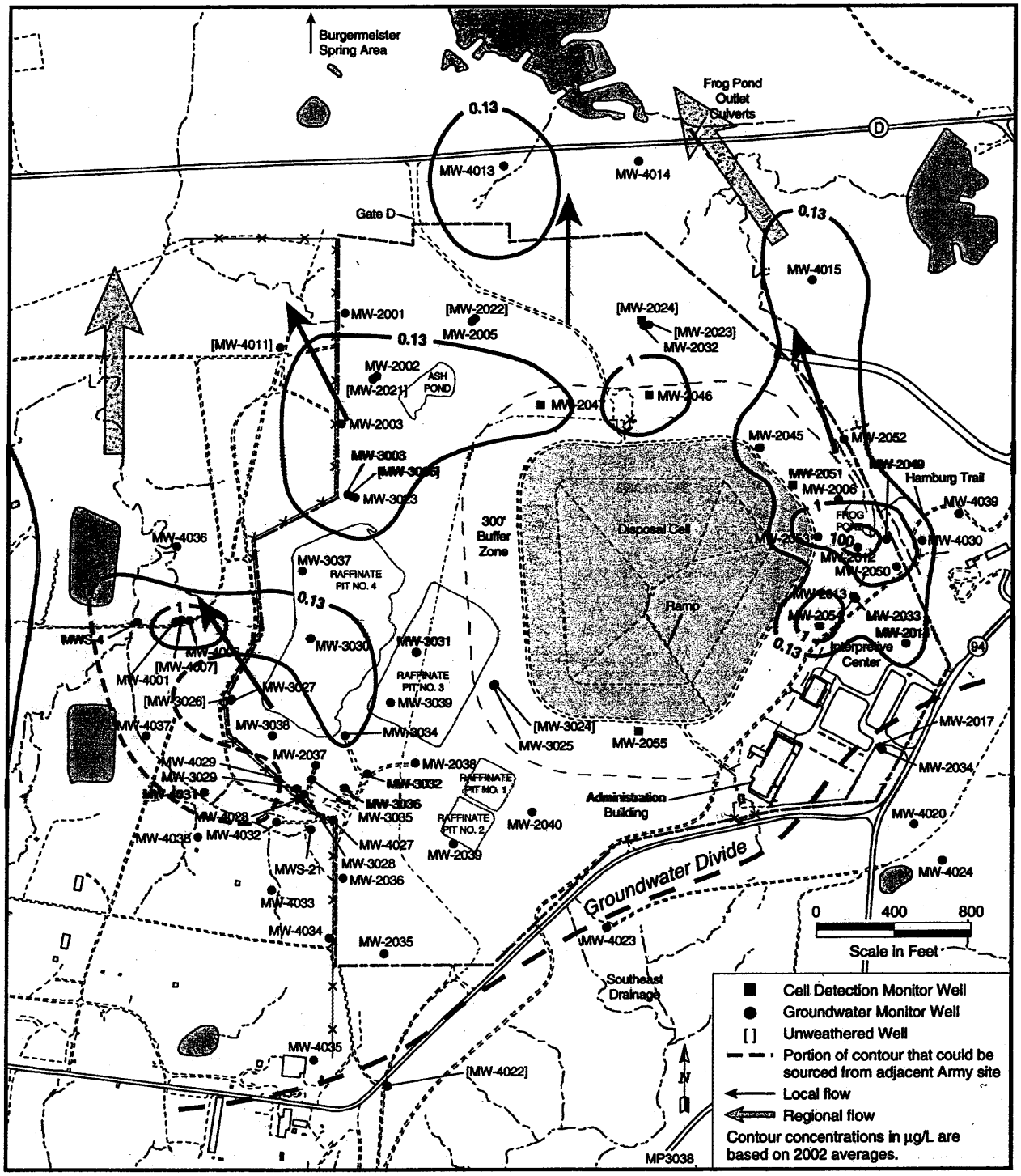


FIGURE 5.7 2,6-DNT Contamination Contour Based on Average Concentrations in 2002 at the Chemical Plant Area

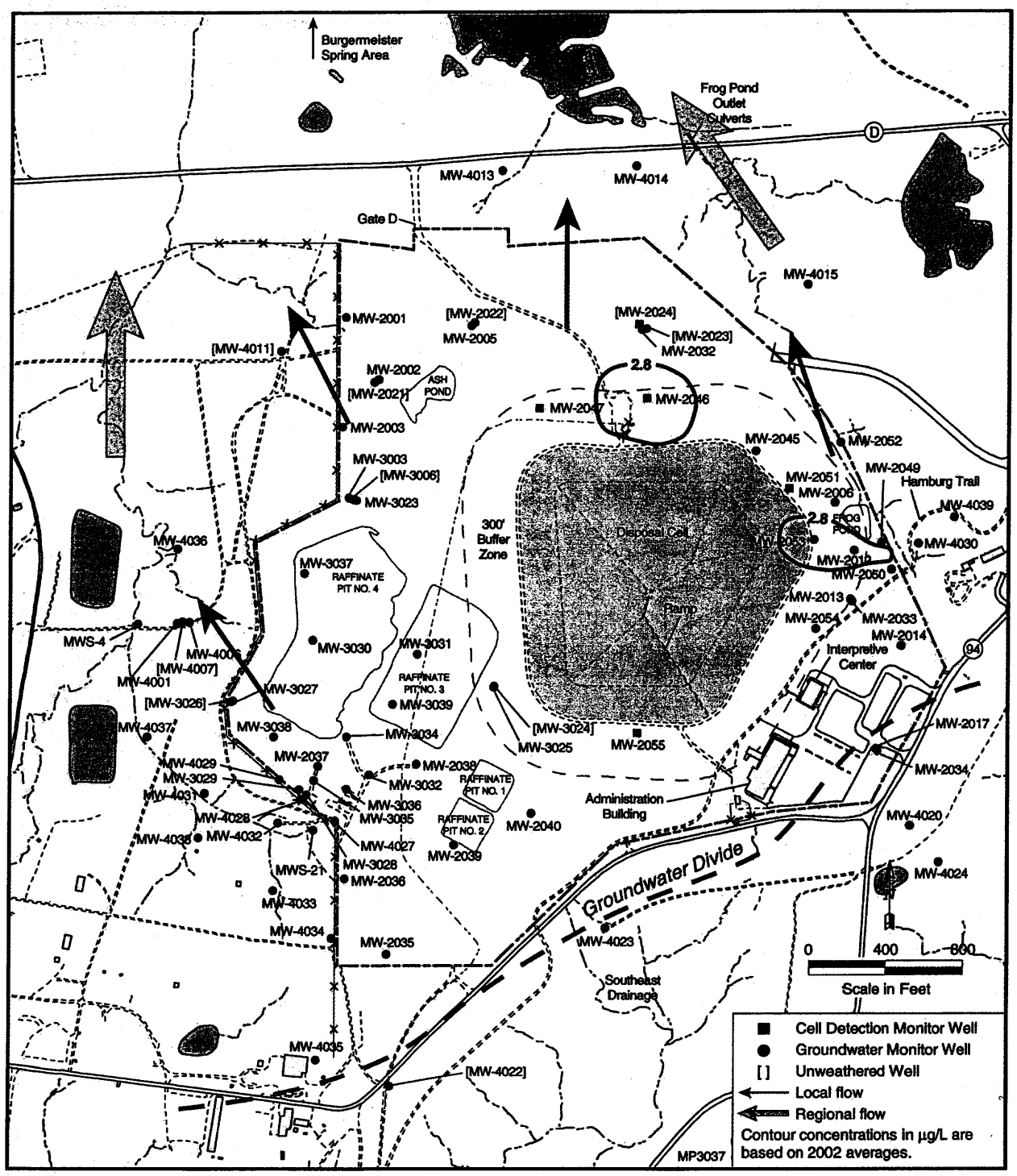


FIGURE 5.8 2,4,6-TNT Contamination Contour Based on Average Concentrations in 2002 at the Chemical Plant Area

achieved. The latest data, collected in 2003 at some locations where TCE was treated and reduced to nondetectable levels, show that concentrations have returned to near-pretreatment levels. This result (rebound) was considered possible and was caused by recontamination from dissolved TCE that is in other nearby portions of the groundwater where it was not reduced by the pilot-phase ICO. Concentrations in the treated areas rebounded to pretreatment levels as a result of the migration of TCE-impacted groundwater at upgradient locations or the equilibration of concentrations from the large chemical gradient existing after treatment. It is noteworthy that the original source of TCE contamination, which was drums discarded in Raffinate Pit 4, was removed during the remedial action for the Chemical Plant Operable Unit.

5.1.2 Nitrate

The MCL for nitrate is 10 mg/L. The highest concentrations of nitrate have been measured in the vicinity of the Raffinate Pits and Ash Pond, which are historical sources of this contaminant. Nitrates are mobile in the shallow aquifer system. Data for 2002 show nitrate concentrations ranging from 0.4 to 826 mg/L, with the maximum reported for MW-4029. Nitrate concentrations that exceed the MCL are observed at locations within the DOE Chemical Plant boundary, locations on MDC property, and locations within the adjacent DA site. Remediation activities in the Raffinate Pits area and Ash Pond in 1998 resulted in slight increases in contaminant concentrations in several of the nearby wells. This effect was considered a possibility because of the large-scale soil excavation that occurred during remediation of the Chemical Plant. It is anticipated to be only temporary. The majority of the wells exhibit stationary trends, with a few beginning to show downward trends.

Nitrate concentrations at Burgermeister Spring vary with changes in flow rate but are generally lower than concentrations measured in groundwater. Lower concentrations occur during high flow rates because of dilution. Data for 2002 indicate nitrate concentrations ranging from 0.94 to 11 mg/L. Nitrate results from Burgermeister Spring (1999 through 2002) show a downward trend during high flow and a stationary trend during base (low) flow. A nitrate concentration of 1.9 mg/L was also detected at SP-5304 in 2002.

5.1.3 Uranium

The MCL for uranium is 30 μg/L (or 20 pCi/L, based on the isotopic ratio determined for the Weldon Spring Site). Uranium concentrations exceeding the MCL are located within the Chemical Plant boundary and at several springs located on MDC property. The Raffinate Pits were the historical source of uranium in groundwater as it entered the aquifer via infiltration through the overburden. Contamination is primarily limited to the weathered portion of the shallow aquifer. Adsorption of uranium onto the overburden limited its extent in groundwater. Data on uranium concentrations collected in 2002 showed ranges of 0.1 to 60 pCi/L, and concentrations in only two wells exceeded the MCL. MW-3024 had 60 pCi/L, and MW-3030 had 57 pCi/L. Both wells are located within the Chemical Plant boundary. Because of the relatively low concentrations, downward trends are not expected to be clearly obvious until several more years of groundwater data are collected.

Uranium has been detected at Burgermeister Spring (SP-6301) and at the Southeast Drainage (SP-5304). In 2002, uranium ranged from 8.6 to 100 pCi/L and from 9.4 to 103 pCi/L at the two springs, respectively. Uranium concentrations measured at Burgermeister Spring are generally higher than those measured in groundwater at the Chemical Plant because of the additional contribution of residual uranium contamination in the subsurface flow path. Residual uranium was the result of overland flow lost to the subsurface in losing streams. Base flow concentrations have shown a downward trend at Burgermeister Spring since 1999 and have also shown a stationary trend under high-flow conditions.

5.1.4 Nitroaromatic Compounds

State of Missouri water quality standards for 2,4-DNT, 1,3-DNB, and NB are 0.11 μg/L, 1.0 μg/L, and 17 μg/L, respectively. There are no federal standards for the nitroaromatic compounds of concern in groundwater at the Chemical Plant. Nitroaromatic compounds occur in groundwater in the northeastern and southwestern portions of the site where TNT production lines were located both on the Chemical Plant site and the adjacent DA site. Contamination occurs predominantly in the weathered portion of the shallow aquifer. In 2002, maximum concentrations of 1,600 μg/L for 2,4-DNT, 1,300 μg/L for 2,6-DNT, 290 μg/L for 2,4,6-TNT, 1.7 μg/L for 1,3-DNB, and 69 μg/L for NB were detected. These maximums were reported for one particular well, MW-2012. Starting in 1999, increasing trends were observed from this monitoring well near the Frog Pond area located within the Chemical Plant boundary. They are most likely due to excavation of TNT-impacted soil in this area or due to excavation of the nearby waste lagoon for the adjacent Weldon Spring Ordnance Works site by the DA. The increase in concentrations is expected to be temporary, since the sources of nitroaromatic contamination have been removed and water quality should improve over time. Nitroaromatic compound contamination at the remainder of the site is significantly lower. Of the nitroaromatic compounds sampled for at Burgermeister Spring in 2002, only 2,6-DNT was detected, at an average concentration of 0.12 μg/L. At the Southeast Drainage, 2,4,6-TNT and 2,6-DNT were detected at average concentrations of 26 μg/L and 0.12 μg/L, respectively.

5.2 SITE HYDROGEOLOGY

Two major geologic units are present beneath the Chemical Plant area: unconsolidated surface materials and underlying limestone bedrock. Unconsolidated surface materials as much as 18 m (60 ft) thick are clay-rich and mostly of glacial origin. The uppermost bedrock unit in the area, the Burlington-Keokuk Limestone, has been separated into two zones with different physical characteristics: a weathered zone underlain by an unweathered zone. The weathered zone ranges in thickness from 3 to 17 m (10 to 55 ft) and consists of highly fractured limestone with solution voids and enlarged fractures. Fracturing in the bedrock is predominantly horizontal and is associated with the bedding plane in the limestone. Small solution features are common in the weathered portion of the Burlington-Keokuk Limestone and range from pinpoint vugs (cavities) to small zones of core loss, typically less than 1.5 m (5 ft) (DOE 1992). These larger features are generally clay filled and do not represent a complex system of open caves or caverns

in the subsurface. The unweathered zone has less fracturing and weathering than the weathered zone.

Three regional bedrock aquifers are present in the vicinity of the Chemical Plant area: a shallow unconfined aquifer (although it may be locally confined), a middle confined aquifer, and a deep confined aquifer. Characterization data indicate that the shallow unconfined aquifer has been affected by former activities at the Chemical Plant area; therefore, it is the groundwater system of primary interest for this ROD. The aquifer consists of the Burlington-Keokuk Limestone, the Fern Glen Formation (both limestone units), and the overburden to the north of the Chemical Plant. The hydrogeology of the Burlington-Keokuk Limestone at the site is comprised of weathered limestone with solution-enlarged joints and bedding planes, losing and gaining stream segments, and preferential flow zones that discharge to springs, resulting in pronounced groundwater troughs in the shallow groundwater piezometric surface. Groundwater flow within the shallow aquifer has a predominantly horizontal component primarily as a result of the structural control of the bedding planes of the limestone bedrock. Because of these lateral controls, groundwater discharges to springs, seeps, and creeks. Vertical movement of water into deeper units is limited because of the small amount of effective surface infiltration, the lateral losses to Burgermeister Spring, and the presence of thick confining units over both the middle and deep aquifers. Even though groundwater from the shallow aquifer has the potential to infiltrate into deeper units, the contribution from the area of impact at the Chemical Plant is small and the travel times for groundwater in the shallow aquifer to infiltrate vertically to the deep aquifer is on the order of 1000's of years (Kleeschulte and Imes 1994). Contaminant data from the unweathered portion of the shallow aquifer (Burlington-Keokuk unit) at the Chemical Plant area have shown little or no impact from site contamination. The potential contribution to the middle and deep aquifers from the Chemical Plant area is minute and will not result in measurable impacts.

An east-west trending groundwater divide results in two distinct flow systems in the Chemical Plant area. Presently, this divide is located along the southern boundary of the Chemical Plant property. Previously, the divide had been situated beneath the Raffinate Pits area because of extensive recharge from the pits; these pits have since been removed. With the removal of this recharge component, the groundwater divide has now shifted to coincide with the bedrock high located along the southern boundary of the site. Following this shift, the impact to the groundwater is only north of the groundwater divide. At the Chemical Plant area, shallow groundwater north of the divide, where the residual groundwater contamination is located, flows to the north into a karst conduit system that discharges at Burgermeister Spring (Figure 5.1). Transport through this conduit can be very rapid, as demonstrated by subsurface dye trace studies performed at the Chemical Plant site in 1995 and 1998 (DOE and DA 1997b). Water discharged at Burgermeister Spring then mixes with other surface water and with ponded water in Lake 34. Any dissolved contaminants in the discharged groundwater are then subject to extensive dilution and, for some, physical and chemical degradation. Because most of the shallow groundwater beneath the Chemical Plant area discharges to the surface in the vicinity of Burgermeister Spring, the spring defines the northernmost extent of direct groundwater transport from the site and provides an ideal location for monitoring endpoint contaminant concentrations.

Groundwater south of the divide at the Chemical Plant area flows south to southeast toward the Missouri River, primarily through the Southeast Drainage. This represents only a small portion of the Chemical Plant, and currently no groundwater contamination attributable to the Chemical Plant site has impacts south of the divide. Therefore, at present, there is no groundwater component to the contamination present in the downgradient springs. Historically, contaminated groundwater from Raffinate Pits 1 and 2 flowed into the Southeast Drainage because the groundwater divide was located beneath the Raffinate Pits area. This drainage was also used as a discharge point for effluent from the Chemical Plant operations, and because this drainage has losing stream segments in its upper reaches, mixing between groundwater and surface water occurred. Springs in the Southeast Drainage are ideal locations for monitoring.

The shallow groundwater system beneath the Chemical Plant area is hydrogeologically complex and characterized by fractures, conduits, paleochannels, and dissolution or weathering features. Because of these features, the aquifer exhibits highly heterogeneous and anisotropic values in hydraulic conductivity and transmissivity from place to place. Pump tests performed in July 1998 and the field test performed in 2001 to determine the effects of groundwater withdrawal and injection on the aquifer further demonstrated the variability of the aquifer and the low unsustainable yields of groundwater (MK-Ferguson and Jacobs Engineering Group 1998).

6 CURRENT AND FUTURE LAND AND RESOURCE USES

Current and potential future land use and groundwater and springwater use are described in this section to provide the basis for the exposure assumptions presented in subsequent sections of this ROD.

6.1 CURRENT LAND USE

The two communities closest to the site are Weldon Spring and Weldon Spring Heights, about 3.2 km (2 mi) 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. Urban areas occupy about 6% of county land, and nonurban areas occupy 90%; the remaining 4% is dedicated to transportation and water uses (MK-Ferguson Company and Jacobs Engineering Group 2001). Francis Howell High School (FHHS) is about 1 km (0.6 mi) northeast of the site along Missouri State Route 94 and is occupied regularly by about 1,700 faculty, staff members, and students.

The MoDOT Weldon Spring maintenance facility, located adjacent to the north side of the Chemical Plant, employs about 10 workers. The Army Reserve Training Area to the west of the site is visited periodically by Army trainees and law enforcement personnel (MK-Ferguson Company and Jacobs Engineering Group 2001). About 300 ha (741 acres) of land east and southeast of the high school is owned by the University of Missouri. The northern third of this land is being developed into a high-technology research park. The conservation areas adjacent to the site are operated by the MDC and employ about 50 people. Two residences are located on the MDC property north of the Chemical Plant (see also discussion and Figure 12.1 in Section 12).

6.2 FUTURE LAND USE

At the Chemical Plant, the 24-ha (60-acre) disposal cell facility that includes the 300-ft (91-m) buffer will remain under the custody of DOE. As currently planned, only three buildings will remain within the Chemical Plant proper after project completion and site closure. The administration building would be made available for use by a local organization. The former access control building contains the Weldon Spring Site interpretive center. The center is a place where members of the public can obtain information about the site. A small water treatment enclosure is located near the leachate sump.

DOE expects that the DA will continue to use the adjacent Weldon Spring Training Area (WSTA) for field training. The MDC is expected to continue to maintain the remaining surrounding areas for recreational use.

6.3 CURRENT GROUNDWATER AND SPRINGWATER USE

The shallow bedrock aquifer that is beneath the boundary of the Chemical Plant property and the adjacent DA and MDC properties is not currently used for drinking water or for irrigation. However, on the basis of EPA guidance for groundwater classification (EPA 1986), site groundwater could be classified as potentially usable from a water quality standpoint. That is, according to the EPA, a potential source of groundwater is one capable of yielding at least 150 gal/d to a well or spring, which is sufficient for the needs of a family. Also, a drinking water source must have a total dissolved solids concentration of less than 10,000 mg/L that can be supplied without treatment. Despite the unlikelihood of the impacted groundwater actually ever being used for household purposes, in accordance with EPA guidelines and for the purpose of making this remedial action determination, this shallow groundwater is categorized as a potentially usable resource.

No active private wells are located within 1 mi (1.6 km) of the Chemical Plant. One well, which is used for irrigation at the Missouri Research Park, is located within 2 mi (3.2 km), but it is cross gradient of the site and therefore should not be affected by the site. No active domestic wells are known to be within the Chemical Plant area, the adjacent Ordnance Works area, or in the Busch Conservation area (Vogel 2003). The privately owned domestic water wells that are located closest to the site are 2.1 mi (3.4 km) to the north-northeast. These wells are estimated to be 70 to 91 m (325 to 350 ft) below the ground surface. Although these wells produce water that includes groundwater from the shallow aquifer, the potential for impact from contaminated groundwater originating from the Chemical Plant site is low. Groundwater field studies have supported that the preferential flow direction for groundwater from the site is to the northwest toward Burgermeister Spring and the 6300 Drainage (DOE and DA 1997b). If active wells were present between the site and this drainage, the likelihood for impact would be high.

In 1982, the Missouri Department of Health and Senior Services (DHSS), which was at that time called the Missouri Department of Health (MDOH), initiated a sampling program of private drinking water wells surrounding the Weldon Spring Site. The number of wells was expanded over time in an effort to fully investigate the area around the Chemical Plant and the

former Army Ordnance Works area. When a well is no longer used for consumption, it is removed from the sampling program. Historically, wells closer to the site were sampled quarterly, and those in outlying areas were sampled annually. Presently, wells are sampled on a semiannual or annual basis. Sampling results indicate background levels of those parameters analyzed, including radiological parameters (Basko 2003). The only impacted wells identified were at Twin Island Lakes (Dardenne Lakes) located northeast of the Chemical Plant and Ordnance Works area, where elevated nitroaromatic compounds were detected. This impact is not due to the DOE Weldon Spring Site and was investigated by the DA as part of its Ordnance Works CERCLA site. More extensive sampling performed by the DA determined that elevated levels of nitroaromatic compounds were present only in the samples from the Twin Island Lakes wells.

6.4 POTENTIAL FUTURE GROUNDWATER AND SPRINGWATER USE

A municipal water supply is currently available to serve the household needs of the area communities. Thus, for the foreseeable future, it is unlikely that the impacted groundwater beneath the Chemical Plant would be used for household purposes. In addition, the impacted, shallow portion of the aquifer is characterized by low yield. The deeper, unaffected, higher-yielding aquifers would more likely serve as a groundwater source in the unlikely event that groundwater use would ever occur

Access to springwater will remain similar to access under current conditions, consistent with recreational land use.

7 SUMMARY OF SITE RISKS

The baseline risk assessment (BRA) (DOE and DA 1997a) prepared for the Chemical Plant area provides an estimate of the potential human health and ecological risk that would be posed by the site if no remedial action was taken. The human health assessment indicates that the site contamination levels are acceptable for a recreational visitor but not for a resident. Further, groundwater concentrations for TCE, nitrate, uranium, and some of the nitroaromatic compounds exceed federal or state drinking water standards or MCLs. Therefore, restrictions on the residential use of groundwater will be necessary to protect human health until a time when contaminant concentrations will have decreased to levels equivalent to or below the MCLs. The ecological assessment indicates that contaminant concentrations in springwater and sediment pose little or no risk to ecological resources in the area and that remediation is not needed from an ecological perspective (DOE and DA 1997a).

Information on current and future land use and resource (groundwater and springwater) use was used to develop the use assumptions that were incorporated in the risk assessment. Section 6 presents information regarding current and future land and resource use for the Chemical Plant area and its vicinity. Section 7.1 summarizes the human health risk assessment and results. Section 7.2 summarizes the ecological risk assessment that was performed for the GWOU.

7.1 HUMAN HEALTH RISK ASSESSMENT

As part of the RI/FS, potential risks to human health and the environment from groundwater and springwater contamination were evaluated by using standard EPA methods. The conclusion is that site groundwater and springwater contamination levels are acceptable for the recreational visitor scenario but not for the resident scenario.

7.1.1 Identification of Contaminants of Concern

The COCs identified in groundwater underlying the Chemical Plant are TCE, nitrate, uranium, and nitroaromatic compounds (2,4-DNT, 2,6-DNT, 2,4,6-TNT, 1,3-DNB, and NB). The COCs identified in springwater are the same as those for groundwater, except for TCE. Table 7.1 presents a summary of these COCs and their associated concentrations.

7.1.2 Exposure Assessment

Risk scenarios were developed on the basis of current and likely future land uses. Foreseeable future land use at the Chemical Plant and surrounding area is likely to be recreational, which is the same as current land use. Therefore, potential exposure is only through access to springwater.

The Army reservists scenario, which accounts for reservists who train at the adjacent Army training area, was not evaluated because the reservists do not have access to any active springs within the training area. Also, the exposure assumptions (e.g., frequency and duration) for the recreational visitor scenario would account for the instances when these reservists would access the springs outside the training area while on personal time.

The assessment presented in the BRA (DOE and DA 1997a) also provided risk estimates for a hypothetical future resident scenario that assumes access to groundwater contaminants. For the hypothetical resident scenario, the assessment assumed ingestion of groundwater from a well for 350 days a year for 30 years; the resident would drink 2 L each day. Aside from the ingestion partway, inhalation through the showering pathway was also evaluated for TCE only.

For the recreational visitor scenario, the assessment assumed conservatively that the recreational visitor would visit the area 20 times a year for 30 years for 4 hours on each visit and that each time, the visitor would ingest a cupful of springwater (about 400 mL). The ingestion and dermal pathways were evaluated for potential exposure to springwater. Table 7.2 tabulates key exposure assumptions and intake parameters used in the evaluations.

TABLE 7.1 Summary of Contaminants of Concern and Exposure Point Concentrations

COC	Exposure Point Concentration (UCL95)[a]
When exposure point is direct contact with groundwater	
TCE	2–3,800 µg/L
Nitrate	0.005–900 mg/L
Uranium	0.22–60 pCi/L
2,4-DNT	0.026–5 µg/L
2,6-DNT	0.023–5 µg/L
2,4,6-TNT	0.044–29 µg/L
1,3-DNB	0.27–0.86 µg/L
NB	0.042–0.062 µg/L
When exposure point is direct contact with springwater[b]	
Uranium	0.33–120 pCi/L
Nitrate	0.14–18 mg/L
2,4-DNT	0.04–0.21 µg/L
2,6-DNT	0.048–2 µg/L
2,4,6-TNT	0.02–120 µg/L

[a] The ranges presented indicate the minimum and maximum upper confidence limit at 95% (UCL95) of the wells or springs evaluated in the BRA (DOE and DA 1997a). This table presents data for the COCs only; the BRA also evaluated other contaminants that were considered to be of potential concern at that time.

[b] 1,3-DNB and NB were not detected in the springs for the BRA evaluation.

7.1.3 Toxicity Assessment

The assessment of radiological human health risks in the BRA was limited to carcinogenic effects. This approach is consistent with EPA guidance, which notes that cancer risk is generally the limiting effect for radionuclides and suggests that radiation carcinogenesis be used as the sole basis for assessing radiation-related human health risks (EPA 1989). The method used to calculate carcinogenic risks for the radionuclides of concern is similar to existing methods used to calculate chemical carcinogens; both use an age-averaged lifetime excess cancer

TABLE 7.2 Exposure Scenario Assumptions and Intake Parameters[a]

Intake Parameter	Current or Future Recreational Visitor	Future Resident
Exposure time (h/event)	4	0.16[b]
Exposure frequency (no. of events/yr)	20	350
Exposure duration (yr)	30	30
Body weight (kg)	70	70 (4)[c]
Spring water ingestion rate (mL/event)	400	NA[d]
Groundwater ingestion rate (L/event)	NA	2 (0.64)[c]
Inhalation rate (m^3/h) (showering scenario for TCE only)	NA	0.83
Surface area (cm^2)	4,200[e]	20,000[f]
Permeability coefficient (cm/h)		
Default	1×10^{-3}	1×10^{-3}
TCE	NA	1.6×10^{-2}

[a] Assumptions and intake parameters are consistent with recommendations by the EPA (1995b, 1992a).

[b] Assumed length of time per day for showering.

[c] Exposure assumptions in parentheses are for an infant ingesting groundwater. These parameters were used to calculate intakes and hazard quotients for nitrates in groundwater because of the greater sensitivity of infants to the toxic effects of this contaminant.

[d] NA = not applicable.

[e] Surface area consists of the arms, hands, and lower legs (EPA 1992a).

[f] Surface area is the whole body (EPA 1992a).

incidence per unit intake. To support this evaluation, the EPA has developed cancer incidence factors per unit intake that are analogous with the slope factors developed for chemical carcinogens.

The following slope factors were used in this assessment: 4.4×10^{-11}/pCi for uranium-234, 4.5×10^{-11}/pCi for uranium-235, and 6.2×10^{-11}/pCi for uranium-238+D (EPA 1995a). The "+D" designation indicates that the risks from associated short-lived decay products (i.e., with radioactive half-lives that are less than or equal to 6 months) are also included. Only ingestion slope factors were used because inhalation and external radiation are not pathways of concern for the receptors being assessed. The activity-weighted average of these slope factors for isotopic conditions present in site groundwater (5.3×10^{-11}/pCi) was used in conjunction with the total concentration of uranium (in pCi/L) to estimate the radiological risk.

The EPA has derived toxicity values for the chemical contaminants of human health concern and assigned reference doses (RfDs) to measure the noncarcinogenic effects of chemicals. The chronic RfD is defined as "an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime" (EPA 1989). To derive an RfD value (expressed

in mg/kg-d), the EPA reviews all toxicity studies available for a given substance and a given route of exposure, determines a "no observed adverse effect level" (NOAEL) or a "lowest observed adverse effect level" (LOAEL) from the study most relevant to humans (the critical study), and applies uncertainty factors to these values. The RfD can be compared with estimated exposure levels to evaluate the potential for deleterious effects. Current available RfD values are specific to either the inhalation or ingestion route of exposure because the toxic mechanism and dose required for toxicity to occur can differ for these routes of exposure. For the BRA, only ingestion RfDs were used because ingestion was determined to be the pathway of concern for the receptors being assessed. Oral RfDs are available for uranium, nitrate, 1,3-DNB, 2,4,6-TNT, 2,4-DNT, 2,6-DNT, and NB.

The short-term toxicity of nitrate was assessed by using infant exposure parameters as well as adult exposure parameters to calculate hazard indices. The use of infant exposure parameters resulted in a calculated hazard index of 1 for a well with a nitrate concentration of 10 mg/L.

Carcinogenic risks from exposure to known and potential carcinogens are evaluated separately from noncarcinogenic risks because theoretically any exposure to a carcinogen increases the risk of cancer by a finite amount. Therefore, the risk from exposure to a carcinogen at a given level can be derived, but an exposure level at which no carcinogenic effect is likely to occur (as for noncarcinogenic endpoints) cannot be defined. The EPA has defined two toxicity values for evaluating the potential carcinogenic effects of a given substance: the weight-of-evidence classification and the slope factor. For substances that have weight-of-evidence classifications of A (human carcinogen), B1 or B2 (probable human carcinogens), and sometimes C (possible human carcinogens), the EPA has calculated slope factors on the basis of data from dose-response studies. The slope factor is defined as a "plausible upper-bound estimate of the probability of a response (i.e., cancer) per unit intake of a chemical over a lifetime" (EPA 1989).

Tables 7.3 and 7.4 summarize the chemical noncarcinogenic toxicity and carcinogenic risk information relevant to the COCs in groundwater and springwater at the Chemical Plant.

7.1.4 Risk Characterization

Tables 7.5 and 7.6 present summaries of the risk results presented in the BRA (DOE and DA 1997a). The risk estimates for the recreational visitor ingesting springwater from each of the contaminated springs are within the acceptable risk range or below the hazard index of 1. The combined effects of radiation and chemicals were estimated to range from greater than 1 in 1 billion to 2 in 1 million.

The risk estimates for the hypothetical resident scenario, however, indicate three things. First, in several wells near the Raffinate Pits area, TCE concentrations could result in a lifetime excess cancer risk of greater than 1 chance in 10,000. Second, in wells near the Frog Pond area, 2,4-DNT and 2,6-DNT contamination could result in a risk of greater than 1 chance in 10,000

TABLE 7.3 Toxicity Values for COCs Related to Ingestion of Groundwater and Springwater: Potential Systemic Effects

Parameter	Chronic RfD (mg/kg-d)	Level of Confidence	Critical Effect	RfD Basis	RfD Source[a]	Uncertainty Factor (UF)[b]
Uranium	0.003	Medium	Weight loss; moderate kidney activity	Oral, rabbit	IRIS	1,000
Nitrate-N	1.6	High	Methemoglobinemia	Oral, human	IRIS	1
1,3-DNB	0.0001	Low	Increased splenic weight	Oral, rat	IRIS	3,000
2,4,6-TNT	0.0005	Medium	Liver effects	Oral, dog	IRIS	1,000
2,4-DNT	0.002	High	Neurotoxicity; bilary tract hyperblasia; Heinz bodies	Oral, dog	IRIS	100
2,6-DNT	0.001	NA[c]	Neurotoxicity; bilary tract hyperblasia; Heinz bodies	Oral	HEAST	100
Nitrobenzene	0.0005	Low	Hematological, adrenal, renal, and hepatic lesions	Inhalation, rat and mouse	IRIS	10,000

[a] Source: *Integrated Risk Information System* (EPA 1997), except as indicated.

[b] The NOAEL or LOAEL dose from the critical study can be obtained by multiplying the chronic RfD by the uncertainty factor.

[c] NA = not applicable.

TABLE 7.4 Toxicity Values for COCs Related to Ingestion of Groundwater and Springwater: Potential Carcinogenic Effects

Parameter	Slope Factor $(mg/kg\text{-}d)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	Slope Factor	
				Basis	Source[a]
2,4,6-TNT	0.03	C: possible human carcinogen	Urinary bladder; transitional cell papilloma; transitional squamous carcinoma	Diet, rat	IRIS
2,4-DNT	0.68	B2: probable human carcinogen	Liver, mammary gland; adenocarcinomas/carcinomas	Water, rat	IRIS
2,6-DNT	0.68	B2: probable human carcinogen	Liver, mammary gland; adenocarcinomas/carcinomas	Water, rat	IRIS
TCE	0.011[b]	B2: probable human carcinogen	Liver	NA[c]	-[d]

[a] Source: *Integrated Risk Information System* (EPA 1997), except as indicated.

[b] TCE slope factor for the inhalation pathway is 0.006 (EPA 1996).

[c] NA = not applicable.

[d] Not available through IRIS.

TABLE 7.5 Risk Characterization Summary: Noncarcinogens

Receptor population: Recreational visitor
Receptor age: Adult[a]
Scenario time frame: Current and future

Exposure Medium	COC[c]	Critical Effect	Noncarcinogenic Hazard Quotient[b]		
			Ingestion	Dermal	Total for Both Pathways
Springwater	Uranium	Kidney toxicity	<0.0001–0.01	<0.0001–0.0002	<0.00001–0.01
	Nitrate	Methemoglobinemia	<0.0001–0.002	<0.00001–<0.00004	<0.0001–0.002
	2,4-DNT	Neurotoxicity	<0.00001–0.00002	<0.00001–<0.00001	<0.00001–<0.00002
	2,6-DNT	Neurotoxicity	<0.00001–0.0003	<0.00001–<0.00001	<0.00001–<0.0003
	2,4,6-TNT	Liver effects	<0.0001–0.04	<0.0001–0.0008	<0.0001–<0.04
Total receptor hazard index					<0.0001–0.052

Receptor population: Resident (hypothetical)
Receptor age: Adult[a]
Scenario time frame: Future

Exposure Medium	COC	Critical Effect	Noncarcinogenic Hazard Quotient for Ingestion[d]
Groundwater	TCE	Liver	-[e]
	Uranium	Kidney toxicity	0.0014–0.82
	Nitrate	Methemoglobinemia	0.0044–15
	2,4-DNT	Neurotoxicity	<0.001–0.068
	2,6-DNT	Neurotoxicity	<0.001–0.30
	2,4,6-TNT	Liver effects	<0.002–1.6
	1,3-DNB	Increased splenic weight	0.24
	NB	Hematological, adrenal, renal, hepatic lesions	0.002–0.003
Total receptor hazard index			0.011–36

[a] Because the toxic effect of nitrate is primarily of concern for infants, nitrate was also evaluated for infant exposure. The hazard quotient for nitrate was about 5.6 times higher for infant exposure than for adult exposure.

[b] Range represents the minimum and maximum noncarcinogenic hazard quotient for the COCs for the 15 springs evaluated for the BRA.

[c] TCE, 1,3-DNB, and NB were not reported in any of the 15 springs evaluated for the BRA.

[d] Range represents the minimum and maximum noncarcinogenic hazard quotient from the wells evaluated.

[e] TCE was not evaluated as a noncarcinogen.

TABLE 7.6 Risk Characterization Summary: Carcinogens

Receptor population: Recreational visitor
Receptor age: Adult
Scenario time frame: Current and future

Exposure Medium	COC	Weight-of-Evidence Classification	Carcinogenic Risk[a] Ingestion	Dermal	Total for Both Pathways
Springwater	Uranium[b]	Carcinogenic	4×10^{-9} to 2×10^{-6}	4×10^{-11} to 2×10^{-8}	4×10^{-9} to 2×10^{-6}
	Nitrate[c]	–	–	–	–
	2,4-DNT	B2: probable human carcinogen	2×10^{-9} to 1×10^{-7}	4×10^{-11} to 2×10^{-10}	2×10^{-9} to 1×10^{-7}
	2,6-DNT	B2: probable human carcinogen	2×10^{-4} to 9×10^{-8}	5×10^{-11} to 2×10^{-9}	2×10^{-9} to 9×10^{-8}
	2,4,6-TNT	C: probable human carcinogen	4×10^{-11} to 2×10^{-7}	9×10^{-13} to 5×10^{-9}	4×10^{-11} to 2×10^{-7}
Total receptor risk					8×10^{-9} to 2×10^{-6}

Receptor population: Resident (hypothetical)
Receptor age: Adult
Scenario time frame: Future

Exposure Medium	COC	Weight-of-Evidence Classification	Carcinogenic Risk from Ingestion[a]
Groundwater	TCE	B2: probable human carcinogen	1×10^{-7} to 7×10^{-4} [d]
	Uranium[b]	Carcinogen	1×10^{-7} to 7×10^{-5}
	Nitrate[c]	–	–
	2,4-DNT[e]	B2: probable human carcinogen	2×10^{-7} to 4×10^{-5}
	2,6-DNT[e]	B2: probable human carcinogen	2×10^{-7} to 9×10^{-5}
	2,4,6-TNT[e]	C: possible human carcinogen	2×10^{-8} to 1×10^{-5}
	1,3-DNB[c]	–	–
	NB[c]	–	–
Total receptor risk			6×10^{-7} to 9×10^{-4}

[a] Range represents minimum and maximum carcinogenic risk for the COCs from the springs or wells evaluated. TCE, 1,3-DNB, and NB were not reported in any of the 15 springs evaluated for the BRA.

[b] Uranium is assessed for its carcinogenic effects as a radionuclide.

[c] Although nitrate, 1,3-DNB, and NB are COCs, they are not classified as carcinogens.

[d] The risk presented for TCE also includes the risk from inhalation through showering.

[e] The total risk from nitroaromatic compounds is approximately 1.4×10^{-4} (sum of the three compounds). Current concentrations of nitroaromatic compounds are higher than those evaluated for the BRA, resulting in a risk of approximately 1×10^{-3}.

(current concentrations are higher and result in a risk of 1 chance in 1,000). Third, in wells near the Raffinate Pits area, uranium concentrations could result in a risk greater than 1 chance in 100,000. The EPA compares these risk results to a risk range of 1 in 1 million to 1 in 10,000 (EPA 1990). For known or suspected carcinogens, the EPA has determined that an excess lifetime cancer risk to an individual of between 1×10^{-4} and 1×10^{-6} (from 1 in 10,000 to 1 in 1 million) is an acceptable level of exposure.

The hazard indices estimated for a recreational visitor at the springs ranged from less than 0.001 to 0.2. (This range accounts for all the contaminants of potential concern as evaluated in the BRA.) For the hypothetical resident scenario, nitrate concentrations at several groundwater locations and at Burgermeister Spring would result in a hazard index greater than 1. The EPA has defined a hazard index of greater than 1 as indicating possible adverse noncarcinogenic health effects.

In conclusion, consistent with EPA guidance (EPA 1999b), the risk assessment results presented in this section serve as the basis for action, and "the response action selected in this ROD is necessary to protect public health or welfare or the environment from actual or threatened releases of contaminants from this site that may present an imminent or substantial endangerment to public health or welfare" (EPA 1999b).

7.2 ECOLOGICAL RISK ASSESSMENT

Biotic surveys of macroinvertebrates, fish, and amphibians that inhabit the Burgermeister Spring drainage indicated no evidence of adverse effects. The spring was determined to contain generally good aquatic habitat, and the species present are typical of those found in similar habitats throughout the Midwest. Under low-flow conditions, as commonly occur in the summer, the stream drainage below the spring becomes intermittent, and portions of the habitat become dry. Surveys of amphibians found a community typical of similar habitats in the Midwest. Fish tissue analyses revealed relatively low levels of contaminant bioconcentrations, all below levels of concern.

8 REMEDIAL ACTION OBJECTIVES

The remedial action objective is to restore contaminated groundwater in the shallow aquifer to its beneficial use by attaining the cleanup standards identified in Table 8.1. These standards are considered protective of human health and the environment under unlimited use and unrestricted exposure.

TABLE 8.1 Cleanup Standards for the Groundwater Operable Unit of the Weldon Spring Site

Contaminant of Concern	Cleanup Standard	Basis of Cleanup Standard
TCE	5 µg/L	Chemical-specific ARAR based on federal MCL for drinking water
Nitrate	10 mg/L	Chemical-specific ARAR based on federal MCL for drinking water
Uranium	30 µg/L[a]	Chemical-specific ARAR based on federal MCL for drinking water
2,4-DNT	0.11 µg/L	Chemical-specific ARAR based on State of Missouri water quality standards
1,3-DNB	1.0 µg/L	Chemical-specific ARAR based on State of Missouri water quality standards
NB	17 µg/L	Chemical-specific ARAR based on State of Missouri water quality standards
2,6-DNT	1.3 µg/L[b]	Risk-based concentration equivalent to 10^{-5} for a resident scenario
2,4,6-TNT	2.8 µg/L	Risk-based concentration equivalent to 10^{-6} for a resident scenario

[a] 30 µg/L converts to 20 pCi/L based on the isotopic ratios of uranium established for the Weldon Spring Site.

[b] 2,6-DNT is a known or suspected carcinogen for which there is no ARAR. The remediation goal for such contaminants is generally set at concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}, with the 10^{-6} level serving as the point of departure. On the basis of site-specific factors, including technical limitations in achieving cleanup levels greater than a 10^{-5} risk level, the remedial goal for the selected remedy is set at 1.3 µg/L, which is the 10^{-5} risk level.

9 DESCRIPTION OF REMEDIAL ALTERNATIVES

Alternatives that encompass a wide range of remediation options were evaluated in the FS (DOE and DA 1998), Supplemental FS (DOE 1999), and Supporting Evaluation (DOE 2003c) reports prepared for the GWOU. The following categories of technologies and remedial options were evaluated: (1) monitoring, (2) institutional controls (ICs), (3) natural processes, (4) in-situ containment, (5) in-situ treatment, (6) groundwater removal, (7) ex-situ treatment, and (8) disposal (primarily of solid waste generated during the implementation of other technologies). Before the three final alternatives presented in this ROD for the remedy were identified, conventional and innovative techniques for groundwater removal and treatment were considered as remedies. However, extensive field testing conducted in 1998, 2001, and 2002 demonstrated that these techniques were ineffective (DOE 2003b). First, the site hydrogeology presents significant implementability problems for pump-and-treat methods; full-scale implementation cannot be effectively done. Moreover, although ICO was locally effective in treating TCE, the site hydrogeology makes full-scale application impractical (DOE 2003b). These active treatment alternatives were thus not retained for further evaluation because they are not implementable on a large scale, perform no better than the passive alternatives at reducing the contaminants, and do nothing to limit the need for ICs. However, ICO did exhibit the potential to treat localized occurrences of TCE under favorable hydrogeological conditions. Sections 9.1 through 9.3 describe the remedy component for each alternative and the common elements and distinguishing features of each alternative.

9.1 ALTERNATIVE 1: NO FURTHER ACTION

The no further action alternative is evaluated as a baseline for comparison with the other alternatives. No action would be taken under this alternative, and ICs would not be provided. However, the existing network of monitoring wells would be abandoned, constituting a one-time cost that would be incurred.

The estimated capital cost for Alternative 1 is $520,000, and the estimated total present net-worth cost is $520,000.

9.2 ALTERNATIVE 2: LONG-TERM MONITORING WITH INSTITUTIONAL CONTROLS

This alternative consists of monitoring to verify the locations and levels of groundwater and springwater contamination, coupled with ICs to prevent exposure to contaminants.

Long-term groundwater monitoring would be conducted via an optimized network developed from the existing monitoring well network. Restrictions on groundwater use would be imposed to ensure that contaminated groundwater was not used for drinking purposes and was not impacted by other activities such as pumping. Long-term groundwater monitoring would be performed to ensure that use restrictions remained appropriate over time. Use restrictions would be imposed through ICs. These ICs would remain in place as long as contaminant concentrations exceeded drinking water levels or MCLs. As required under CERCLA, periodic reviews would be conducted no less than every 5 years to ensure that the remedy remained protective. It is expected that with time, natural processes occurring at the site (dilution and dispersion) would decrease contaminant concentrations to meet cleanup standards.

Use restrictions would apply to the area covering the impacted groundwater, including an appropriate hydraulic buffer. DOE would monitor groundwater use by establishing a long-term surveillance program. For the land DOE controls (Chemical Plant property), DOE would place a notation on the federal acquisition land records. Restrictions within this notation would accrue to succeeding owners of the land. Similar restrictions would be placed on DA property, which would be further supported with a memorandum of agreement (MOA) between DOE and DA. DOE would obtain formal agreements with the state, as applicable, for the surrounding areas (e.g., agreements with MDC, MDNR, or MoDOT). These ICs would be indefinite-term licenses, easements, or permits, as applicable.

The estimated capital cost for Alternative 2 is $450,000; the estimated annual operations and maintenance (O&M) cost is $160,000; and the estimated total present net-worth cost is $2,700,000.

9.3 ALTERNATIVE 3: MONITORED NATURAL ATTENUATION (MNA) WITH INSTITUTIONAL CONTROLS

As was the case for Alternative 2, this alternative consists of monitoring to verify the locations and levels of groundwater and springwater contamination. However, this alternative also establishes performance goals for the natural attenuation processes that are expected to occur. ICs would be used to restrict groundwater use during the period of remediation.

Long-term groundwater monitoring would be conducted via an optimized network. Dilution and dispersion are the primary natural processes acting to reduce all contaminant concentrations in groundwater at the Chemical Plant area over time. Conditions do not appear to be favorable for biological processes degrading the TCE, nitroaromatic compounds, nitrates, or uranium. The source removal actions performed according to the Chemical Plant ROD (DOE 1993) ensure that there will be no further contaminant contribution to the groundwater. As a result, groundwater contaminant concentrations are expected to decrease with time.

On the basis of predictive calculations, it is anticipated that groundwater contaminant concentrations will attenuate to levels meeting remediation goals within a reasonable timeframe. The monitoring program would be designed to verify decreases in contaminant concentrations over time consistent with this prediction. In addition, contaminants are expected to attenuate within the current area of impact and are not expected to expand to other groundwater systems. The monitoring program would also be designed to verify this expectation.

As part of Alternative 3, ICs would also be required to provide protection of human health and the environment because of the approximately 100 years that it would take to achieve cleanup standards. The ICs would be the same as those described for Alternative 2. Similarly, routine inspections for indications of groundwater use would be performed to ensure use restrictions were being adhered to.

The estimated capital cost for Alternative 3 is $540,000; the estimated annual O&M cost is $340,000; and the estimated total present net-worth cost is $5,400,000.

10 SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

The three final alternatives are compared against the nine criteria stipulated in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA 1990). The nine criteria are discussed in Sections 10.1 through 10.9. The nine evaluation criteria are categorized into three groups: threshold criteria, primary balancing criteria, and modifying criteria. The threshold category consists of the first two criteria that an alternative must meet in order to be eligible for selection. The primary balancing category consists of the next five criteria that are used to assess the relative advantages and disadvantages of each alternative. The modifying category is made up of the last two criteria.

10.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

All of the alternatives except the no further action alternative would provide adequate protection of human health and the environment because they include components for eliminating, reducing, or controlling exposure to the contaminated media. All alternatives except the no further action alternative include ICs to restrict groundwater use during the remedial action period until protective levels or ARARs are met.

10.2 COMPLIANCE WITH ARARS

The principal ARARs for the impacted groundwater are the drinking water standards known as MCLs under the Safe Drinking Water Act and Missouri water quality standards. MCLs have been established for a number of common organic and inorganic contaminants. These levels regulate the concentrations of contaminants in public drinking water supplies and are considered relevant and appropriate for groundwater aquifers that have the potential for use as drinking water. Implementation of Alternative 1 would not provide any means to determine when cleanup standards were met, nor would it provide any ICs to restrict groundwater use. Implementation of Alternative 2 would provide monitoring data so that it could be determined when cleanup standards were met and when ICs could be terminated. Under Alternative 3, attainment of ARARs would be a condition of adequate performance, and it is estimated that the ARARs would be met in a period of approximately 100 years. Alternative 3 would rely on verification of natural attenuation processes to attain ARARs.

10.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Alternative 3 would be more effective over the long term than Alternative 2 because it has specific performance standards, coupled with performance monitoring. However, the two alternatives are equally permanent.

10.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME OF CONTAMINANTS THROUGH TREATMENT

None of the three alternatives would reduce toxicity, mobility, or volume by means of treatment, since treatment is not a component of any of the three alternatives. Active treatment alternatives have been thoroughly investigated and determined to be ineffective.

10.5 SHORT-TERM EFFECTIVENESS

Alternatives 2 and 3 would be comparatively effective over the near term. Potential short-term impacts associated with monitoring, implementation of ICs, and abandonment of wells are expected to be low, with less than one case of occupational injury and no occupational fatalities expected during construction or abandonment of wells.

10.6 IMPLEMENTABILITY

From a construction standpoint, both Alternatives 2 and 3 would be implementable by using conventional methods for monitoring contamination and constructing wells. The more rigorous monitoring objectives of Alternative 3 would make its design somewhat more difficult to develop than the design for Alternative 2, but not substantially so. The establishment of ICs would present some administrative challenges, but these are considered surmountable, given that current land use and groundwater use are not affected by needed restrictions and that impacted lands are owned by the federal or state governments. In any event, the challenges would be the same for each alternative.

10.7 COST

Cost estimates for the three alternatives evaluated are presented in Table 10.1. Alternative 3 has the highest capital, annual, and total present net-worth costs of the three alternatives. As a disclaimer, the information for the cost estimates is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the AR or a relative percent difference (RPD) amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50% to –30% of the actual project cost.

10.8 STATE ACCEPTANCE

The following "State Acceptance Statement" was provided by the State of Missouri:

> "The state of Missouri does not concur on the Record of Decision because the proposed remedy — monitored natural attenuation — will not provide adequate long-term protection of human health, public welfare and the environment under the current circumstances. The state believes that the selected remedy could be effective if adequate technical design is provided. We expect primary documents to include the extent of all contamination, monitoring wells in appropriate locations, contaminant concentrations that indicate increased risk, contingencies that can be readily implemented, and a better developed long-term stewardship plan. The state must also be involved as a full partner with DOE and EPA to provide the necessary independent oversight and monitoring of the site."

10.9 COMMUNITY ACCEPTANCE

The local St. Charles community generally supported the remedy selected. However, objections were raised by members of the public in surrounding communities (e.g., St. Louis

TABLE 10.1 Summary Cost Estimate for the Final Alternatives ($)

Cost Item	Alternative 1: No Further Action	Alternative 2: Long-Term Monitoring with ICs	Alternative 3: MNA with ICs
Abandonment of wells	520,000[a]	450,000[b]	325,000[c]
Construction of new wells	0	$0	205,000[d]
Total capital cost	520,000	450,000	530,000
Analysis of samples[e]	0	3,500[f]	14,000[g]
Shipping and supplies	0	400	1,400
Labor	0	40,000	160,000
Routine well maintenance and replacement	0	30,000	50,000
Inspections, report preparation, and administration[h]	0	70,000	70,000
10% contingency[i]	0	15,000	30,000
Total annual cost	0	160,000	340,000
Present net worth of annual cost[j]	0	2,250,000	4,850,000
Total present net worth[k]	520,000	2,700,000	5,380,000

a Abandonment of 79 wells.

b Abandonment of 60 wells.

c Abandonment of 41 wells.

d Construction of 2 wells. Includes cost for establishing access roads and other associated activities.

e Samples were from 38 existing DOE wells, 2 new DOE wells, 1 Army well, and 4 springs. Samples were analyzed for all or a combination of the COCs.

f Sampling frequency is assumed to be annual.

g Sampling frequency is assumed to be semiannual, but estimate also takes into account an average of some sampling done quarterly and some done annually.

h Cost is based on one-third of similar costs shown in the LTS&MP to carry out activities primarily related to ICs. LTS&MP cost estimates are for three operable units.

i Estimate is for 10% contingency of the items shown above.

j Present net worth of annual cost was calculated by using a discount rate of 7% and assuming 100 years of monitoring.

k Total present net worth combines the present net worths of the annual cost, total capital cost, and cost for the abandonment of the wells that remain at the end of the remedial (monitoring) action period. It is assumed to be (in today's dollars) $225,000 for Alternative 2 and $330,000 for Alternative 3. The total capital cost shown was not discounted because it is assumed that it will be expended by the first year of the remedial action.

County). Additional issues that were beyond the scope of the proposed action (e.g., worker safety) were also raised by members of these communities.

11 PRINCIPAL THREAT WASTES

The NCP establishes the expectation that treatment will be used to address principal threats wherever practicable [Section 300.430(a)(1)(iii)(A)]. The principal threat concept refers to source materials. Since contaminated groundwater is not considered to be a source material, this provision does not apply to the GWOU.

12 SELECTED FINAL REMEDY

12.1 SUMMARY OF THE RATIONALE FOR THE SELECTED REMEDY

Alternative 3, MNA with ICs to limit groundwater use, provides the best balance of trade-offs among the alternatives when compared against the evaluation criteria. Alternative 3 would be more expensive than Alternative 2, primarily because of the more rigorous monitoring requirements that would be applied, but the greater cost would be offset by greater long-term effectiveness.

MNA is also considered appropriate on the basis of an examination of EPA policy and guidance. According to EPA's guidance for MNA (EPA 1999a), "MNA is appropriate as a remedial approach where it can be demonstrated capable of achieving a site's remediation objectives within a timeframe that is reasonable compared to that offered by other methods and where it meets the applicable remedy selection criteria. EPA expects that MNA will be most appropriate when used in conjunction with other remediation measures (e.g., source control, groundwater extraction), or as a follow-up to active remediation measures that have already been implemented."

Extensive field testing on active remediation technologies support the conclusion that pump-and-treat methods and in-situ treatment methods cannot be effectively deployed on a large scale and would not significantly reduce the timeframes needed to achieve the site's remediation objectives. In addition, the MNA remedy is selected as a follow-up to extensive source control remediation measures that have already been implemented. Therefore, there is no ongoing contamination of the groundwater.

The guidance presents an outline of factors that should be considered in determining whether MNA is appropriate for a particular site. The Weldon Spring groundwater condition compares favorably with all of these considerations as follows:

- *Whether the contaminants present in soil or groundwater can be effectively remediated by natural attenuation processes.* — The soil medium was remediated through excavation and disposal as part of the Chemical Plant

Operable Unit which resulted in the treatment and/or isolation of all source materials, including the principal threat wastes. Predictive modeling and long-term trend analysis support the conclusion that groundwater can be effectively remediated by natural attenuation processes.

- *Whether or not the contaminant plume is stable and the potential for the environmental conditions that influence plume stability to change over time.* — Over 20 years of environmental monitoring indicate that the contaminant plumes are stable. In this case, "stable" contaminant behavior is evidenced by continued migration and dispersion along existing flow paths and gradients within structurally controlled preferential flow paths.

- *Whether human health, drinking water supplies, other groundwaters, surface waters, ecosystems, sediments, air, or other environmental resources could be adversely impacted as a consequence of selecting MNA as the remediation option.* — The endpoint for most of the contaminated groundwater is surface discharge in springs and seeps to the north. Contaminant concentrations in the springs and seeps are sufficiently low that they result in no adverse impacts to human health or ecosystems. No evidence of expansion to other uncontaminated groundwater systems has been observed, nor is it expected, given the hydrogeoloical constraints.

- *Current and projected demand for the affected resource over the time period that the remedy will remain in effect.* — There is no projected demand for the impacted resource. Residential use of the area is unlikely, and the impacted groundwater is shallow and low-yielding, making it an improbable choice as a drinking water source. Also, a municipal water supply is readily available.

- *Whether the contamination, either by itself or as an accumulation with other nearby sources (on-site or off-site), will exert a long-term detrimental impact on available water supplies or other environmental resources.* — A municipal water supply is available for use. Contaminated groundwater at the Chemical Plant area and at the adjacent Army site is not expected to impact this municipal water supply. The ecological assessment indicates that contaminant concentrations in springwater and sediment pose little or no risk to ecological resources in the area.

- *Whether the estimated timeframe of remediation is reasonable compared to timeframes required for other more active methods (including the anticipated effectiveness of various remedial approaches on different portions of the contaminated soil and/or groundwater).* — Extensive field testing demonstrated that the available active restoration techniques could not be effectively deployed on a large scale. The hydrogeology is poorly suited for pump-and-treat or in-situ treatment methods. As a result, the use of active methods would not have a significant effect on the remediation timeframes estimated for MNA.

- *The nature and distribution of sources of contamination and whether these sources have been, or can be, adequately controlled.* — Sources of groundwater contamination have been removed via response actions implemented for the Chemical Plant Operable Unit and have been stabilized and permanently disposed of in the on-site disposal facility.

- *Whether the resulting transformation products present a greater risk, due to increased toxicity and/or mobility, than do the parent contaminants.* — Dilution and dispersion are the principal mechanisms of attenuation for both the inorganic and organic COCs in the subsurface. Biodegradation of TCE and the nitroaromatics in the subsurface is expected to be a negligible component, so transformation to more mobile or toxic constituents is not anticipated to be a concern. Geochemical conditions do not exist in the aquifer to result in reduction of nitrate. Upon discharge to surface water, rapid and complete volatilization, photodegradation, and biodegradation of the TCE and nitroaromatics is expected. Biodegradation and uptake by plants, to a limited extent, are expected to decrease nitrate levels in surface water.

- *The impact of existing and proposed active remediation measures upon the MNA component of the remedy, or the impact of remediation measures or other operations/activities (e.g., pumping wells) in close proximity to the site.* — Source control remediation under the Chemical Plant ROD involved significant disturbance of the subsurface and may have influenced contaminant concentrations in the groundwater. These influences could persist in the near term but are not expected to affect the long-term behavior of the attenuation processes.

- *Whether reliable site-specific mechanisms for implementing ICs (e.g., zoning ordinances) are available, and if an institution responsible for their monitoring and enforcement can be identified.* — The groundwater impacts are confined to federal and state land, and DOE has responsibility for implementation and enforcement of ICs. Therefore, ICs can be reliably used to limit groundwater use over the foreseeable future.

12.2 DESCRIPTION OF THE SELECTED REMEDY

The ultimate objective for the groundwater portion of this remedial action is to restore contaminated groundwater in the shallow unconfined aquifer to its beneficial use. The aquifer could potentially be used as a drinking water source, even though it is not currently being used as such. However, because of low yields and because of the availability of a municipal drinking water source, there is a low likelihood that the aquifer would ever be used for that purpose. On the basis of information obtained during the remedial investigation and a careful analysis of all remedial alternatives, MNA is expected to achieve this objective within a reasonable timeframe.

A further objective of the remedy is to restrict the use of groundwater and springwater to prevent contaminated groundwater from being used for drinking water purposes and to prevent the use of groundwater for other uses that might adversely impact the performance of the remedy (such as irrigation wells, where pumping might alter the flow path of the impacted groundwater).

This section provides the basis for the performance standards of the two main components of the selected remedy. Section 12.2.1 discusses the plans for the identification, preparation, implementation, and enforcement of the ICs needed on DOE, MDC, MoDOT, and DA property. Section 12.2.2 discusses the monitoring strategy for the groundwater COCs at the Chemical Plant area.

12.2.1 Institutional Controls

The primary purpose of the ICs that will be implemented is to restrict use of contaminated groundwater and springwater and to provide a buffer zone around contaminated groundwater and springwater to prevent human-induced impacts on groundwater flow.

For the IC component of the selected remedy, instruments or mechanisms that are appropriate with regard to land ownership and that are considered to be implementable, reliable, and enforceable were considered. The affected land area would involve federally owned and state-owned properties. To restrict groundwater and springwater use effectively, restrictions on groundwater use would be implemented within the Chemical Plant boundary that is under the jurisdictional control of DOE, while restrictions on groundwater and springwater use would be implemented at the MDC, MDNR, MoDOT, and DA properties surrounding the Chemical Plant. The IC area extends to Burgermeister Spring to the north and includes the Southeast Drainage to the south. A hydraulic buffer zone of 305 m (1,000 ft) to preclude well placement (which could alter the flow path of contaminated groundwater) would also be included in the IC area from the site to the Burgermeister Spring (see Figure 12.1). This buffer zone encompasses the preferential flow paths that connect to Burgermeister Spring. Also, groundwater flow within the IC boundary is toward the spring.

For the Chemical Plant property, a notation would be placed on the federal acquisition land records, with specified restrictions to accrue to succeeding owners of the land. Restrictions that derive from the Chemical Plant Operable Unit would prohibit the construction of a residential dwelling or facility for human occupancy. Except for giving DOE access to the groundwater for sampling and investigative purposes, the notation would prohibit access to groundwater for any use (primarily to prevent human-induced impacts on the contaminated groundwater flow). These restrictions would be for an indefinite term. If the land was conveyed to another party, notice of the restrictions or prohibitions would be placed within the conveyance document.

For properties in the area surrounding but outside the Chemical Plant (e.g., those owned by MDC, MDNR, MoDOT, or DA), indefinite-term licenses, easements, and permits, as applicable, are being considered. These instruments would specify groundwater and springwater

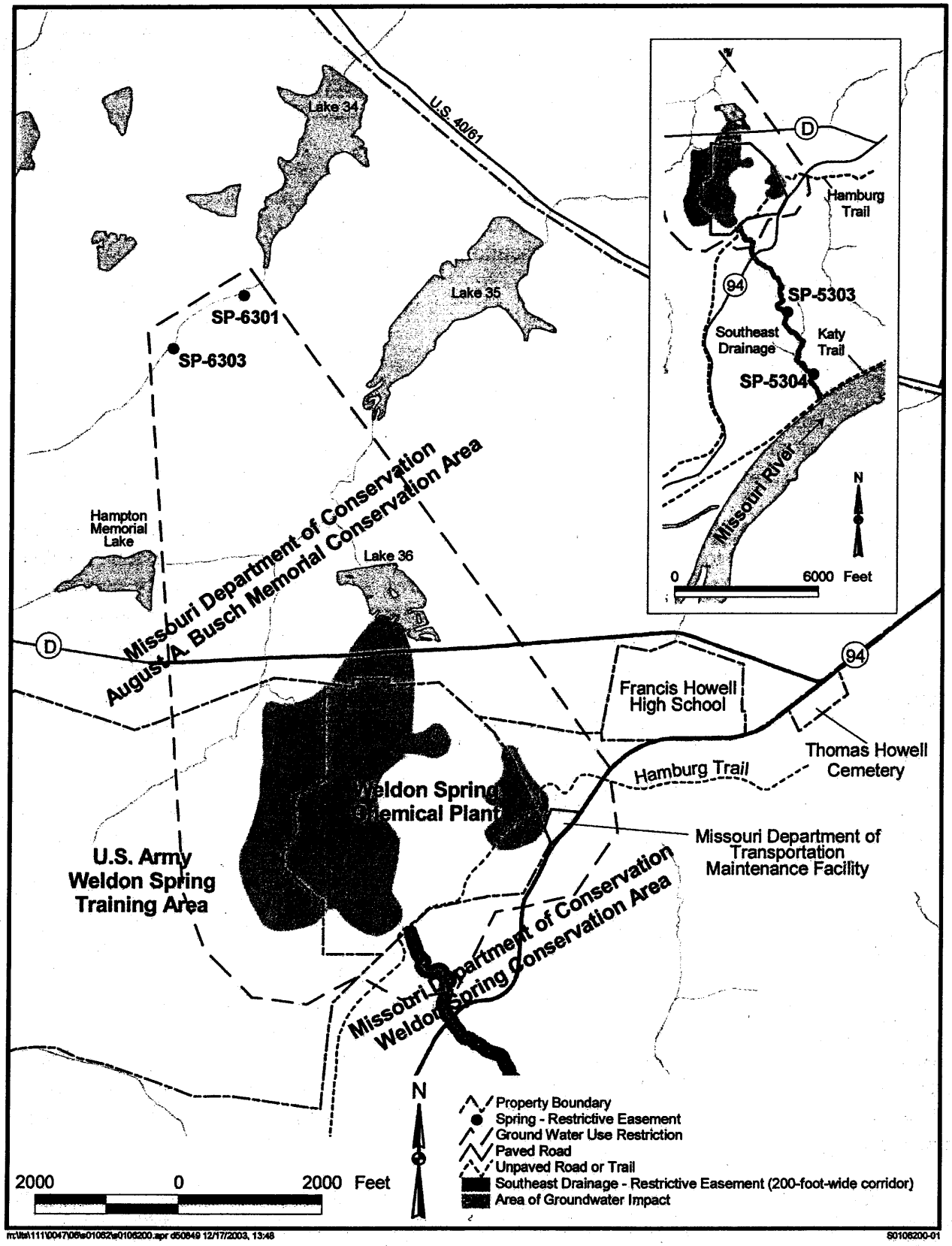


FIGURE 12.1 Locations of Institutional Controls at the Chemical Plant Area

access restrictions for the current owners or users of the land. These instruments would also give DOE continued access to monitor and analyze the groundwater for a period of time to be defined. Decisions on which ICs would be used will be made during the remedial design process.

Implementation of these long-term activities will be incorporated into the site LTS&MP (DOE 2003a). This document will serve as an Operation and Maintenance Plan under CERCLA. It will contain the monitoring and maintenance requirements from the Chemical Plant Operable Unit, Quarry Residuals Operable Unit, and GWOU RD/RA Work Plans. It will also provide for the implementation of the ICs.

12.2.2 Basis for Performance Monitoring Strategy

Contaminant Migration. The groundwater contamination originated with the Raffinate Pits and other source areas at the site of the former Chemical Plant. Downward migration of contaminated groundwater eventually intercepted zones where the horizontal permeability increases, such as the residuum layer, the weathered upper portion of the Burlington-Keokuk Limestone, or fractures and solution features oriented parallel to the limestone bedding. The contaminated water then flowed laterally through the permeable zones until it encountered vertical fractures or other pathways to the water table.

Contaminated groundwater ultimately finds its way off site through conduits and fractures. The slope of the bedrock and gradient of the water table is toward the north. The preferred groundwater flow paths occur in bedrock troughs on top of the Burlington-Keokuk limestone. Although the sources of contamination have been removed and there is no continuing contribution to groundwater contamination, these later migration processes are still ongoing.

Most off-site migration occurs laterally through solution-enlarged conduits and bedding planes. No well-defined plumes of large concentration have been detected north of the site, although site contaminants have been detected in springs in the August A. Busch Conservation Area. The recharge area for the impacted springs — Burgermeister Spring (6301) and 6303 — are the northern and western part of the site. Vertical movement of groundwater into deeper units is limited by the preferential horizontal flow component imposed by the geology and the presence of thick confining units over both the middle and deep aquifers.

The expectation is that the contamination detained in the Chemical Plant area will continue to disperse to the north along existing gradients and flow paths, and concentrations will continue to become more dilute as natural recharge from rainwater continues to act on the system. Although contaminant concentrations will decrease with time, temporary increases may be observed as a result of seasonal variability or fluctuations in the dispersion pattern. Without any sources for ongoing contamination, groundwater quality will continue to improve. The overall area of contamination will not change significantly because the pathways for dispersion, described above, are controlled by bedrock structures that are not expected to change. Significant lateral expansion of the area of impact is not expected. The IC boundary shown in Figure 12.1 includes a sufficient margin around the area of contamination to account for any uncertainty regarding the lateral extent of the area of contamination. Vertical movement of groundwater is

limited due to the overriding horizontal component and by the structural control of bedding planes and the abundance of horizontal fractures and voids found in the upper weathered part of the bedrock. Because vertical movement of groundwater is very limited, contamination is not expected to be measurable deeper than the limits already identified. Slight impacts have been observed in the upper portion of the unweathered Burlington-Keokuk limestone in the Chemical Plant area.

Performance Goals and Monitoring Strategy. Based on the above-described contaminant migration patterns, the following performance goals are identified: 1) Contaminants will attenuate at a rate sufficient to meet cleanup standards in approximately 100 years; 2) Contaminant migration will remain confined to the currently impacted groundwater system; 3) Contaminant levels at potential exposure points (i.e., springs) will not pose unacceptable risks to receptors and will decline over time.

To assure these goals are being met, a groundwater monitoring program will be developed using new and/or existing monitoring wells to evaluate contaminant behavior according to the following strategy:

- Objective 1 is to monitor the unimpacted water quality at upgradient locations in order to maintain a baseline of naturally occurring constituents from which to evaluate changes in downgradient locations. This objective will be met by using wells located upgradient of the contaminant plume.

- Objective 2 is to verify 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 concentration over time. Performance will be gauged against long-term trends. It is anticipated that some locations could show temporary upward trends due to the recent source control remediation, ongoing dispersion, seasonal fluctuations, analytical variability, or other factors. However, concentrations are not expected to exceed historical maximums.

- Objective 3 is to ensure that lateral migration remains confined to the current area of impact. Contaminants are expected to continue to disperse within known preferential flowpaths associated with bedrock lows (paleochannels) in the upper Burlington-Keokuck 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 non-existent.

- Objective 4 is to monitor locations underlying the impacted groundwater system to confirm that there is no significant vertical migration of contaminants. This will be evaluated using deeper wells screened and influenced by the unweathered zone. No significant impacts at these locations should be observed.

- Objective 5 is to monitor contaminant levels at the impacted springs which 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. Current contaminant concentrations at these locations are protective of human health and the environment under current recreational land uses. Continued improvement of the water quality in the affected springs should be observed.

- Objective 6 is to monitor for hydrologic conditions at the site over time in order to identify any changes in groundwater flow that might affect the protectiveness of the selected remedy. The static groundwater elevation of the monitoring network will be measured to establish that groundwater flow is not changing significantly and resulting in changes in contaminant migration.

As described above, the groundwater monitoring program will be designed to verify that MNA is performing as expected. The program will also serve to recognize any of the following observations that could lead to reconsideration of the remedy:

- A sustained upward trend in contaminant concentrations in groundwater or in springs and seeps, indicating that undiscovered sources may be present.

- Trends in concentrations that are inconsistent with meeting cleanup goals within a reasonable timeframe.

- Significant increases in the areal or vertical extent of contamination, resulting in new impacts to adjacent groundwater systems.

The RD/RA Work Plan will describe appropriate response activities to be undertaken in the event that any of these conditions are observed or suspected. Trigger concentrations will be assigned at appropriate locations as indicators. First tier responses will range from data verification and increased monitoring (including possible fish sampling) to reevaluation of MNA timeframes. Ultimately the remedy will be reevaluated in the event any of these observations are confirmed. Should an alternative to MNA be needed, it will be implemented in accordance with the CERCLA process for post-ROD changes. If the remedy requires immediate action, a time-critical removal will be conducted in accordance with CERCLA. Alternatives to MNA will be reevaluated and will include ICO as well as other treatment or containment technologies that may be available in the future.

This ROD also serves as an amendment to a prior IROD signed in September 2000. The IROD focused on the TCE plume and selected ICO as the appropriate remedy. The MCL for

TCE (5 µg/L) was determined to be an ARAR and identified as the cleanup goal. The other contaminants were not addressed. Pilot-phase ICO was performed in April and May 2002. The treatment did not perform adequately under actual field conditions and was not implemented in full scale. The treatment method that will be used to address cleanup of TCE was reevaluated as part of the evaluation process for this ROD. The selected remedy for TCE in this ROD constitutes a fundamental change to the remedy selected in the IROD.

The specific monitoring locations and the specific trigger concentrations will be defined in the RD/RA Work Plan that implements this ROD. Figure 12.2 depicts a schematic of the concept of the approach for establishing monitoring locations to meet the stated objectives.

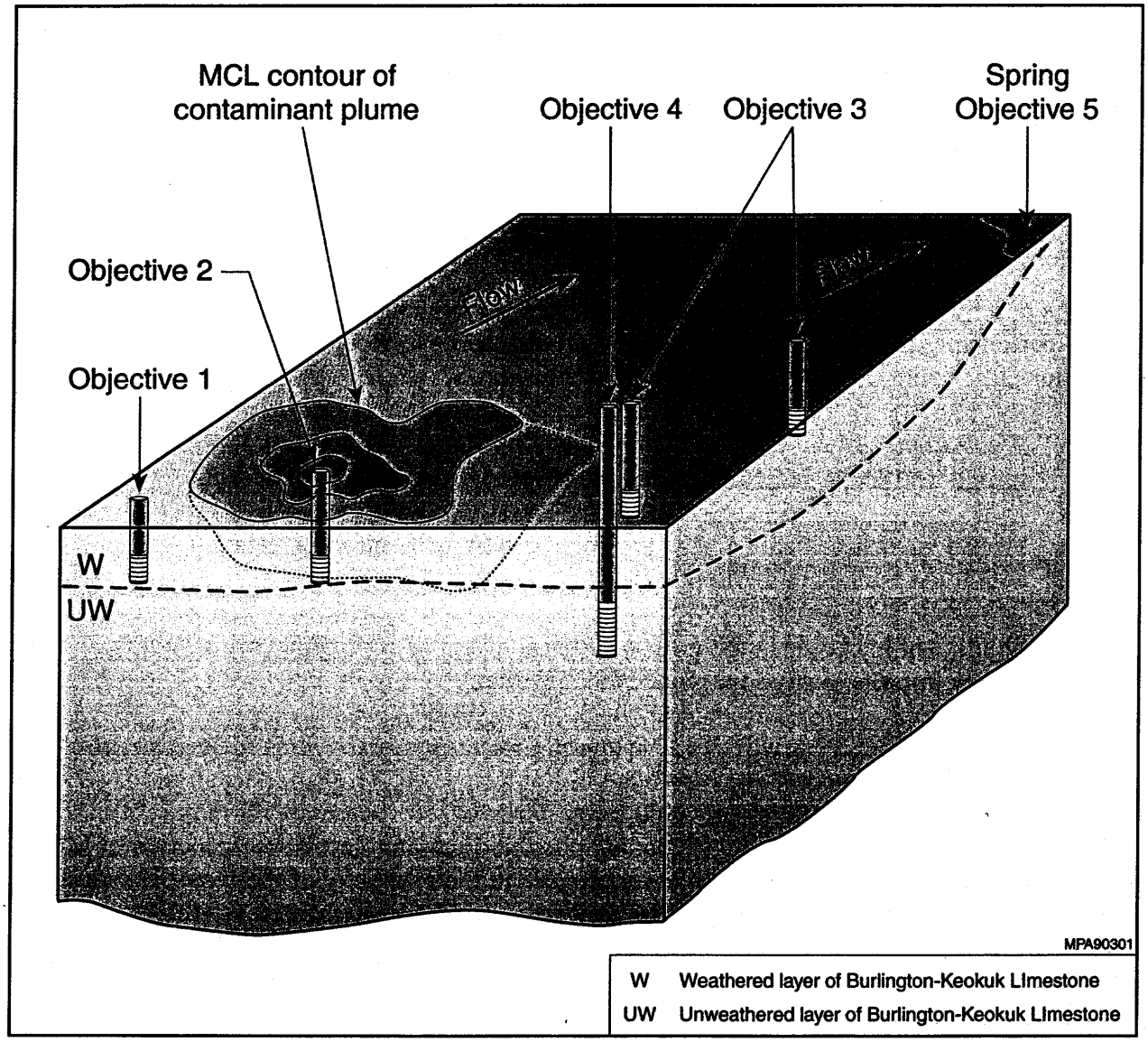


FIGURE 12.2 Schematic of the MNA Network

13 STATUTORY DETERMINATIONS FOR SECTION 121 OF CERCLA

In accordance with the statutory requirements of Section 121 of CERCLA, as amended, the remedial actions selected shall:

- Be protective of human health and the environment,
- Comply with ARARs,
- Be cost effective,
- Utilize permanent solutions and alternative treatment technologies to the maximum extent practicable,
- Prefer treatment as a principal element, and
- Undergo a review no less than every five years.

13.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The selected remedy will be protective of human health and the environment because any use of the contaminated groundwater and springwater will be restricted until contaminant levels have decreased to the cleanup standards. These restrictions will also prevent the flow patterns of the contaminated groundwater from being affected during the natural attenuation period of the selected remedy.

13.2 COMPLIANCE WITH ARARS

As required by Section 121(d)(4) of CERCLA, the selected remedy will comply with all chemical-specific ARARs as presented in Table 8.1 and action-specific ARARs as discussed here. Action-specific ARARs are standards that restrict or control specific remedial activities related to the management of hazardous substances or pollutants for a variety of media. These requirements are triggered by a particular activity, not by specific chemicals or the location of the activity. Several action-specific ARARs may exist for any specific action. These action-specific ARARs do not in themselves determine the appropriate remedial alternative; instead, they indicate performance levels to be achieved for the activities performed under the selected remedy. On-site actions must comply with all substantive provisions of an ARAR but do not need to comply with related administrative and procedural requirements (e.g., filing reports or obtaining a permit). The term "on-site" includes the areal extent of contamination and of all suitable areas in very close proximity to the contamination that is necessary to implement the response action. No permit applications will be necessary for any on-site activities. The selected remedy will comply with all pertinent action-specific ARARs. That is, Missouri requirements for well construction (10 CSR 23-4.050; CSR is *Code of State Regulation*) will be an ARAR for any newly installed wells or for the plugging of wells under the selected remedy.

13.3 COST EFFECTIVENESS

The selected alternative is considered cost effective because it provides a high degree of effectiveness and permanence at a reasonable cost. The cost is only marginally higher than that of the other available alternative, yet it provides significant improvements in terms of protectiveness over the remediation timeframe.

13.4 UTILIZATION OF PERMANENT SOLUTIONS AND ALTERNATIVE TREATMENT TECHNOLOGIES TO THE MAXIMUM EXTENT PRACTICABLE

Dilution and dispersion processes will decrease contaminant levels over time to levels that would allow unrestricted use and constitute a permanent solution. The selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practicable manner at the site. Available and applicable treatment technologies (including pump-and-treat and ICO) have been evaluated and either determined to be not effective (pump-and-treat) or effective for localized contamination only (ICO for TCE).

13.5 PREFERENCE FOR TREATMENT AS A PRINCIPAL ELEMENT

The selected remedy does not include treatment as a principal element because the available treatment options were found to be generally ineffective. This was verified through field testing of pump and treat techniques and an in-situ treatment technology. It should be noted that some source materials, including the principal threat wastes, were treated as part of the source control remediation under the Chemical Plant ROD.

13.6 FIVE-YEAR REVIEWS

This remedy will ultimately result in hazardous substances, pollutants, or contaminants remaining on the site at levels that allow for unlimited use and unrestricted exposure, but it will take more than 5 years to achieve these conditions (i.e., meet remedial action objectives and cleanup levels). A policy review will be conducted in conjunction with the statutory review required for other operable units for the Weldon Spring site.

13.7 SIGNIFICANT CHANGES

The selected remedy is the same as the preferred alternative in the PP presented to the public for review and comment, with one change. After further consultation with the EPA and consideration of the appropriate manner in which to address the possibility of failure of the natural attenuation processes to achieve the cleanup goals, ICO is not specifically identified as a contingency action in the selected remedy. In the PP, ICO was identified as a contingency action that might be implemented under appropriate circumstances in the event natural attenuation processes did not achieve the anticipated reduction in contaminant levels over time. During the

pilot-scale testing, ICO treatment technology had limited success in treating TCE in a localized area, but it was not considered effective either for treatment of TCE on a large scale or for treatment of other contaminants in the groundwater. Since the actual conditions that might be encountered as part of an MNA remedy failure cannot be reasonably predicted at this time, an ICO treatment system cannot be designed now, ready to install in the event of a remedy failure, as ordinarily would be the case for a contingent remedy. Furthermore, new technologies could be developed in the future that might more effectively address TCE and other contaminants, such that if conditions were encountered leading to consideration of active remediation technologies, ICO might not be the best choice.

The expectations for remedy performance and the conditions constituting remedy failure have not changed. However, the selected remedy now indicates that if the MNA performance leads to remedy reconsideration, alternative remedies will be evaluated, and a remedy will be selected and implemented in accordance with the CERCLA process. On the basis of the current state of knowledge, ICO would be one of the technologies that would be evaluated, but not necessarily the only technology. This change opens the evaluation process to other, potentially better, alternative remedies, which may emerge in the future. In anticipation of concerns that not having selected ICO as a contingency remedy may delay response in the future, DOE points out that the CERCLA process calls for consideration of the urgency of the need to respond, and it specifically provides for time-critical removal actions if urgent response action is required.

14 REFERENCES

(Documents included in this list are only those cited in this ROD and are listed only to facilitate location of the information discussed in this ROD. The documents listed in this section are part of the AR for this GWOU.)

Basko, R., 2003, e-mail from Basko (Missouri Department of Health and Senior Services, St. Louis, MO) to R. Cato (Weldon Spring Site Remedial Action Project, St. Charles, MO), May 22.

DOE, 1992, *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site,* DOE/EIS-0185D (DOE/OR/21548-074, Vol. I), prepared by MK-Ferguson Company and Jacobs Engineering Group, Inc., Weldon Spring, MO, for U.S. Department of Energy, Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, Nov.

DOE, 1993, *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site,* DOE/OR/21548-376, prepared by U.S. Department of Energy, Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, Sept.

DOE, 1999, *Supplemental Feasibility Study for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri,* DOE/OR/21548-783, prepared by Argonne National Laboratory, Argonne, IL, for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, June.

DOE, 2000, *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, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN, Sept.

DOE, 2003a, *Long-Term Surveillance and Maintenance Plan for the Weldon Spring, Missouri, Site,* GJO-2002-342-TAC, Draft, U.S. Department of Energy, Grand Junction Office, Grand Junction, CO, May.

DOE, 2003b, *Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri,* DOE/GJ/79491-932, prepared by Argonne National Laboratory, Argonne, IL, for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, Aug.

DOE, 2003c, *Supporting Evaluation for the Proposed Plan for Final Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri,* DOE/GJ/79491-934, prepared by Argonne National Laboratory, Argonne, IL, for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, Aug.

DOE and DA, 1997a, *Baseline Risk Assessment for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri*, DOE/OR/21548-568, prepared by Argonne National Laboratory, Argonne, IL, for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, and U.S. Department of the Army, Corps of Engineers, Kansas City District, Kansas City, MO, July.

DOE and DA, 1997b, *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant area and the Ordnance Works Area, Weldon Spring Site, Weldon Spring, Missouri*, DOE/OR/21548-571, prepared by MK-Ferguson Company and Jacobs Engineering Group, Inc., Weldon Spring, MO, and Argonne National Laboratory, Argonne, IL, for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, and U.S. Department of the Army, Corps of Engineers, Kansas City District, Kansas City, MO, July. (see p. 5-10 for TCE and p. D-9 for 2,6-DNT)

DOE and DA, 1998, *Feasibility Study for Remedial Action for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri,* DOE/OR/21548-569, prepared by Argonne National Laboratory, Argonne, IL, for U.S. Department Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, and U.S. Department of the Army, Corps of Engineers, Kansas City District, Kansas City, MO, Dec.

EPA, 1986, *Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy,* Final Draft, U.S. Environmental Protection Agency, Washington, DC.

EPA, 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A),* EPA/5401/1-89/002, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC.

EPA, 1990, "National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule (40 CFR Part 300)," *Federal Register* 55(46):8666-8865, U.S. Environmental Protection Agency, March 8.

EPA, 1992a, *Dermal Exposure Assessment: Principles and Applications*, EPA/600/8-91-011B, Interim Report, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Jan.

EPA, 1992b, *First Amended Federal Facilities Agreement*, Docket No. CERCLA-VII-85-F-0057, prepared by U.S. Environmental Protection Agency for U.S. Department of Energy Weldon Spring Site, St. Charles, MO, Jan.

EPA, 1995a, *Health Effects Assessment Summary Tables, FY-1995 Annual*, EPA/540/R-95-036, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, May.

EPA, 1995b, *Exposure Factors Handbook*, EPA/600/P-95/002 (PB95-252532), U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC, Jan.

EPA, 1996, *Risk Assessment Issue Paper for: Carcinogenicity Information for Trichloroethylene (TCE) (CASRN 79-01-6),* by U.S. Environmental Protection Agency, Attachment III to a facsimile transmittal from the Superfund Technical Support Center (Cincinnati, OH) to H. Hartmann (Argonne National Laboratory, Argonne, IL), Oct. 17.

EPA, 1997, *Integrated Risk Information System,* database, U.S. Environmental Protection Agency, accessed Feb. 1997.

EPA, 1999a, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites,* OSWER Directive No. 9200.4-17P, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Apr. 21.

EPA, 1999b, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents,* EPA 540-R-98-031, OSWER Directive No. 9200.1-23P, PB98-963241, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, July.

Kleeschulte, M.J., and J.L. Imes, 1994, *Geohydrology, Water Quality, and Simulation of Ground-Water Flow at the Weldon Spring Chemical Plant and Vicinity, St. Charles County, Missouri, 1987–90,* U.S. Geological Survey Open-File Report 93-648, prepared in cooperation with the U.S. Department of Energy, Rolla, Mo.

MK-Ferguson Company and Jacobs Engineering Group, 1998, *Completion Report for the Pilot Pumping Test for the Groundwater Operable Unit at the Weldon Spring Site,* DOE/OR/21548-757, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, St. Charles, MO, Oct.

MK-Ferguson and Jacobs Engineering Group, 2001, *Weldon Spring Site Environmental Report for Calendar Year 2000, Rev. 0,* DOE/OR/21548-886, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, MO, July.

Vogel, J., 2003, e-mail from Vogel (Missouri Department of Conservation, St. Charles, MO) to P. Thompson (U.S. Department of Energy, Weldon Spring Site Remedial Action Project, St. Charles, MO), Apr. 3.