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REMEDIATION VENTURE OFFICE

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LONG-TERM MONITORING PLAN FOR GROUNDWATER AND SURFACE WATER

Final

March 2010

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Final

March 2010

APPROVALS:

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Rocky Mountain Arsenal **Revision 0**
Long-Term Monitoring Plan for Groundwater and Surface Water **March 2010**

APPROVALS

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ROCKY MOUNTAIN ARSENAL

Long-Term Monitoring Plan for Groundwater and Surface Water
FINAL

March 2010

Prepared by:

Tetra Tech EC, Inc.
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Prepared for:
Rocky Mountain Arsenal Remediation Venture Office
Department of the Army
Shell Oil Company
U.S. Fish and Wildlife Service

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APPENDICES

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ACRONYMS

ARAR	Applicable or Relevant and Appropriate Requirement
Army	United States Army
BANS	Basin A Neck System
BCHPD	Bicycloheptadiene
BRES	Bedrock Ridge Extraction System
CBSG	Colorado Basic Standard for Groundwater
CBSMSW	Colorado Basic Standards and Methodologies for Surface Water
CCR	Construction Completion Report
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFS	Confined Flow System
cm/sec	Centimeters Per Second
COC	Contaminant of Concern
CRL	Certified Reporting Limit
CSRG	Containment System Remediation Goal
CQAP	Chemical Quality Assurance Plan
CWTP	CERCLA Wastewater Treatment Plant
DBCP	Dibromochloropropane
DCN	Design Change Notice
DCPD	Dicyclopentadiene
DIMP	Diisopropylmethyl phosphonate
DNAPL	Dense Non-Aqueous Phase Liquid
DSR	Data Summary Report
ELF	Enhanced Hazardous Waste Landfill
EPA	United States Environmental Protection Agency
ESD	Explanation of Significant Difference
FCS	First Creek System
FS	Feasibility Study
ft	Foot or Feet
ft/day	Feet Per Day
FY	Fiscal Year
FWENC	Foster Wheeler Environmental Corporation
FYR	Five-Year Site Review
FYRR	Five-Year Review Report
FYSR	Five-Year Summary Report

GAC	Granular Activated Carbon
gpm	Gallons Per Minute
HHRC	Human Health Risk Characterization
HI	Hazard Index
HLA	Harding Lawson Associates
HRC	Hydrogen Release Compound
HWL	Hazardous Waste Landfill
IC	Institutional Control
ICS	Irondale Containment System
IRA	Interim Response Action
IRMAICP	Interim Rocky Mountain Arsenal Institutional Control Plan
LNAPL	Light Non-Aqueous Phase Liquid
LTMP	Long-Term Monitoring Plan
LWTS	Landfill Wastewater Treatment System
µg/L	Micrograms per Liter
mg/L	Milligrams per Liter
MCL	Maximum Contaminant Level
MCR	Monitoring Completion Report
MRL	Method Reporting Limit
NBCS	North Boundary Containment System
NBE	North Boundary Enhancement
NCP	National Contingency Plan
NDMA	n-Nitrosodimethylamine
NPS	Northern Pathway System
NWBCS	Northwest Boundary Containment System
OAR	Operational Assessment Report
OCP	Organochlorine Pesticides
O&F	Operational and Functional
O&M	Operations and Maintenance
OGITS	Off-Post Groundwater Intercept and Treatment System
OU	Operable Unit
PMRMA	Program Manager Rocky Mountain Arsenal
PPLV	Preliminary Pollutant Limit Value
PQL	Practical Quantitation Limit

QC	Quality Control
QAP	Quality Assurance Program
QAPP	Quality Assurance Project Plan
Railyard	Railyard Classification Yard
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
Refuge Act	National Wildlife Refuge in the Rocky Mountain Arsenal National Wildlife Refuge Act
RI	Remedial Investigation
RMA	Rocky Mountain Arsenal
ROD	Record of Decision
RS/S	Remediation Scope and Schedule
RVO	Remediation Venture Office
RYCS	Railyard Containment System
SAP	Sampling and Analysis Plan
SAPC	Steering and Policy Committee
SARA	Superfund Amendments and Reauthorization Act
Shell	Shell Oil Company
STF	South Tank Farm
TBC	To Be Considered
TCE	Trichloroethylene
TCHD	Tri-County Health Department
TOC	Top-of-Casing
TtEC	Tetra Tech EC, Inc.
TtEMI	Tetra Tech EM, Inc.
TtFW	Tetra Tech FW, Inc.
UFS	Unconfined Flow System
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
UV	Ultraviolet
UXO	Unexploded Ordnance
WRCP	Well Retention and Closure Program

EXECUTIVE SUMMARY

This Long-Term Monitoring Plan (LTMP) for Groundwater and Surface Water supersedes the 1999 LTMP. The long-term monitoring programs were revised to reflect the current remedy status as well as future remedy and post-remedy monitoring. This document incorporates agreements that were reached with the Regulatory Agencies during the resolution process for the 2005 Five-Year Review Report (FYRR). The revised LTMP relies on a process-oriented approach where objectives, criteria, and decision processes are used to make program-related decisions.

A key component of the LTMP revisions is the development of performance criteria that were established to meet the specific objectives of each of the containment and mass removal systems. This resulted in the development of a performance monitoring category that incorporates the 1999 conformance category. Another important revision affects the shut-off monitoring and shut-off criteria; a consultative process between the Remediation Venture Office (RVO) and the Regulatory Agencies, consisting of the United States Environmental Protection Agency, Colorado Department of Public Health and Environment, and Tri-County Health Department, will be employed for decisions related to the shut-off criteria and monitoring programs. The revised system-related monitoring categories, with changes shown in italics, are as follows:

- *Compliance Monitoring*: Effluent water quality monitoring conducted to confirm that Containment System Remediation Goals (CSRGs) are met by on-post and off-post treatment systems. Compliance is based on running averages for the last four quarters instead of the current single samples.
- *Performance Monitoring*: Water level and water quality monitoring performed to measure performance against specific criteria. *This new category includes the previous conformance monitoring category.*
- *Pre-Shut-Off Monitoring*: Monitoring or operational activities to confirm that shut-off should proceed and that the shut-off monitoring program should be initiated. A program will be designed for each specific system.
- *Shut-Off Monitoring*: Water quality monitoring at or near systems that have met shut-off criteria for a time period of at least 5 years. *This monitoring is to be conducted in accordance with a revised shut-off approach, with sampling frequencies reduced from the current quarterly sampling for 5 years to quarterly for the first and last years and annual in intervening years.*
- *Post-Shut-Off Monitoring*: Monitoring to track groundwater levels, flow directions, and water quality in the area after successful completion of the shut-off monitoring program and termination of system operation.
- *Operational Monitoring*: Monitoring of containment system extraction wells and monitoring wells located near the systems to optimize system performance and ensure that Remedial Action Objectives are met. *Monitoring to evaluate whether individual extraction wells can be shut off or will remain shut-off is conducted under this program instead of the current 5-year shut-off monitoring.*

The site-wide monitoring program categories were also re-evaluated and the revised categories are shown below with changes to the definition or monitoring program included in italics.

- Water Level Tracking: On-post water level monitoring used to track the effects of the soil remedy to groundwater in the *On-Post Operable Unit.*
- Water Quality Tracking: On-post water quality monitoring of indicator analytes is conducted to track contaminant migration in and downgradient of source areas within the identified plumes.
- Confined Flow System (CFS)Monitoring: Monitoring as required by the On-Post Record of Decision (ROD) requirement to monitor water quality in the confined aquifer in three areas—Basin A, South Plants, and Basin F.
- Exceedance Monitoring: Long-term water quality monitoring of off-post groundwater to assess contaminant concentration reduction and remedy performance and to create groundwater CSRG exceedance area maps to support well permit institutional controls. *(Number of analytes reduced per routine CSRG analyte list.)*
- Off-Post Water Level Monitoring: Water level monitoring off post conducted in support of the exceedance monitoring to assess flow paths and contaminant migration in the exceedance areas. *(Separated from "Water Level Tracking" because it serves a different purpose.)*
- Surface Water Monitoring: Off-post and on-post surface water monitoring to assess changes in surface water quality related to the RMA remedy. *ROD-related surface water monitoring was added to LTMP. Surface water monitoring will continue off post, but will be discontinued on post based on completion of the soil remedy.*

The re-evaluation of the monitoring programs resulted in the following changes to monitoring networks, frequencies, and analytes:

- Monitoring Networks
  i. An increase in the number of water level tracking wells from 361 to 388.
  ii. An increase in the number of water quality tracking wells from 40 to 59.
  iii. Changing the approach to system monitoring from 16 downgradient conformance wells to 98 upgradient, cross-gradient, and downgradient performance water quality wells.
- Monitoring Frequencies
  i. Water quality tracking frequency consists of once in 5 years for source wells and twice in 5 years for others.
  ii. Eight water quality tracking wells changed from twice to once in 5 years.
  iii. Shut-off monitoring frequency for containment systems changed from 5 years of quarterly monitoring to a minimum of 5 years of monitoring with quarterly monitoring the first and last year and annual monitoring in the intervening years.

- Analytes
  i. The CSRG analytes to be used for routine monitoring for the boundary and off-post systems were evaluated based on a set of criteria developed for influent, extraction well, and upgradient well data and the respective analyte lists and were revised accordingly.
  ii. The monitoring programs that are affected by changes in the routine CSRG analyte list include:
     - Compliance monitoring
     - Performance monitoring
     - Exceedance monitoring
     - Operational monitoring
  iii. CFS indicator analytes were evaluated and new analyte lists specific to the respective monitoring areas, Basin A, Basin F, and South Plants, were developed.

During the 2005 FYRR resolution process and LTMP revision it became apparent that changes to the RODs would be necessary to address concerns and facilitate review and decision processes. A ROD Change Document that addresses the three water-related issues listed below is being issued to document the ROD changes associated with LTMP implementation.

- *Shut-Off Criteria*: New shut-off criteria are designed to apply to shut-off of extraction systems or discrete portions of extraction systems rather than individual extraction wells. The extraction well monitoring ROD requirement will be removed. The frequency of shut-off monitoring will also be changed as described in Section 4.9. System shut-off will be preceded by a pre-shut-off monitoring phase and followed by a post-shut-off monitoring phase.

- *Practical Quantitation Limit (PQL)*: A new standardized and more specific approach based on 2008 Colorado Department of Health and Environment PQL guidance and 40 Code of Federal Regulations 136 Appendix B will be used to establish PQLs for the compounds that have method reporting limits (MRLs) that are greater than the CSRGs.

- *Fluoride CSRG*: A change in the fluoride CSRG for the Off-post Groundwater Intercept and Treatment System and North Boundary Containment System from the ROD agricultural Colorado Basic Standard for Groundwater (CBSG) of 2 milligrams per liter (mg/L) to the human health CBSG of 4.0 mg/L.

1.0 INTRODUCTION

This Long-Term Monitoring Plan (LTMP) describes how the groundwater and surface water monitoring requirements specified in the On-Post and Off-Post Records of Decision (RODs) for the Rocky Mountain Arsenal (RMA) (FWENC 1996, HLA 1995) will be implemented. The LTMP is governed by both the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (as amended by the Superfund Amendments and Reauthorization Act [SARA]), the National Contingency Plan (NCP) and associated guidance and the Colorado Hazardous Waste Act and conforming regulations. The primary objective of the LTMP groundwater monitoring is to collect and evaluate water level and water quality data to assess:

- Effectiveness of the ROD remedies
- Performance and effectiveness of on-post and off-post groundwater treatment systems

This LTMP updates and replaces the 1999 LTMP (FWENC 1999) and the Water Years 2003, 2004, 2005, 2006, and 2007 Monitoring Well Networks Update Reports (FWENC 2003b, TtFW 2004b, PMRMA 2006, PMRMA 2008a, PMRMA 2008b).

Other groundwater monitoring programs at RMA are not addressed in the LTMP. Specifically, the groundwater monitoring associated with the Hazardous Waste Landfill (HWL), Enhanced Hazardous Waste Landfill (ELF), Basin F, and the Landfill Wastewater Treatment System (LWTS) Resource Conservation and Recovery Act (RCRA) closure and post-closure activities is addressed in separate plans. Though not part of the LTMP, these other monitoring programs are governed by both CERCLA as amended by SARA, the NCP, and associated guidance and the Colorado Hazardous Waste Act and conforming regulations. For additional detail see Section 5.6.

It should also be noted that several portions of the RMA remedy have specific groundwater monitoring requirements that are not subject to change through the LTMP processes, for example, analytes, frequency, and monitoring network. Any changes to these project specific monitoring programs must be formally detailed in a Decision Document approved by the Regulatory Agencies. Once a Decision Document is final, changes to the monitoring network will be tracked through the LTMP.

1.1 LTMP Revision

This LTMP documents changes made to the site-wide monitoring program based on current remedy status, ROD revisions since 1999, and follow-up actions recommended in the 2005 Five-Year Review Report (FYRR). Specifically, the revised LTMP:

- Develops the performance criteria based on recommendations in the 2005 FYRR (PMRMA 2007a) and establishes the decision processes for system performance and system shut-off for all on-post containment, mass removal, and treatment systems.
- Incorporates specific objectives and performance criteria for the Off-Post Groundwater Intercept and Treatment System (OGITS) that are consistent with the system's mass removal purpose.

- Develops revised shut-off criteria and shut-off monitoring requirements for individual system applications for all on-post containment and mass removal systems and the off-post mass removal system.
- Modifies monitoring categories associated with the containment and mass removal systems with regard to well networks, monitoring frequencies, and statistical method applications.
- Revises, as appropriate, the site-wide monitoring categories identified in the 1999 LTMP and amended in the 2003 Well Retention and Closure Program (WRCP) (FWENC 2003a).
- Develops specific performance criteria to evaluate the site-wide monitoring categories; revises well networks, indicator analyte lists, and monitoring frequencies; and identifies statistical method applications to demonstrate achievement of the respective criteria.
- Incorporates a consultative process to address and resolve groundwater and surface water monitoring program issues.
- Identifies performance triggers for consultation for each extraction/treatment system and monitoring category and describes the consultation process for each.
- Revises the site-wide monitoring well networks based on historical data and performance criteria.

1.2 Site History

The United States Army (Army) established RMA in 1942 to produce chemical warfare agents and incendiary munitions used in World War II. Following the war and through the early 1980s, the Army continued to use these facilities. Beginning in 1946, some RMA facilities were leased to private companies to manufacture industrial and agricultural chemicals. Shell Oil Company (Shell), the principal lessee, manufactured primarily pesticides at RMA from 1952 to 1982. Common industrial and waste disposal practices during those years resulted in significant levels of contamination. The principal contaminants are organochlorine pesticides (OCPs), heavy metals, agent-degradation products and manufacturing by-products, and chlorinated and aromatic solvents.

The Remedial Investigation (RI) and subsequent investigations identified chemicals at more than 180 sites contaminating soil, ditches, stream and lakebed sediments, sewers, groundwater, surface water, biota, and structures. Unexploded ordnance (UXO) has been identified at several locations on site. Contaminated areas identified in the RI included approximately 3,000 acres of soil, 15 groundwater plumes, and 798 structures. Sites that posed potential immediate risks to human health and the environment were addressed through Interim Response Actions (IRAs), which were followed by the actions required by the On-Post ROD (FWENC 1996). The overall remedy required by the On-Post ROD includes:

- Interception and treatment of contaminated groundwater at three existing boundary treatment plants and existing on-post groundwater IRA systems.

- Construction of new RCRA- and Toxic Substances Control Act-compliance landfills on post. The on-post facilities include the HWL and a triple-lined landfill, referred to as the ELF.
- Demolition of structures with no designated future use and disposal of the debris in either the new, on-post HWL or the Basin A consolidation area, depending upon the degree of contamination.
- The contaminated soil at RMA is addressed primarily through containment in the on-post HWL (or ELF) or under covers. Areas that have caps or covers require long-term maintenance and will be retained by the Army. These areas will not become part of the wildlife refuge.
- The Basin A disposal area is used for consolidation of biota risk soil and structural debris from other RMA contamination areas and is covered with a RCRA-equivalent cover including a biota barrier.

Groundwater contamination migrated off post prior to the implementation of groundwater pump and treat systems, resulting in the necessity for the Off-Post Operable Unit (OU). The Off-Post remedy includes extraction and treatment of the contaminated groundwater plumes, closure of poorly constructed wells that could be acting as migration pathways, and revegetation of 160 acres of soil. The Off-Post ROD also required institutional controls (ICs) to prevent the use of groundwater exceeding remediation goals.

The area is ecologically unique and was designated as a future National Wildlife Refuge in the Rocky Mountain Arsenal National Wildlife Refuge Act (Refuge Act) of 1992 (PL 102-402 1992). As components of the soil remedy are completed, jurisdiction of surface media will be administratively transferred to the United States Fish and Wildlife Service (USFWS) or other parties purchasing the land, except for the property and facilities continuing to be used for response actions. In addition, the portions of the On-Post OU transferred to other parties will be subject to restrictions prohibiting residential or industrial use, use of water on the site as a source of potable water, hunting and fishing for consumptive use, and agricultural use. Current and future land use of the Off-Post OU has not been restricted, although groundwater use has been restricted through a series of ICs identified in the Off-Post ROD.

The Rocky Mountain Arsenal National Wildlife Refuge was officially established on April 21, 2004. As of September 1, 2006, nearly 80 percent of RMA had been deleted from the National Priorities List and more than 12,000 acres transferred to the USFWS. The areas that have been transferred are shown on Figure 1.2-1.

1.3 Remedial Action Objectives for Groundwater

The groundwater monitoring data collected under this LTMP are evaluated to determine the effectiveness of the remedial actions in achieving the ROD Remedial Action Objectives (RAOs). The RAOs for on-post and off-post groundwater are described below.

1.3.1 On-Post Groundwater

The following RAOs for on-post groundwater, designed to comply with the On-Post ROD (FWENC 1996) requirement for protection of human health and the environment, provide the objectives for capture and treatment of contaminated groundwater:

- Ensure that the boundary containment and treatment systems protect groundwater quality off post by treating groundwater flowing off RMA to the specific remediation goals identified for each of the boundary systems.
- Develop on-post groundwater extraction/treatment alternatives that establish hydrologic conditions consistent with the preferred soil alternatives and also provide long-term improvement in the performance of the boundary control systems.

1.3.2 Off-Post Groundwater

The following RAOs for off-post groundwater were designed to comply with the Off-Post ROD (HLA 1995) requirement for protection of human health and the environment and provide the objectives for capture and treatment of contaminated groundwater:

- **Human Health**
  - Reduce the Contaminant of Concern (COC) concentrations in groundwater and/or prevent exposure associated with groundwater within the Off-Post OU to meet groundwater remediation goals and to attain the National Contingency Plan-prescribed cumulative risk range.
  - Prevent domestic use of, ingestion of crops irrigated with, and ingestion of livestock watered with groundwater containing COCs at concentration levels in excess of groundwater remediation goals.
- **Environmental Protection**
  - Prevent acute or chronic toxicity to biota from groundwater within the Off-Post OU by containing COC concentrations in excess of groundwater remediation goals.

1.3.3 Remedial Action Objectives for Surface Water

The On-Post and Off-Post RODs both include surface water monitoring requirements. The On-Post ROD (FWENC 1996) identified the following surface water monitoring requirements:

- The Army will continue to conduct air, groundwater, and surface water monitoring programs at RMA, and will continue to fund USFWS to conduct on-post wildlife monitoring programs. Samples will be collected periodically to assess the effectiveness of the remedy for protection of human health and the environment.
- Surface water will be monitored and managed in a manner consistent with the selected remedy.

The On-Post ROD also identified the following RAOs for ecological and human health protection:

- Ensure that biota are not exposed to biota COCs in surface water in concentrations capable of causing acute or chronic toxicity.

- Ensure that biota are not exposed to COCs in surface water, due to migration from soil or sediment, at concentrations capable of causing acute or chronic toxicity via direct exposure or bioaccumulation.
- Prevent migration of COCs from soil or sediment that may result in off-post groundwater, surface water, or windblown particulate contamination in excess of off-post remediation goals.

The Off-Post ROD (HLA 1995) identified the following surface water monitoring requirements:

- Groundwater and surface water monitoring: Samples will be collected periodically from groundwater monitoring wells and surface water locations throughout the Off-Post Study Area and analyzed to assess changes in groundwater and surface water quality during and after remediation.

The Off-Post ROD description of the selected alternative includes further clarification of the purpose and objectives of the off-post surface water monitoring program:

- In addition, the preferred alternative includes long-term monitoring of off-post groundwater and surface water to assess contaminant concentration reduction and remedy performance. Groundwater monitoring will continue utilizing both monitoring wells and private drinking water wells. Selected surface water monitoring locations will be included to evaluate the effect of groundwater treatment on surface water quality. Monitoring will continue after the system shut-off to assure continued compliance with containment system remediation goals.

1.4 Plan Organization

The LTMP is divided into 13 text sections as follows:

- Section 1—Introduction
- Section 2—Hydrogeologic Setting and Remediation Systems
- Section 3—Long-Term Monitoring Approach
- Section 4—System-Related Monitoring Programs
- Section 5—Project-Specific Monitoring Programs
- Section 6—Site-Wide Monitoring Programs
- Section 7—Well Maintenance
- Section 8—Well Retention
- Section 9—Statistical Methods
- Section 10—Quality Assurance
- Section 11—Data Evaluation and Reporting
- Section 12—Schedule
- Section 13—References

Tables not included in the text are provided under a separate tab behind the text portion of the plan. All figures are provided under a separate tab.

Three appendices provide supporting information for the LMTP. Appendix A describes the aquifer testing program conducted on post and off post and provides information used to estimate groundwater travel times in various areas of RMA. Concentration time-trend graphs for Confined Flow System (CFS) wells are contained in Appendix B, and the off-post Private Well Monitoring Program is described in Appendix C.

2.0 HYDROGEOLOGIC SETTING AND REMEDIATION SYSTEMS

Before finalization of the On-Post and Off-Post RODs, the Army and Shell completed a thorough data collection program during a RI/Feasibility Study (FS) and implemented source controls and IRAs to protect human health and the environment at RMA. Fourteen IRAs were established prior to issuance of the RODs to provide immediate containment or treatment of some of the more highly contaminated areas at RMA and thus minimize the potential for exposure to or migration of contamination. These remedial activities included implementation of several groundwater containment and treatment systems to control groundwater contaminant plumes. The RODs require continued operation of these systems until specific shut-off criteria are met. In addition, the On-Post ROD requires excavation and containment of contaminated soil, which has been substantially completed at the time of issuance of this LTMP. Remediation of contaminated soil is expected to reduce contaminant mobility and thereby enhance the effectiveness of the groundwater containment systems.

This section describes RMA's hydrogeologic setting, contaminant plumes and associated containment and treatment systems, and soil containment areas where contaminated soil has or will be contained by covers and caps. The groundwater-related remedial actions that have been or continue to be implemented are also described.

2.1 Geology

The geological and hydrostratigraphic units of interest for this LTMP include surficial, unconsolidated alluvial, and eolian sediments, collectively referred to as the alluvium, underlain by the Denver and Arapahoe Formation bedrock (Ebasco 1989). The unconsolidated alluvium consists primarily of silts, sands, and gravels and is up to 100 feet (ft) thick. The thickest deposits of these alluvial sediments occur in paleochannels eroded into the underlying Denver Formation. At RMA, the Denver Formation, which consists of sandstones, siltstones, lignites, and claystones, crops out at only a few isolated locations. The unit ranges from approximately 200 to 500 ft in thickness and is separated from the underlying Arapahoe Formation by a relatively impermeable claystone interval 30 to 50 ft thick. The Arapahoe Formation consists of 400 to 700 ft of interbedded conglomerate, sandstone, siltstone, and shale. The Arapahoe Formation is of interest where it subcrops beneath the alluvium in the part of the Off-Post OU near the South Platte River. The upper parts of the bedrock formations were altered by weathering. This weathering occurred as the bedrock was exposed and eroded prior to deposition of the alluvial sediments.

2.2 Hydrogeology

As part of the RI, a large network of monitoring wells was installed on post and off post to characterize the hydrogeology of the RMA area (Ebasco 1989, 1992). Groundwater flow occurring within the alluvium and the upper weathered portion of the Denver Formation is referred to as the Unconfined Flow System (UFS). Where the Denver Formation is missing near the South Platte River, the weathered upper portion of the Arapahoe Formation is part of the UFS. Deeper water-bearing units within the Denver and Arapahoe Formations are separated from the UFS by low-permeability confining units and are referred to as the CFS. Depending on site-specific hydrological characteristics, varying degrees of hydraulic interchange are possible between surface water and groundwater and between the UFS and CFS. In general, both chemical and hydraulic data indicate little hydraulic interchange between the UFS and CFS.

Water enters the UFS as infiltration of precipitation; seepage from lakes, reservoirs, streams, canals, and buried pipelines; and in places, flow from the underlying CFS. In the developed portions of the Off-Post OU, some water enters the UFS as infiltration from individual sewage disposal system leach fields. Water is discharged from the UFS as seepage to lakes and streams, and underflow to off-post areas north and west of RMA. Comparison of water levels in adjacent UFS and CFS wells shows that there is a potential for downward flow into the CFS in some areas (USGS 1997). However, because the hydraulic conductivity of the CFS is generally very low at the UFS-CFS contact, there is very little flow between the two systems. The UFS also discharges to several production wells, including high-volume wells operated by the South Adams County Water and Sanitation District to the west of RMA.

In the On-Post OU and throughout much of the Off-Post OU, the uppermost portion of the CFS consists of Denver Formation sandstone or fractured lignite confined above and below by relatively impermeable shale or claystone. Water enters the CFS primarily in recharge areas at the margins of the Denver Basin some distance from RMA. In some areas, downward flow from the UFS may recharge the CFS, but the amount of groundwater flow between the UFS and CFS is believed to be minimal at RMA because of the low hydraulic conductivity of the confining layers at the top of the CFS. Water is discharged from the CFS into the UFS and is withdrawn from production wells in the Off-Post OU.

The UFS is the principal migration route for groundwater contaminants at RMA. Some low-level contamination is present in isolated portions of the CFS, but the spread of contamination has been minimal as a result of the limited permeability and discontinuous nature of the water-bearing zones in the upper part of the CFS. No contaminant migration pathway has been identified in the CFS, and no production wells at RMA obtain water from the CFS.

Figure 2.2-1 shows the three flow systems for shallow groundwater at RMA: the Irondale, Central, and First Creek. As the potentiometric surface map in Figure 2.2-2 illustrates, the general groundwater flow direction in the UFS at RMA is north and northwest toward the South Platte River. High groundwater flow volumes and velocities at RMA are associated with thick, permeable sand and gravel deposits of the Platte River Valley, which occur along the Western Tier (e.g., Sections 4, 9, and 33) of RMA, and with similar deposits along First Creek. The saturated portion of these alluvial sediments is generally thicker and coarser grained than alluvial sediments in the central portion of RMA. Groundwater flow velocities and volumes in the central portion of RMA are significantly lower than in the Western Tier or First Creek areas because groundwater in the central portion flows through predominantly thin, fine-grained alluvium and low-permeability bedrock. Superimposed on the regional groundwater flow system is a large groundwater mound centered over a bedrock high beneath the former South Plants area. Groundwater in this area flows radially away from the South Plants mound and eventually toward the Western Tier or the northern boundary.

Since the groundwater elevations in the Central Flow System are higher than in the Irondale or First Creek flow systems, central RMA is isolated from the regional groundwater flow, which occurs as underflow at the south boundary of RMA in the Irondale and First Creek flow systems. In the Central Flow System, the shallow groundwater flow is derived from limited local recharge caused by infiltration of precipitation falling within central RMA. Consequently, the volume of flow in the Central Flow System is much less than that in the Irondale and First Creek flow systems. The total flow in the Central Flow System, shown in Figure 2.2-3, was estimated to be only about 50 gallons per minute (gpm); whereas, it was estimated at 250 gpm in the First Creek Flow System and 1,800 gpm in the Irondale Flow System (MK Environmental Services 1993a).

Paleochannels incised in the bedrock surface and subsequently filled with alluvial deposits locally influence groundwater flow and the direction and rate of movement of groundwater contaminant plumes at RMA. This is especially true where the water table intersects bedrock with lower hydraulic conductivity on either side of the alluvium-filled channels.

Because RMA is located in a semiarid environment, the amount of annual groundwater recharge from precipitation is low (precipitation is approximately 15 inches per year). Sources of manmade recharge have historically contributed to the groundwater mound in South Plants. These manmade sources include leaking potable and process water systems, sanitary and storm sewer systems, infiltration of steam plant cooling water discharged to ditches, and infiltration of precipitation that ponds in depressions and ditches adjacent to buildings and roadways. In the long term, water levels in the mound area are expected to decrease as a result of remedial activities that include eliminating manmade recharge, regrading the area, and installing covers and caps in the Basin A and South Plants areas that will reduce infiltration of precipitation (FWENC 1996). Figure 2.2-4 shows groundwater elevations in 2004. Comparison of groundwater elevations from 1999 and 2004 (Figure 2.2-5) shows that the mound has been reduced by more than 10 ft in elevation due to remediation activities. Once the soil caps and covers are installed over the major groundwater contaminant source areas in central RMA, they will significantly reduce recharge such that groundwater levels are expected to continue to fall over time.

Groundwater flow in the vicinity of the former Basin F, within the saturated alluvium, is from the southeast and flows at first northwest, then north, and then northeast. The saturated alluvium ranges from extremely thin (less than 5 ft thick) to seasonally localized unsaturated conditions where the unconfined groundwater flow is in the underlying weathered Denver Formation. The depth to groundwater is approximately 40 to 50 ft. Water levels measured within the vicinity of Basin F remain relatively unchanged, but are expected to decrease once the cover is placed over the Basin F area.

2.3 Groundwater Plumes and Groundwater Remediation Systems

This section describes each groundwater extraction and treatment system and identifies the plumes and plume groups they are designed to remediate. More detailed descriptions of the systems and their requirements are presented in Section 4. The RMA On-Post FS identified 15 groundwater contaminant plumes that were consolidated into the following five groups (Figure 2.3-1):

- North Boundary Plume Group
- Northwest Boundary Plume Group
- Western Plume Group
- Basin A Plume Group
- South Plants Plume Group

Groundwater contaminant plumes in each of these groups were treated at three boundary containment and treatment systems: the North Boundary Containment System (NBCS), the Northwest Boundary Containment System (NWBCS), and the Irondale Containment System (ICS). Additional extraction and treatment systems were installed as IRAs at the Motor Pool, Railyard, Basin F, and Basin A Neck areas and off post at the OGITS. The additional on-post systems were installed to improve the performance of the boundary systems by reducing contaminant loading. The ICS, including the Motor Pool IRA extraction wells have met shut-off criteria and were shut off on October 1, 1997, and April 1, 1998, respectively. The Railyard Containment System (RYCS) extracts and treats Railyard contamination previously treated at ICS. The extraction well north of Basin F was shut down in 2000 because of declining water levels, groundwater flow, and influent concentrations, and mass removal efficiency having reached low asymptotic conditions.

The Section 36 Bedrock Ridge Extraction System (BRES) was installed in accordance with the On-Post ROD to prevent further migration from the Basin A area toward First Creek. Extracted water is treated at the Basin A Neck System (BANS).

As part of the soil remedy, the Complex Trenches slurry wall and dewatering system were installed in accordance with the On-Post ROD to augment containment:

> *Installation of a slurry wall into competent bedrock around the disposal trenches. Dewatering inside the slurry wall is assumed for purposes of conceptual design and will be reevaluated during remedial design,*

The On-Post ROD goals in Table 9.5-1 were to:

- *Minimize groundwater flow across the slurry wall with a design goal of 1 x 10^{-7} cm/sec hydraulic conductivity.*
- *Construct slurry wall with sufficient thickness to withstand maximum hydraulic gradient*
- *Construct slurry wall with materials that are compatible with the surrounding groundwater chemistry.*

- *Minimize migration by keying the slurry wall in an underlying low permeability strata, and*
- *Dewater as necessary to ensure containment.*

The specific dewatering goal was determined in the design document (RVO 1997), which was to lower groundwater levels below the elevation of the disposal trench bottoms. The design document identified the lowest elevations of the disposal trenches for performance monitoring purposes. Extracted water is treated at the BANS. Additional detail is provided in Section 5.1.

The Shell Trenches slurry wall was installed in accordance with the On-Post ROD to augment containment:

- *Expansion of the existing slurry wall around the trenches. Dewatering inside the slurry wall is assumed for purposes of conceptual design and will be reevaluated during remedial design,*

The On-Post ROD goals in Table 9.5-1 were the same as for the Complex Trenches. The groundwater levels within the slurry wall were below the bottoms of the disposal trenches when the design document was issued, so dewatering was unnecessary for the Shell Trenches. Since then, infiltration of precipitation has caused water levels to rise above the trench bottom at one borehole location. However, a RCRA-equivalent cover has been constructed over the Shell Trenches area and it is expected that the dewatering goal will be achieved after the cover vegetation is established. For cover compliance, the vegetation is expected to be established 5 years after the cover is constructed and seeded. The final inspection for the Shell Trenches cover and revegetation was held on October 2, 2007. Therefore, achievement of the performance goal is expected to occur by October 2, 2012, after the 5-year period required to establish vegetation. Additional detail is provided in Section 5.2.

The South Tank Farm (STF) and Lime Basins groundwater extraction/recharge and monitoring systems of the Groundwater Mass Removal Project comprise a remedy project that was installed and became operational in 2006. These are short-term mass removal projects and groundwater extracted from these respective systems is treated at the CERCLA Wastewater Treatment Plant (CWTP). The Groundwater Mass Removal Project requires the reinjection of treated groundwater that is being conducted in accordance with applicable requirements under the Underground Injection Control Program and is operated under a reinjection exemption that allows recharge of groundwater at concentrations that exceed the Colorado Basic Standards for Groundwater (CBSGs) (Washington Group International 2005a). The Groundwater Mass Removal Project will continue until June 30, 2010, or until the CWTP is decommissioned, whichever is longer (TtEC 2006b). In Fiscal Year 2009 (FY09), the average flow rates for the mass removal systems were 1.24 gpm for STF, and 0.82 gpm for the Lime Basins (while operating). The Lime Basins system was shut down for part of the year due to cover construction, and the detection of dense non-aqueous phase liquid (DNAPL) in two of the Lime Basins dewatering wells.

Due to a change in the Lime Basins soil remedy in 2005, an encircling slurry wall and dewatering system were installed to contain Lime Basins contamination (TtEC 2005). This project is separate from the Lime Basins Mass Removal Project. The Lime Basins dewatering system consists of six new dewatering wells and associated monitoring wells. A RCRA-equivalent cover was also installed over the Lime Basins as part of the Integrated Cover System. Extracted water is currently treated at the CWTP and will be treated at the BANS after the decommissioning of the CWTP in 2010. The Lime Basins dewatering system commenced operation in March 2009 and is independent of the Lime Basins mass removal system. The Lime Basins dewatering flow rate was 0.4 gpm in 2009. The dewatering system was shut down in August 2009 due to the detection of DNAPL in two of the dewatering wells.

CSRGs were established for each containment/treatment system on the basis of applicable or relevant and appropriate requirements (ARARs) and health-based criteria. The ARAR-based values were either CBSGs, federal maximum contaminant levels (MCLs), or non-zero MCL goals. The health-based values were derived from site-specific criteria and were based on United States Environmental Protection Agency (EPA) health advisories and/or EPA Integrated Risk Information System database criteria. CSRGs were selected for compounds likely to be encountered at each of the existing boundary, internal, and off-post systems. The CSRGs and where CSRGs cannot be quantified using current laboratory methods, the Practical Quantitation Limits (PQLs) for the respective system effluents as of April 2007 are presented in Tables 2.3-1 through 2.3-5. PQLs are discussed further in Section 10.2.

Brief descriptions of each of the systems and the plumes/plume groups they intercept are presented in Sections 2.3.1 through 2.3.6. More detailed descriptions of the systems and their respective requirements are presented in Section 4. System performance information is presented in the Operational Assessment Report (OARs) for the five-year site review (FYR) period (PMRMA 2005a, 2005b, 2005c, 2003, 2002).

2.3.1 Northwest Boundary Plume Group and Groundwater Remediation System

The Northwest Boundary Plume Group includes the Basin A Neck Plume, the Sand Creek Lateral Plumes, and the dieldrin plume that extends from South Plants to the Southwest Extension of the NWBCS. The Basin A Neck Plume extends from Basin A in Section 36 to the northwest boundary of RMA. The Sand Creek Lateral Plumes appear to originate in the vicinity of the Sand Creek Lateral in the western portion of Section 35 and merge with the Basin A Neck Plume. The original NWBCS, located in the southeast quarter of Section 22, was installed to intercept and treat groundwater contaminant plumes migrating from the South Plants and the Basin A areas to the RMA boundary.

The NWBCS is a containment system designed to prevent further off-post migration of contaminated groundwater (USACE 1985). A summary of the elements in the Off-Post ROD relevant to the LTMP include:

- Continued operation of the NWBCS until shut-off criteria are met
- Natural attenuation of chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the on-post remedial action
- ICs to prevent the future use of groundwater exceeding remediation goals by mapping of contaminants that exceed CSRGs and notification in well permits where groundwater could potentially exceed CSRGs

- Provision of a water supply for well owners with wells within the diisopropylmethyl phosphonate (DIMP) plume footprint

For the specific language and additional detail, refer to Sections 7.1 and 9.0 of the Off-Post ROD.

The selected remedy in the On-Post ROD for the NWBCS and the other two boundary systems requires:

> *Operation of the three boundary systems, the NBCS, NWBCS, and ICS, continues. These systems include extraction and recharge systems, slurry walls (NBCS and NWBCS) for hydraulic controls, and carbon adsorption for removal of organics. The systems will be operated until shut-off criteria are met.*

The NWBCS includes three different components: the Original System, the NWBCS Northeast Extension, and the NWBCS Southwest Extension. The Original System, installed in 1984, consists of 15 extraction wells, 21 recharge wells, and a 1,425-ft-long slurry wall. The slurry wall extends across a portion of the system (from wells 22311 through 22315) and the hydraulic barrier only portion extends from wells 22301 through 22310. The recharge wells are located northwest (downgradient) of the extraction wells and slurry wall. The system creates a reverse (counter-regional) hydraulic gradient to contain the contaminant plumes. The NWBCS Northeast Extension, which was added in 1990, included the installation of two extraction wells and 665 ft of slurry wall. The NWBCS Southwest Extension was installed in 1991 to prevent the further off-post migration of contaminated groundwater by containing a dieldrin plume that extended from South Plants to the Southwest Extension of the NWBCS. It consisted of 3 extraction wells and four recharge wells. No slurry wall is present in this area. An additional extraction well was installed in 1996. Contaminated groundwater for the combined system is processed through a granular activated carbon (GAC) adsorption system prior to injection to the aquifer. In FY09, the NWBCS flow rate averaged 863 gpm.

CSRGs for the NWBCS effluent were established for eight contaminants potentially present in the groundwater migrating toward the northwest boundary. The CSRGs and PQLs for the NWBCS effluent as of October 2007 (PMRMA 2007a) are presented in Table 2.3-1.

2.3.2 North Boundary Plume Group and Groundwater Remediation System

The NBCS is located immediately south of the RMA north boundary in Sections 23 and 24. The system treats water from the North Boundary Plume Group as the plumes approach the north boundary of RMA. The North Boundary Plume Group includes the Basins C and F Plume and the North Plants Plume. The Basins C and F Plume flows primarily within alluvial-filled paleochannels and to a lesser extent through weathered bedrock. The North Plants Plume flows primarily within sandy alluvial material.

The sources of the Basins C and F Plume contamination are the two basins that were used for disposal of a wide range of chemical waste between the late 1950s and the early 1970s. Extensive source removal was conducted under the Basin F IRA. Liquid waste was removed and later treated through submerged quench liquid incineration, and the Basin F wastepile was constructed for containment of contaminated soils from the most contaminated part of Basin F.

Under the selected on-post remedy, waste was removed from the wastepile and portions of the former Basin F area and placed in the ELF.

The NBCS is a containment system designed to prevent further off-post migration of contaminated groundwater (USACE 1985). A summary of the elements in the Off-Post ROD relevant to the LTMP include:

- Continued operation of the NBCS until shut-off criteria are met
- Natural attenuation of chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the on-post remedial action
- ICs to prevent the future use of groundwater exceeding remediation goals by mapping of contaminants that exceed CSRGs and notification in well permits where groundwater could potentially exceed CSRGs
- Provision of a water supply for well owners with wells within the DIMP plume footprint

For the specific language and additional detail, refer to Sections 7.1 and 9.0 of the Off-Post ROD.

The selected remedy in the On-Post ROD for the NBCS requires:

> *Operation of the three boundary systems, the NBCS, NWBCS, and ICS, continues. These systems include extraction and recharge systems, slurry walls (NBCS and NWBCS) for hydraulic controls, and carbon adsorption for removal of organics. The systems will be operated until shut-off criteria are met. Chloride and sulfate are expected to attenuate naturally to CSRGs.*

The containment system originally consisted of a soil bentonite barrier with extraction wells upgradient and injection wells downgradient of the barrier wall. This system was originally installed as a pilot project in 1979 and extended to its current extent in 1981. The system was originally unable to maintain a reverse hydraulic gradient and, consequently, was modified by replacing the recharge wells with 15 recharge trenches. As a result of the changes, a reverse hydraulic gradient has been maintained across the entire alluvial system and most of the bedrock portion of the UFS since 1992. A carbon adsorption system is used to remove organic compounds and ultraviolet (UV) oxidation is used to treat n-nitrosodimethylamine (NDMA) prior to recharge. The UV-oxidation treatment system has been treating NDMA since September 1997 (Morrison Knudsen Corporation 1998).

In 2003, two groundwater extraction wells were added upgradient of the NBCS to intercept the plumes nearer to the source, provide added operational flexibility, prevent the plumes from shifting toward less contaminated areas, and accelerate groundwater cleanup. The additional groundwater from the wells also helps maintain the reverse hydraulic gradient at the NBCS. In FY09, the NBCS flow rate averaged 193 gpm.

The North of Basin F Groundwater Plume Remediation System was constructed upgradient of the NBCS to reduce the contaminant load on the system and accelerate cleanup of contaminated groundwater associated with Basin F. The system began operations on October 1, 1990, and was shut off on September 22, 2000. The decision to permanently discontinue operation was based on mass removal efficiency having reached low asymptotic conditions due to reduced influent concentration and flow that made continued operation infeasible. The Construction Completion Report (CCR) for the North of Basin F well was approved by EPA in 2005 (Washington Group International 2005b).

In situ anaerobic biodegradation treatment was initiated in the Basin F Plume in May 2005 for the purpose of reducing contaminant load on the NBCS through implementation of the North Boundary Enhancement (NBE) system. Operation and monitoring of this Hydrogen Release Compound (HRC) injection system was discontinued in 2007, because the system was unsuccessful in achieving its contaminant reduction goals (Design Change Notice [DCN] No. 4, 2007, as applied to George Chadwick and Tetra Tech [2005]; NBE Termination Report, URS Washington Division 2009).

CSRGs for the NBCS effluent were established for 29 contaminants potentially present in the groundwater migrating toward the north boundary. The CSRGs and PQLs for the NBCS effluent as of October 2007 are presented in Table 2.3-2. Of the compounds listed, chloride and sulfate levels were to be reduced to CSRGs through attenuation over time periods of 30 (year 2026) and 25 (year 2021) years respectively, as discussed in Section 2.5.

2.3.3 Western Plume Group and Groundwater Remediation Systems

The Western, Motor Pool, and Railyard plumes are collectively defined as the Western Plume Group. The Irondale, Motor Pool, and Railyard systems were identified in the On-Post ROD (FWENC 1996) as integral to controlling the migration of these contaminant plumes.

The selected remedy in the On-Post ROD for the ICS requires:

> *Operation of the three boundary systems, the NBCS, NWBCS, and ICS, continues. These systems include extraction and recharge systems; slurry walls (NBCS and NWBCS) for hydraulic controls, and carbon adsorption for removal of organics. The systems will be operated until shut-off criteria ... are met.*

The ICS, which became operational in 1981, was located at the southern end of the RMA northwest boundary in Sections 33 and 28 and consisted of a hydraulic control system of extraction and recharge wells and a GAC treatment system. The ICS was originally designed to treat all groundwater extracted from the Western Plume Group. The On-Post ROD then added treatment of groundwater from the Rail Yard and Motor Pool IRA systems to the ICS. In October 1997, the Irondale extraction system was shut off after having met shut-off criteria, and 5 years of shut-off monitoring was successfully completed in August 2002 (PMRMA 2005a). The CCR for the Irondale shut-down was approved by EPA on May 21, 2003 (Washington Group International 2003).

The Motor Pool extraction system, located in Section 4, was shut off in April 1998 and shut-off monitoring was conducted through December 2003 (PMRMA 2005b). During the shut-off monitoring period, trichloroethylene (TCE) concentrations in shut-off monitoring well 04535 were detected above the CSRG for two sample events in 2002. These elevated detections corresponded to a rise in the water table in the Motor Pool area. For this reason, the shut-down monitoring period for the Motor Pool was extended from April 2003 to December 2003.

When the Irondale and Motor Pool extraction systems were shut off, treatment of the remaining Railyard Plume was moved from the ICS to the new RYCS in July 2001. Recharge of the treated water was also transferred from the ICS to the Railyard. Two Railyard extraction wells located downgradient of the primary Railyard extraction well field, wells 03306 and 03307, were converted to recharge wells 03401 and 03402. In FY09, the average flow rate for the Railyard system was 119 gpm. Table 2.3-3 shows CSRGs for TCE and dibromochloropropane (DBCP), established in the On-Post ROD for the ICS, which apply to the Railyard system.

2.3.4 Basin A Plume Group and Groundwater Remediation Systems

The Basin A Plume Group includes the Basin A, the South Plants North, and the Section 36 Bedrock Ridge plumes. Contaminated groundwater flow in the South Plants North and Basin A plumes occurs principally within saturated alluvium, with lesser flow through the underlying weathered bedrock. However, in the Section 36 Bedrock Ridge area, the water table generally lies below the alluvium and groundwater flows predominantly within weathered bedrock.

Basin A was used as a disposal basin. Wastes from Army and Shell manufacturing facilities were discharged into this unlined disposal basin in Section 36. Groundwater contamination migrating out of Basin A originates in two different areas, Basin A and South Plants.

The BANS is located in the northeast quarter of Section 35 and the southeast quarter of Section 26 and intercepts and treats plumes migrating northwest from Basin A. It was originally installed as an IRA to treat water migrating from the Basin A and northern South Plants areas. However, as a result of the ROD implementation, it also treats groundwater from the BRES and the Complex Trenches dewatering system. The BANS treated water from the North of Basin F extraction well until it was shut down in 2000 after its mass removal efficiency reached low asymptotic conditions.

The BANS, BRES, and the Complex Trenches dewatering system are described separately in Sections 2.3.4.1 through 2.3.4.3.

2.3.4.1 Basin A Neck System

The selected remedy in the On-Post ROD for the BANS requires:

> *Operation of existing on-post groundwater IRA systems continues... The Basin F extraction system continues to extract water that is treated at the Basin A Neck system and the Basin A Neck system continues to extract and treat water from Basin A until shut-off criteria are met.*

The On-Post ROD established the following RAO:

> *(d)evelop on-post groundwater extraction/treatment alternatives that establish hydrologic conditions consistent with the preferred soil alternatives and also provide long-term improvement in the performance of the boundary control systems*

The following objectives for the BANS were identified in the IRA Decision Document (Army 1989):

- *Minimize the spread of contaminated groundwater migrating through the Basin A Neck as soon as practicable;*
- *Improve the efficiency and efficacy of the boundary treatment system;*
- *Collect operational data on the interception, treatment, and recharge of contaminated groundwater from this area that may be useful in the selection and design of a Final Response Action; and*
- *Accelerate groundwater remediation within RMA.*

The BANS consists of seven alluvial extraction wells, a slurry wall, an air stripper, and a GAC adsorption system for treatment, and five gravel-filled recharge trenches. Two of these trenches were installed in 2004. The three original trenches are located across the more permeable, deeper portions of the Basin A Neck area paleochannel downgradient from the extraction wells. A soil/bentonite slurry wall extends across the Basin A Neck area between the extraction wells and the recharge trenches to limit recirculation of water between the two systems and inhibit flow of contaminants not captured by the extraction wells. In FY09, the BANS extraction wells averaged a total flow rate of 13.8 gpm.

CSRGs for the BANS effluent were established for 22 contaminants potentially present in the groundwater migrating toward the Basin A Neck. The CSRGs and PQLs for the BANS effluent as of October 2007 are presented in Table 2.3-4.

Treated water from the CWTP was previously conveyed to the Basin A Neck treatment plant by an underground pipeline, combined with effluent from the plant at a maximum rate of 5 gpm, and reinjected in the Basin A Neck recharge trenches. However, the CWTP is, as described in Section 2.3, currently used for treatment of water extracted under the Groundwater Mass Removal Project and the Lime Basins Project, and this water is reinjected in the South Plants area and recharge trenches north of the Lime Basin area under a reinjection exemption that allows recharge of groundwater at concentrations that exceed the CBSGs (Washington Group International 2005a). Groundwater from the Lime Basins Area project will be conveyed to and treated at the BANS treatment plant once the CWTP is decommissioned.

2.3.4.2 Section 36 Bedrock Ridge Extraction System

The selected remedy in the On-Post ROD for the Section 36 BRES requires:

> *A new extraction system will be installed in the Section 36 Bedrock Ridge area. Extracted water will be piped to the Basin A Neck system for treatment (e.g., by air stripping or carbon adsorption).*

The BRES extraction wells were installed, in accordance with the On-Post ROD (FWENC 1996), to prevent further migration of the Section 36 Bedrock Ridge Plume northeast out of the Basin A area toward the First Creek drainage. The extracted water is treated and recharged to the groundwater at the BANS.

The evaluation of the BRES, which originally consisted of three extraction wells, led to a decision to modify the system to improve plume capture. A fourth extraction well, 36306, was installed and became operational in 2005. Water extracted in the Bedrock Ridge area is piped to the BANS for treatment by GAC and air stripping. In FY09, the flow rate for the BRES averaged 3.3 gpm.

2.3.4.3 Complex Trenches Dewatering

The selected remedy in the On-Post ROD for the Complex Trenches requires:

> *Installation of a slurry wall into competent bedrock around the disposal trenches. Dewatering within the slurry wall is assumed for purposes of conceptual design and will be re-evaluated during remedial design.*

The On-Post ROD also stated the following dewatering goal for the Complex Trenches in ROD Table 9.5-1:

- *Dewater as necessary to ensure containment.*

The dewatering goal was further refined in the Complex Trenches and Shell Section 36 Trenches Groundwater Barrier Project 100 Percent Design Document (RVO 1997a), which states:

- *The dewatering objective is to lower the water table to below the elevation of the disposal trench bottoms.*

Installation of the Complex Trenches slurry wall began in 1998 and the project was completed in 2000. Testing of the groundwater extraction trench was completed in February 2000 and operation of the dewatering system began in March 2001.

To meet the ROD-derived requirement of ultimately lowering the water table to below the bottom of the Complex Trenches, water is extracted at a flow rate that typically ranges between 1 and 2 gpm and piped to the BANS for treatment. In FY09, the flow rate averaged 2.0 gpm. Meeting the Complex Trenches dewatering goals likely will not be achieved until the Integrated Cover System is completed and the vegetation has been established. For cover compliance, the vegetation is considered to be established 5 years after the cover is completed and revegetated, at which time irrigation is assumed to end. Irrigation of the cover during the 5-year period for establishing the vegetation may cause recharge inside the slurry-wall enclosure and increase the volume of water that must be pumped to meet the dewatering goals. Therefore, meeting the dewatering goals will not be required until the end of the 5-year period when the vegetation is established and irrigation has ended. Cover construction, revegetation, and initial irrigation for the Complex Trenches portion of the Integrated Cover System was completed on September 9, 2009. Consequently, achievement of the dewatering goals is expected to occur by September 9, 2014, after the 5-year period required to establish vegetation.

2.3.4.4 Shell Trenches

The selected remedy in the On-Post ROD for the Shell Trenches slurry wall requires:

> *Expansion of the existing slurry wall around the trenches. Dewatering within the slurry wall is assumed for purposes of conceptual design and will be re-evaluated during remedial design.*

The On-Post ROD also stated the following dewatering goal for the Shell Trenches in ROD Table 9.5-1:

- *Dewater as necessary to ensure containment.*

The dewatering goal was eliminated in the Complex Trenches and Shell Section 36 Trenches Groundwater Barrier Project 100 Percent Design Document (RVO 1997a), which states:

- *For the Shell Trenches, the groundwater levels are already below the bottoms of the trenches, making dewatering unwarranted.*

The Shell Trenches slurry wall was installed in March and April 1999. Infiltration of precipitation during remedial activities and cover construction caused water levels inside the slurry-wall enclosure to rise such that the water elevation was above the bottom of a disposal trench at one of six borehole locations. Therefore, the dewatering goal has not been met. However, a RCRA-equivalent cover has been constructed over the Shell Trenches area and it is expected that the dewatering goal will be achieved after the cover vegetation is established. For cover compliance, the vegetation is expected to be established 5 years after the cover is constructed and seeded. Cover construction, revegetation, and initial irrigation for the Shell Trenches portion of the Integrated Cover System was completed on September 15, 2007. The final inspection for the cover revegetation was held on October 2, 2007. Consequently, achievement of the dewatering goal is expected to occur by October 2, 2012, after the 5-year period required to establish vegetation.

2.3.4.5 Lime Basins Dewatering

The Lime Basins soil remedy was changed in the 2005 Section 36 Lime Basins Remedy ROD Amendment (TtEC 2005) to include an encircling slurry wall and dewatering well system to lower water levels below the Lime Basins waste and create an inward hydraulic gradient across the slurry wall. The groundwater pumped by the Lime Basins dewatering system is treated at the CWTP and reinjected in the Lime Basins recharge trenches until the CWTP is decommissioned in 2010. After shutdown of the CWTP, it is planned to treat the Lime Basins groundwater at the BANS to meet CSRGs and reinjected in the BANS recharge trenches.

For the Lime Basins, the ROD Amendment provides:

- *Standard: Dewater as necessary to maintain a positive gradient from the outside to the inside of the barrier wall and maintain groundwater level below the level of the Lime Basins waste for as long as the surrounding local groundwater table is in the alluvium.*
- *Monitor to ensure that the dewatering standard is met. If the groundwater table drops below the level of the alluvium inside the wall, monitor annually thereafter to check that the groundwater table remains below the alluvium inside the wall.*

The performance criteria for the Lime Basins are presented below.

- Maintain a positive gradient from the outside to the inside of the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).
- Maintain a groundwater level below the elevation of the Lime Basins waste (5242 ft) inside the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).

Although achieving the Lime Basins dewatering goals does not rely on installation of the cover, the associated revegetation and irrigation may affect the timeframe for meeting the dewatering goals. The cover is designed to reduce the infiltration of precipitation, which will reduce the volume of water that must be pumped to achieve the dewatering goals. The vegetation plays a critical role in the effectiveness of the cover, but first must be established, which requires irrigation. For cover compliance, the vegetation is expected to be established 5 years after the cover is constructed and seeded. Irrigation of the cover for establishing the vegetation may cause recharge inside the slurry-wall enclosure and increase the volume of water that must be pumped to meet the dewatering goals. Therefore, meeting the dewatering goals will not be required until the end of the 5-year period when the vegetation is established and irrigation has ended. Cover construction, seeding, and irrigation for the Lime Basins portion of the Integrated Cover System were completed on September 9, 2009. Consequently, achievement of the dewatering goals is expected to occur by September 9, 2014, after the 5-year period required to establish vegetation.

2.3.5 South Plants Plume Group

The South Plants Plume Group includes the South Plants Southeast, Southwest, North Source, and STF plumes. Groundwater in these plumes flows principally within the weathered, upper portion of the Denver Formation. Small portions of the South Plants North Source and South Plants Southeast plumes also flow within areas of thin, saturated alluvium. Contamination in the South Plants area originated from chemical manufacturing and storage in the area.

The STF was constructed in 1942 in the northwest quarter of Section 1, in the southern part of South Plants, as part of the initial construction at RMA. The STF included 11 storage tank locations that were used by Hyman and Shell for storage of dicyclopentadiene (DCPD), crude bicycloheptadiene (BCHPD) bottoms, isopropyl alcohol, sulfuric acid, D-D fumigant, and DBCP. In 1948, during the period when CF&I was leasing facilities at South Plants, 100,000 gallons of benzene were spilled in an undisclosed location. In 1979, Shell detected benzene in soil samples collected in the STF area.

The South Plants North Source Plume migrates toward the BANS. Some contamination, including the STF Plume, also migrates south toward the South Lakes.

The selected remedy in the On-Post ROD requires:

> *Lake-level maintenance or other means of hydraulic containment or plume control will be used to prevent South Plants plumes from migrating into the lakes at concentrations exceeding CBSGs in groundwater at the point of discharge. Groundwater monitoring will be used to demonstrate compliance.*

An evaluation of contaminant migration was conducted in accordance with the *Rocky Mountain Arsenal South Lakes Sampling and Analysis Plan for Groundwater* (USGS 2001) during the 2000–2005 FYR period. This monitoring program, which focused on monitoring contaminant migration into Lake Ladora, revised a previous evaluation project (FWENC 1997). The monitoring program for Lake Ladora was conducted between 2001 and 2003 and consisted of monthly and quarterly groundwater sampling and water level measurements. During this monitoring, concentrations of contaminants in the lake point-of-compliance wells, representing the discharge points, were below the CBSGs and not related to water levels in Lake Ladora (USGS 2004).

The results from the South Lakes groundwater investigation led to the conclusion that lake-level maintenance or other means of hydraulic containment or plume control are not necessary to prevent plume migration into the lakes at concentrations exceeding CBSGs (USGS 2004), which is documented in the Explanation of Significant Difference (ESD) for Groundwater Remediation and Revegetation Requirements (TtEC 2006b). The ESD served to eliminate from the remedy hydraulic containment, including lake-level maintenance, or other means of plume control, to prevent migration of contaminated groundwater into the lakes. Lake-level maintenance during remediation is still required to support aquatic ecosystems in Lake Ladora, Lake Mary and Lower Derby Lake (FWENC 1996). The Interim Rocky Mountain Arsenal Institutional Control Plan (IRMAICP) (under development) addresses the management of contaminated human health exceedance sediments in Lower Derby Lake as remediation takes place. In addition, groundwater monitoring will be conducted as part of the long-term monitoring program for groundwater to assess any change in future conditions (monitor plume migration from South Plants toward the South Lakes).

In early 2006 an ESD was approved to implement short-term groundwater mass removal remedies within the STF Plume and the former Lime Basins areas (TtEC 2006b). These remedies entail the extraction of groundwater from the STF Plume and the Lime Basins area with treatment of the extracted groundwater to reduce the contaminant mass within the respective plumes. The extracted groundwater is treated at the CWTP for recharge to the vicinity of the respective extraction well fields. Extraction began in 2006 and will continue until June 30, 2010, or until the CWTP is decommissioned, whichever is longer. The monitoring for this project is not part of the long-term monitoring program. A separate short-term monitoring program is presented in the Final Design Analysis Report (Washington Group International 2005a).

2.3.6 Off-Post Groundwater Plumes and Remediation System

The Off-Post OU is one of two operable units at RMA. The Off-Post ROD was signed by the Army, the EPA, and the Colorado Department of Public Health and Environment (CDPHE) on December 19, 1995, with concurrence of the USFWS and Shell. A summary of the elements in the Off-Post ROD relevant to the LTMP include:

- Continued operation of the OGITS until shut-off criteria are met
- Natural attenuation of chloride and sulfate concentrations to meet applicable standards for groundwater in a manner consistent with the on-post remedial action
- ICs to prevent the future use of groundwater exceeding remediation goals by mapping of contaminants that exceed CSRGs and notification in well permits where groundwater could potentially exceed CSRGs
- Provision of a water supply for well owners with wells within the DIMP plume footprint

For the specific language and additional detail, refer to Sections 7.1 and 9.0 of the Off-Post ROD.

The mass removal objectives identified in the IRA Decision Document (HLA 1989) for OGITS are as follows:

- *Mitigate migration of contaminants in alluvial groundwater as soon as practicable.*
- *Treat contaminated alluvial groundwater to provide a beneficial impact on groundwater quality.*

In addition, the RMA Federal Facilities Agreement states:

> *(t)he Organizations intend that the Response Actions at the Arsenal will be sufficient to assure that groundwater and surface water flowing beyond the Arsenal boundaries will be of a quality that is protective of human health and the environment and that Response Actions will be sufficient to prevent the vertical and horizontal migration of on-post contaminated groundwater and surface water so that off-post surface water and groundwater may be used in areas outside of the Arsenal boundaries.*

Water quality monitoring, termed exceedance monitoring, is conducted in compliance with the Off-Post ROD to create plume maps for contaminants that exceed CSRGs. The plume maps are provided to the Office of the State Engineer and to Commerce City, Brighton, and Adams County officials for their use in issuing well permits and notifications of potential contamination issues. The notification and agency review process is described in detail in the 2005 FYRR (PMRMA 2007a), which also includes data that show significant reductions in the off-post contaminant plumes have been achieved since the ROD implementation.

The OGITS was designed to extract and treat contaminated alluvial groundwater from the First Creek and Northern pathways, downgradient of the NBCS, and return treated water to the alluvial aquifer. The OGITS was originally installed before completion of the Off-Post ROD as an IRA, but later became part of the Off-Post ROD remedy (HLA 1995). The response action objectives for the system were identified as follows (HLA 1989):

- *Mitigate migration of contaminants in alluvial groundwater as soon as practicable.*
- *Treat contaminated alluvial groundwater to provide a beneficial impact on groundwater quality.*

The major remedy components identified for operation of the OGITS in the Off-Post ROD are:

- *Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels using groundwater extraction wells.*
- *Treatment of the organic COCs present in the groundwater using carbon adsorption.*
- *Recharge of treated groundwater to the UFS using ... recharge wells and trenches.*

The OGITS includes two extraction and recharge systems consisting of extraction wells, recharge trenches, and recharge wells in the Northern and First Creek paleochannels. The northern paleochannel system consisted of 12 extraction wells and 24 recharge wells and has since been modified. The First Creek paleochannel system consists of five extraction wells and six recharge trenches. Water is treated by GAC adsorption before reinjection. System performance information is presented in the OARs for the FYR period (PMRMA 2005a, 2005b, 2005c, 2003, 2002). CSRGs for the OGITS effluent were established for 34 contaminants potentially present in the Off-Post OU (Table 2.3-5).

The Northern Pathway System (NPS) has been operating since 1993. Both the groundwater contaminant concentrations and the areal extent of groundwater contamination have significantly decreased since operation of the NPS began. Four of the NPS extraction wells were turned off on July 1, 2004 (PMRMA 2005c). Two First Creek System (FCS) extraction wells were turned off in September 2003 (PMRMA 2005b). The OGITS was originally designed to extract and treat an average flow rate of 300 gpm from the Northern paleochannel, an average flow rate of 180 gpm from the First Creek paleochannel, and a peak flow of 1.5 times the average flow.

An agreement was reached with Amber Homes in 2004 that the NPS and the associated recharge wells used for reinjection of treated groundwater would be relocated to accommodate new development (George Chadwick Consulting 2005). It is expected that the modified system will expedite cleanup of alluvial groundwater between the old and new extraction systems. The new NPS extraction wells will be operated concurrently with the remaining original NPS extraction wells until the latter meet the ROD-specified shut-off criteria.

The new extraction system along Highway 2 has been designed to meet or exceed the contaminant removal efficiency of the original system. Specific design requirements for the new extraction well system are as follows:

- Achieve similar flow rates in the new extraction wells at Highway 2 as in the original extraction wells within the same plume and flow paths.
- Capture the majority of the plume mass for carbon tetrachloride, chloroform, DBCP, DIMP, dieldrin, and tetrachloroethylene.

Additional details on the modifications to the system are presented in Section 4.8.

2.4 Soil Containment Areas

Several portions of the RMA remedy have specific groundwater monitoring requirements that are not subject to change through the LTMP processes, for example, analytes, frequency, and monitoring network. Any changes to these project specific monitoring programs must be formally detailed in a Decision Document approved by the Regulatory Agencies. Once a Decision Document is final, changes to the monitoring network will be tracked through the LTMP.

The On-Post ROD identified the following RAOs for the soil medium:

- **Human Health**
  - *Prevent ingestion of, inhalation of, or dermal contact with soil or sediments containing COCs at concentrations that generate risks in excess of 1 x 10^{-4} (carcinogenic) or an HI greater than 1.0 (noncarcinogenic) based on the lowest calculated reasonable maximum exposure (5th percentile) PPLV values (which generally represent the on-site biological worker population).*

- *Prevent inhalation of COC vapors emanating from soil or sediments in excess of acceptable levels, as established in the HHRC.*
- *Prevent migration of COCs from soil or sediment that may result in off-post groundwater, surface water, or windblown particulate contamination in excess of off-post remediation goals.*
- *Prevent contact with physical hazards such as UXO.*
- *Prevent ingestion of, inhalation of, or dermal contact with acute chemical agent hazards.*

- **Ecological Protection**
  - *Ensure that biota are not exposed to COCs in surface water, due to migration from soil or sediment, at concentrations capable of causing acute or chronic toxicity via direct exposure or bioaccumulation.*
  - *Ensure that biota are not exposed to COCs in soil and sediments at toxic concentrations via direct exposure or bioaccumulation.*

In general, the remedies for contaminated soil have been implemented to reduce contaminant mobility and thereby enhance the effectiveness of the groundwater containment systems. Several soil containment areas have been constructed for this purpose. These areas, which are shown in Figure 2.4-1, include landfills that have caps with liners and leachate collection systems and containment areas that have soil covers with percolation monitoring. The on-post ROD specifies the groundwater monitoring for soil sites where human health exceedances are left in place as follows:

- Where human health exceedances are left in place at soil sites, groundwater will be monitored, as necessary, to evaluate the effectiveness of the remedy.

The areas where human health exceedance soils are left in place are:

- South Plants Central Processing Area
- South Plants Balance of Areas, SPSA-2d Ditch
- Shell Disposal Trenches
- Section 36 Lime Basins
- Complex Army Trenches
- Basin A

Groundwater monitoring associated with select containment remedies at RMA are subject to both RCRA and CERCLA requirements and are addressed in monitoring plans and reports separate from the LTMP. The select containment remedies include:

- The former Basin F/Basin F Wastepile
- The HWL
- The ELF

Groundwater monitoring associated with containment areas that fall under CERCLA are included in the LTMP as specific remedy monitoring components or as part of the water level or water quality tracking programs. The Complex Trenches, Shell Trenches, and Lime Basins remedies include slurry walls and dewatering components to enhance containment in addition to RCRA-equivalent covers. For these sites, water level monitoring is conducted to evaluate the effectiveness of each remedy.

The South Plants; South Plants Balance of Areas, SPSA-2d Ditch; and Basin A remedies utilize RCRA-equivalent covers for soil containment. For these remedies, water level and water quality monitoring are conducted to evaluate the effectiveness of each remedy. To distinguish the different monitoring requirements, these three sites are grouped under Source Monitoring, and monitoring is integrated within the water level and water quality tracking categories. Changes to the project-specific CERCLA monitoring programs will be documented in Decision Documents approved by the Regulatory Agencies and incorporated into and tracked through revisions to the LTMP. The CERCLA monitoring programs related to soil containment areas are addressed as follows in this LTMP:

- Complex Trenches—Section 5.1
- Shell Trenches—Section 5.2
- Lime Basins—Section 5.3
- North Plants LNAPL—Section 5.4
- Source Monitoring—Section 5.5
  - South Plants Central Processing Area—Section 6.1.1, Water Level Tracking; Section 6.1.2, Water Quality Tracking
  - South Plants Balance of Areas, SPSA-2d Ditch—Section 6.1.1, Water Level Tracking; Section 6.1.2, Water Quality Tracking
  - Basin A—Section 6.1.1 Water Level Tracking; Section 6.1.2, Water Quality Tracking

The monitoring network tables identify the specific wells associated with the respective source areas.

2.5 Chloride and Sulfate Attenuation

The RMA On-Post OU identified natural attenuation as a remedy for chloride and sulfate at NBCS, and a study was conducted to evaluate remediation goals as well as remediation timeframes for these compounds (MK Environmental Services and FWENC 1996). Based on regional data and flow rates upgradient of the NBCS, the CSRG for chloride was set at the CBSG of 250 milligrams per liter (mg/L), and the timeframe for achieving the CSRG in the NBCS effluent was predicted to be 30 years. For sulfate the CSRG was set at 540 mg/L based on regionally high levels of sulfate in groundwater, and the timeframe for achieving this was predicted to be 25 years. The development of the background CSRG for sulfate and the attenuation time estimates are detailed in a separate document (MK Environmental Services and FWENC 1996).

Since the reductions in chloride and sulfate concentrations are not achieved by "natural attenuation" as outlined by EPA (EPA 2001), the use of the term for this application has been cause for confusion. For that reason, the term has been changed to "attenuation."

The Off-Post ROD incorporated the same attenuation requirements for OGITS and specified that chloride and sulfate are to meet applicable standards for groundwater in a manner consistent with the on-post remedial action.

The sulfate attenuation goal for the NBCS effluent was achieved within 5 years as reported in the 2000 FYRR (PMRMA 2000), rather than the 25 years required in the On-Post ROD. During the last FYR period, the chloride concentrations in the NBCS effluent increased slightly in 2002 due to start-up of the South Channel wells, and have since maintained a decreasing concentration trend (PMRMA 2007a). The average NBCS effluent concentrations in FY08 were 175 mg/L for chloride and 413.5 mg/L for sulfate, which are both below the respective CSRGs. The attenuation is therefore deemed to be on track in accordance with expectations (MK Environmental Services and FWENC 1996). More information regarding chloride and sulfate attenuation as it pertains to NBCS operations is provided in the FY08 OAR (PMRMA 2009).

The On-Post ROD specified that the CSRGs for chloride and sulfate were to be met at the OGITS within 30 and 25 years, respectively, of the issuance of the On-Post ROD (FWENC 1996). This means that the CSRGs will have to be met at the NBCS by 2026 for chloride and 2021 for sulfate. The CSRGs are expected to be achieved through attenuation occurring upgradient of the OGITS, consistent with the on-post remedy. The average FY08 effluent concentrations for chloride and sulfate at OGITS were 314 mg/L and 540 mg/L, respectively, which reflect a chloride level above the CSRG and a sulfate level that corresponds to the CSRG. The data indicate that attenuation for OGITS is on track to meet both CSRGs within the given timeframe.

2.6 On-Post Confined Flow System Monitoring

The On-Post ROD describes the CFS monitoring component of the ROD remedy as follows:

- *Monitoring of the CFS is to be conducted in the South Plants area, the Basin A area, and close to Basin F. Data from these wells are assessed to determine whether contaminant levels within the CFS are increasing or migrating significantly with time.*
- *Specific monitoring wells will be selected during remedial design.*

As stated in the Detailed Analysis of Alternatives Report (FWENC 1995a), the Army and Shell have conducted studies to evaluate the water quality of the deeper, confined aquifer at RMA (HLA 1994, MK Environmental Services 1994). These studies indicated that a small number of confined wells showed consistent patterns of contamination in the following areas:

- South Plants
- Basin A
- Section 26 (Basins C and F)

The Denver Formation is comprised primarily of sequences of interbedded claystone and siltstone, with interspersed and generally isolated, coarser-grained water-bearing zones. Only a few major sand beds can be correlated over significant lateral distances. These sand units are generally surrounded by fine-grained siltstones and claystones of low hydraulic conductivity. In situ and laboratory hydraulic conductivity tests conducted in these finer-grained sediments indicate very low vertical hydraulic conductivities (i.e., typically 10^{-8} centimeters per second [cm/sec] or less), and that these layers limit vertical flow through the formation. These hydraulic conductivities are less than the 10^{-7} cm/sec requirement for RCRA landfill liners. Horizontal flows and seepage velocities through even the most permeable sand units are also quite low. This information supports the conceptualization of the confined Denver Formation at RMA as a formation that has limited potential for contaminant migration, either vertically or horizontally (MK Environmental Services 1994).

The Detailed Analysis of Alternatives Report (FWENC 1995a) concluded that there is no evidence of widespread contamination in the confined aquifer. Leakage of contaminants from the UFS to the deeper CFS only occurs locally where conditions favor vertical migration. Lateral migration of contaminants that have been detected in the CFS is limited and will occur at very slow rates. The planned capping of Basin A and South Plants will reduce downward vertical gradients through reduction of water levels in the UFS, thereby reducing the spread of contaminants to and within the CFS.

A limited number of organic analytes have been detected historically at low concentrations in the confined aquifer. With few exceptions, the contaminant concentrations are low and decrease with depth. No increasing trends in organic analyte concentrations have been observed in CFS monitoring network in the past 10 years. Chloride concentrations also show stable to decreasing trends in most wells.

2.7 NDMA Monitoring and Remedial Action

The On-Post and Off-Post RODs stipulate the completion of an assessment of the NDMA plume and preparation of a study that supports design refinement for achieving NDMA remediation goals specified for the boundary groundwater treatment systems. As required by the On-Post ROD, the NBCS was modified to treat NDMA in September 1997 based on the NDMA plume assessment (RVO 1997b). A monitoring program for wells north of the NBCS was developed in the NDMA Evaluation Report (HLA 1996a). The primary objective of the evaluation was to monitor the start-up of the NDMA UV-oxidation system at the NBCS and to track the resulting changes in NDMA concentrations. Based on the results of this monitoring program, the 2000 FYRR (PMRMA 2000) recommended that part of the future NDMA monitoring program be incorporated into other existing programs (i.e., NBCS Conformance, Off-Post Exceedance, and OGITS Operational monitoring). Consequently there is no longer a need for a separate NDMA monitoring program.

2.8 Private Well Monitoring Off Post

2.8.1 Private Well Monitoring

The Private Well Monitoring Program is administered by Tri-County Health Department (TCHD) via a Memorandum of Agreement with the Army (PMRMA 1997) and summarized in the 2005 FYRR (PMRMA 2007a). Under this program, TCHD samples private wells and surface water sources in the off-post study area. The program is separate and independent from the Army administered and conducted off-post monitoring program. The primary purpose of private well monitoring is to provide water quality data to address community health concerns and communicate the effectiveness to the public related to off-post groundwater contamination.

Data from TCHD's private well monitoring program will be used to help delineate the CSRG Exceedance area. The Off-Post OU Remediation Scope and Schedule (RS/S) (HLA 1996b) stated that off-post private wells will be selected for sampling based on the following criteria:

- Available well construction data indicate the well is properly completed within one aquifer
- The well is used for domestic use
- The well is not located near other similarly completed wells that are scheduled to be sampled
- One or more of the following:
  - The well aids in defining the CSRG exceedance area.
  - The well has been requested for sampling by the owner
  - The well has indicated detections above the CSRG limit in recent sampling events.

In addition, newly installed private wells within the CSRG exceedance area and off-post CFS wells that may act as conduits for contaminants to migrate from the shallower UFS to the CFS will be sampled. (See Section 2.8.2.)

TCHD samples surface water in former gravel pits to verify that discharges to the South Platte River do not contain DIMP above 8 parts per billion. TCHD maintains a database with demographic information regarding private wells in the CSRG exceedance area.

TCHD prepares and provides a candidate sampling list based on historical data for the Remediation Venture Office (RVO), EPA, and CDPHE to review annually. In the past, sampling of up to 50 private wells took place each summer with the permission of the well owners. The list is reviewed by RVO and the other Regulatory Agencies before implementation. Currently, approximately 25 to 35 wells are sampled each year.

As new demographic information and the water quality data become available in the area of interest, they are entered into TCHD and RVO Environmental Databases. The results of the program are provided annually by TCHD to the RVO, EPA, and CDPHE. Henceforth, the private well monitoring program will be included in the Off-Post Institutional Controls Program Plan.

2.8.2 Off-Post Confined Flow System Monitoring

The 2000 FYRR (PMRMA 2000) concluded that the number of off-post CFS wells monitored as part of the Private Well Network program should be reduced based on evidence of well construction problems. The report recommended that wells 1070B, 343A, 359A, 486C, 588A, 589A, 848A, and 914B should be monitored for DIMP and that wells 1070B and 914B should also be monitored for chloroform. The 2000 FYRR recommended that this sampling should continue annually until contaminant concentrations fall below analytical reporting limits, or until the well has been sampled at least five times and the mean concentration plus two standard deviations is less than the CSRG.

A Fact Sheet entitled "Documentation of Non-Significant or Minor Off-Post ROD Change at RMA of the CFS Well Evaluation Criteria" was prepared (RVO 2001a, 2001b). Some of the wells in the Private Well Network (wells 343A, 486C, 588A, and 589A) were not available for sampling during the 2000–2004 time period. Wells 343A and 486C are not in use and permission was not given for sampling wells 588A and 589A. Since the wells could no longer be sampled and concentrations were below CSRGs, they were therefore dropped from the CFS network. In 2004, CFS wells 1171A, 376A, 544A, 545A, 548A, 848A, and 986B were added to TCHD's CFS sampling program. Wells 544A, 545A, 548A, and 848A met the criteria for discontinuing monitoring during the 2000–2005 FYR period, and wells 359A, 376A, 914B, 986B, 1070B, and 1171A met the criteria during the 2005–2010 FYR period. Thus, all the CFS wells specified in the 2001 Fact Sheet, and the wells added to TCHD's monitoring program in 2004 have met the criteria and the annual CFS monitoring may be discontinued. TCHD may still sample CFS wells at their discretion or if requested by the well owner. As stated previously, the private well monitoring program will be included in the Institutional Controls Program Plan. Further details on the Private Well Monitoring Program are provided in Appendix C.

2.9 North Plants LNAPL

The Petroleum Release Evaluation Report (TtFW 2004a) concluded light non-aqueous phase liquid (LNAPL) was present in association with groundwater beneath the former North Plants Production Area. In 2001 attempts were made to recover the LNAPL (approximately 18 gallons were recovered) and monitoring was conducted in 2003, 2004, 2005, and 2007. A pilot study on removal of LNAPL was initiated in 2009 (URS Washington Division and TtEC 2008). The wells were installed in February 2009, and monitoring began in March 2009. As of January 2010, sufficient LNAPL has not been present in the wells to commence recovery operations. The project is being performed in accordance with the *Petroleum Storage Tank Owner/Operator Guidance Document* (Colorado Department of Labor 1999).

2.10 Surface Water

Surface water quality has been monitored by collecting and analyzing data from streams, ditches, lakes, and ponds at RMA since the late 1980s. The 2008 *Surface Water Quality Monitoring Report for the Rocky Mountain Arsenal* (RVO 2008) summarizes the surface water data collected since the On-Post ROD and Off-Post ROD were signed (FWENC 1996, HLA 1995).

Surface water monitoring programs were conducted at RMA in order to meet the ROD requirements for surface water monitoring. On-post monitoring was conducted through 2009, but is no longer necessary as contaminated soil excavation for the On-Post remedy has been completed. Off-post surface water monitoring, not including storm event monitoring, will continue to be conducted in accordance with the RAOs for surface water presented in the Off-post ROD.

As reported in the 2008 *Surface Water Quality Monitoring Report for the Rocky Mountain Arsenal*, the on-post surface water sampling program shows that very little contamination is present in the surface water bodies. Most of the detected concentrations above aquatic standards have been intermittent and occur in water flowing onto RMA at sites located at the south boundary. Application of road deicers south of RMA appears to have short-term effects on the interceptors, Havana Pond and Upper Derby Lake. Increasing trends in chloride, sodium, and sulfate concentrations have been observed in the South Lakes and First Creek. Increasing concentrations of sulfate in First Creek likely are due to a combination of urban runoff south of RMA, upstream development, and groundwater discharge into the creek.

Off-post, DIMP was the only organic contaminant that affected surface water quality because of occasional discharges of the off-post shallow alluvial groundwater in the First Creek Pathway system area into First Creek. Surface water samples taken from the off-post gaging station at Highway 2 were intermittently above the Colorado Basic Standards and Methodologies for Surface Water (CBSMSWs) and CSRGs for DIMP, arsenic, chloride, fluoride, and sulfate from FY96 through FY07. The levels of chloride, fluoride, and sulfate have declined such that they are below the CSRGs. During the same time period, when on-post contaminated soil remediation and groundwater treatment were in progress, the on-post First Creek surface water sampling sites near the north boundary did not have an organic target analyte detection, but arsenic was above the CSRG. The arsenic levels above the CSRG at two sites are below background concentrations.

3.0 LONG-TERM MONITORING APPROACH

3.1 Development of Monitoring Programs

3.1.1 Monitoring History

As a result of the off-post detections of DIMP and DCPD in 1974, the state of Colorado issued three administrative orders in 1975. In response to these orders, the Army initiated a regional sampling and hydrogeologic surveillance program. Since 1974, numerous groundwater and surface water monitoring programs have been conducted at RMA. From 1975 to 1984 groundwater and surface water were monitored under the 360 Degree Monitoring Program. Starting in 1984, groundwater monitoring was conducted under the RI/FS at RMA. The RI/FS monitoring investigated the nature and extent of contamination in groundwater and surface water and continued local long-term monitoring initiated under the 360 Degree Program. Groundwater monitoring was also conducted locally around the boundary systems. The NBCS and ICS were completed in 1981 and the NWBCS was completed in 1984. All three systems were modified under the Boundary Containment System Improvements IRA beginning in 1988 and ending in 1991. In 1987, the Army separated the long-term and boundary systems monitoring from the RI/FS and initiated the Comprehensive Monitoring Program. A detailed history of the RMA groundwater monitoring programs is provided in Appendix A of the RI Summary Report (Ebasco 1992). The general objectives of these early programs were to locate source areas, define the nature and lateral and vertical extent of contamination, determine data gaps for the FS, assess effectiveness of containment systems, determine flow rates and contaminant concentrations migrating towards systems, detect off-post migration of contaminants, and establish long-term trends in contaminant levels. Specific objectives of the Comprehensive Monitoring Program (R.L. Stollar & Associates 1990) were to:

- Maintain a regional groundwater monitoring program for regulatory database and RI/FS verification.

- Maintain project groundwater monitoring for regulatory database, RI/FS verification, and system operations.
- Monitor groundwater quality and hydrology to assess changes in the rate and extent of contaminant migration and the distribution of contaminants in both on- and off-post areas.

The fall 1989 sampling event under this program was called the "benchmark" well network and provided the most complete delineation of contaminant plumes to that date. A total of 621 wells (419 UFS and 202 CFS) were sampled. A target analyte list for this program was developed through review of previous monitoring programs. In addition to the target analytes, gas chromatograph/mass spectrograph laboratory data were reviewed to assess whether new analytes should be added to the target analyte list. Analyte lists used for later sampling programs were subsets of the Comprehensive Monitoring Program target analyte list.

The internal groundwater extraction systems were installed in 1990/1991 (BANS, Basin F, Railyard, and Motor Pool) and 2000/2001 (BRES and Complex Trenches). The STF and Lime Basins mass removal systems were installed in 2006. The OGITS was installed in 1993 and the NPS modifications were installed in 2006.

The Off-Post ROD was signed on December 19, 1995, and the On-Post ROD was signed on June 11, 1996. The ROD objectives for groundwater include operating the existing on-post and off-post groundwater containment/treatment systems until shut-off criteria are met, satisfying requirements for monitoring where wastes are left in place, and providing data for the FYRs. The LTMP (FWENC 1999) selected Water Year 1994 as the baseline year used in the first FYR (2000) because it represented the most extensive sampling effort completed prior to the signing of the two RODs. In total, 678 wells were sampled for this monitoring event. With the signing of the RODs in 1995 and 1996, monitoring objectives changed from the previous programs that primarily focused on defining the nature and extent of contamination to providing data to track the remedy during and after implementation.

3.1.2 Application of Historical Information

Historical data and remedy completion status were evaluated to revise the monitoring program and meet the monitoring objectives established in the RODs. Data collected during the RI/FS and subsequent monitoring programs provide a conceptual understanding of the magnitude and direction of groundwater flow across RMA. A total of approximately 4,000 borings and 620 monitoring wells were sampled during the RI to evaluate geology, hydrogeology, and contamination at RMA. Additional sampling was conducted during the FS. Groundwater chemistry data have been used to delineate source areas and the nature and extent of contamination in areas downgradient of the contaminant sources. Chemical data are also used for evaluating the effectiveness of remedial activities including the operation of containment and mass removal systems. The monitoring well network is positioned within contaminant flow paths that were delineated through many years of groundwater monitoring. Water level measurements, geologic descriptions, and aquifer test data have been used to develop numerical groundwater models that provide further definition to the conceptual understanding of groundwater flow and contaminant migration. Over 300 aquifer tests have been conducted on post and off post near RMA. The results of these aquifer tests have been compiled from literature references and RMA documents and reports and are provided in Appendix A. This information can be used to calculate flow velocity. Groundwater flow rates, together with practical field program logistics, are used to determine appropriate sampling frequencies for each portion of the well network.

3.1.2.1 RMA Groundwater Flow Volumes and Velocities

Water level data were used in combination with hydrogeologic data to define and quantify groundwater volumes and flow rates across the site. Water levels were also used to calculate vertical hydraulic gradients and understand interactions between groundwater and surface water. The groundwater flow system at RMA can be divided into three distinct subsystems consisting of the Irondale Flow System, the First Creek Flow System, and the Central Flow System (Figure 2.2-1). The magnitude of flows ranges from approximately 1,800 gpm in the Irondale Flow System, 250 gpm in the First Creek Flow System, and approximately 50 gpm in the Central Flow System (Figure 2.2-3) (MK Environmental Services 1993a).

The groundwater average linear velocity can be used when planning a monitoring program to help determine an adequate sampling frequency to detect significant changes in groundwater chemistry with sufficient time to react to these potential changes. Estimated groundwater average linear velocities for the primary contaminant flow paths have been calculated for the site (Ebasco 1989). Average linear velocity estimates rely on assumptions that have a fairly large degree of uncertainty and give a wide range of possible average linear velocities for each flow path. Because of this uncertainty, it is conservative to assume that the faster flow rate estimates are actually occurring at the site. For example, if the travel-time estimate from the source to the monitoring network ranges from 5 to 50 years and sampling is conducted every 10 years, then some changes in groundwater chemistry could occur and not be detected if the travel time is 5 years. Because the site-wide remedy includes construction of caps and covers over large areas, it is anticipated that the hydraulic gradient and average linear velocities will be reduced in the Central Flow System, resulting in longer travel times in the future. Therefore, velocity and travel-time estimates calculated in the past provide a conservative safety factor compared to future slower flow rates and longer travel times. Average groundwater velocities and/or travel times using more recent data are estimated where appropriate to reduce/refine the wide ranges of the estimates in the 1989 Ebasco report.

South Plants Pathways

Groundwater pathways in the former South Plants have historically radiated from the centrally located water table mound in this area. The primary pathways associated with contaminant migration include the north pathway from South Plants toward Basin A and a second pathway trending southwest toward Lake Ladora.

Groundwater in the north pathway flows primarily through saturated alluvium with lesser flow through the unconfined bedrock. The alluvium is unsaturated in South Plants and the hydraulic gradient is extremely flat (Appendix A). From the north end of South Plants, where the alluvium is saturated, to the middle of Basin A, the travel time is currently estimated to be approximately 28 years (Appendix A).

Groundwater in the southwest pathway flows through both alluvium and bedrock. An estimate of the groundwater travel time between the STF Groundwater Mass Removal System and Lake Ladora was made in the Design Analysis Report (Washington Group International 2005a). The average groundwater flow velocity was estimated to range from 95 to 162 ft per year (0.26 to 0.44 feet per day [ft/day]). Over a distance of 1,200 ft downgradient of the STF Plume, the travel time was estimated to range from 7.4 to 12.6 years using hydraulic gradients in 2004 and 2005. Using the 2006 hydraulic gradient and the information provided in Appendix A, the travel time is estimated as 8.7 years.

Basin A to BANS Pathway

Contamination migration from Basin A sources and other upgradient sources occurs primarily in saturated alluvium from Basin A through Basin A Neck. The bedrock underlying the alluvium in the southwest portion of Section 36 consists of weakly cemented to unconsolidated sandstone, which has hydraulic characteristics that are similar to those of the saturated alluvium.

Groundwater in Section 36 flows through both the alluvium and bedrock. Groundwater flow in weakly cemented sandstone may have similar or slightly slower velocities. Recent data indicate that the travel time from the south end of Basin A to the BANS is approximately 20 years (Appendix A).

BANS to NWBCS Pathway

A continuation of the Basin A Neck pathway extends from beneath Basin D to the northwest boundary. Flow in this area is primarily through alluvial deposits. Saturated thickness typically is 10 ft or less; however, a north-trending channel with a saturated thickness of 20 to 30 ft is located in the western part of Section 27. Hydraulic conductivity estimates from aquifer tests near the NWBCS indicate that values of 500 to 1,600 ft/day are typical for this north-trending channel (Appendix A). The average hydraulic conductivity in the Basin A-Neck channel from two pumping tests at the BANS is 40 ft/day (Appendix A). Similar hydraulic gradients in the Basin A-Neck channel west of the BANS suggest that hydraulic conductivity is similar to the BANS estimate. The groundwater travel time from the BANS to the NWBCS is estimated to be approximately 11 years (Appendix A).

Other NWBCS Pathways

Other contaminant migration pathways from sources upgradient of the NWBCS include the South Plants West Plume (Original System), South Plants Southwest Plume (Southwest Extension), and Sand Creek Lateral Plumes (Original System). Travel times in these pathways were not evaluated in the Water RI. The travel time for the South Plants West Plume from Section 3 to the NWBCS is estimated to be approximately 3.5 years (Appendix A). For the South Plants Southwest Plume, the travel time downgradient of Lake Mary to the NWBCS Southwest Extension is estimated be approximately 2.4 years (Appendix A).

Basin F Pathway

Contaminant migration from Basin C and Basin F occurs in alluvial material and weathered bedrock. The Basin F pathway extends north to the NBCS. In the area between Basin F and the NBCS, groundwater flows primarily in coarse-grained basal alluvial sediments with substantially less flow through fine-grained alluvium and weathered bedrock. A long-term decrease in groundwater levels has resulted in lower overall flux of contaminants approaching the NBCS through a thin saturated section of coarse alluvium and finer grained alluvium and bedrock. Recent chemical trend data indicate that the travel time from Basin F to the NBCS is 5 to 6 years (see Appendix A). Based on a linear velocity calculation, the travel time from Basin F to the NBCS is estimated to be about 6 years, with excellent agreement for the two travel time estimates for this pathway (Appendix A).

North Plants Pathway

The travel time from North Plants to the NBCS was not estimated in the Water RI; however, it is estimated to be approximately 6 years based on the information included in Appendix A.

Western Tier Pathway

Contaminant migration from the Railyard and Motor Pool areas occurs in coarse-grained alluvial sand and gravel. Contaminants flow towards the RYCS extraction wells where they are treated and then returned to groundwater through two recharge wells.

Using hydraulic conductivity data from aquifer tests in wells located in or near the groundwater flow path, the travel time from the RYCS to the RMA boundary is estimated to range between 2.5 and 3.1 years (Appendix A).

Off-Post First Creek and Northern Pathways

Contaminant migration in the Northern pathways occurs in fine- to coarse-grained sands that comprise most of the saturated alluvium, overlain by finer grained materials (silts or silty or clayey sands). Contaminant migration in the First Creek pathway occurs in coarser grained sands interfingered with lenses or layers of finer grained silts, silty sands, or clayey sands.

The average linear velocity in the Northern pathway is estimated to be 3.3 ft/day using an estimated hydraulic conductivity of 176 ft/day and hydraulic gradient of 0.005. The travel time from the NBCS to the Northern pathway portion of OGITS is estimated to be 5.2 years. The travel time from the NPS to the South Platte River, which is a distance of 2.3 miles, is estimated to range from 3 to 9 years (Appendix A).

Average linear velocity in the First Creek pathway is estimated to be 3 ft/day using an estimated hydraulic conductivity of 130 ft/day and hydraulic gradient of 0.005. The travel time from the NBCS to the First Creek portion of OGITS is estimated to be 2.9 years. The travel time from the FCS to the South Platte River, which is a distance of 2.7 miles, is estimated to range from 2.5 to 11 years (Appendix A).

The hydraulic conductivity values estimated from the aquifer test data fall within the range reported for unconsolidated silty sand to clean sand aquifers (HLA 1990). Total groundwater flows through the First Creek and Northern pathways have been estimated at 130 and 200 gpm, respectively. As mentioned previously, aquifer test results are compiled in Appendix A.

3.1.2.2 Historical Groundwater Modeling Summary

Several groundwater models have been applied for a variety of purposes at RMA. A summary of different models and their respective applications is provided in Table 3.1-1.

Table 3.1-1. Groundwater Model Applications and References

Model	Application	Reference
Preliminary Recharge Estimates for the RMA Regional Flow Model	Regional Model for RMA	MK Environmental Services 1987
Regional Groundwater Flow Model	Regional Model for RMA	HLA 1990
South Plants/Basin A Numerical Groundwater Flow Model	Evaluation of South Plants/Basin A groundwater control alternatives	FWENC 1995b
NBCS Numerical Groundwater Flow Model	Evaluation of long-term NBCS operations	Warner 1999
Bedrock Ridge Analytical Model	Bedrock Ridge Extraction System design	Morrison Knudsen Corporation 1999
Basin A Groundwater Numerical Flow Model	Design of Complex Trenches dewatering system	RVO 1997c
Off-post FS Models—North and Northwest Areas Numerical Models	Evaluation of off-post remedial alternatives	HLA 1992
South Tank Farm and Lime Basins Analytical Models	Design of South Tank Farm and Lime Basins mass removal systems	RVO 2005

3.1.3 Groundwater Program Changes

During the 2005 FYR process several issues were identified for resolution in the LTMP or associated documents. Some of these changes will require formal modification of the RODs. These recommended changes are summarized in Table 3.1-2.

Table 3.1-2. Recommended Groundwater Program Changes*

Item #	Item	Reasons for Change	Explanation of Change
1	Shut-Off Criteria	ROD shut-off criteria allow differing interpretations. The same ROD criteria, however, applied to all systems and required extraction well shut-off monitoring.	New criteria identify the shut-off process which allows flexibility for defining the starting points for shut-off monitoring and monitoring frequencies, and removes the On-Post ROD requirement for extraction well monitoring are included in the LTMP.
2	Practical Quantitation Limit (PQL)	The PQL is defined in the On-Post ROD as "current certified reporting limit or practical quantitation limit readily available from a certified commercial laboratory," and in the Off-Post ROD as "PQL attainable by the U.S. Army." Concerns that normal fluctuations in laboratory data can effect the PQL when set at the reporting level, as well as method sensitivity issues and errors, highlighted the need to re-evaluate the current approach for establishing PQLs.	A standardized approach will be used to establish PQLs for the compounds that have method reporting limits (MRLs) greater than the CSRGs. See Section 10.2 for additional detail.
3	Fluoride Standard	The purpose of the off-post remedy was to: "1) reduce groundwater concentrations, (2) reduce risk to human health and the environment, and (3) reduce the potential human exposure to contaminated UFS groundwater." The potential risks to ecological receptors were shown to be negligible—"(t)he results of the direct toxicity evaluation indicated no potential adverse impacts ... to cattle from ingestion of contaminated soil or groundwater." The Off-Post ROD also recognized the changing land use and concluded that "(r)ural residential (including agricultural) land use is expected to decrease in the Offpost OU...." These expectations have become realized with residential development and rezoning to non-agricultural uses occurring along the boundaries. Despite these conclusions, and unlike any other CSRG in the off-post ROD, the agricultural, rather than the human health CBSG, was selected for fluoride. There is no basis for this selection in the administrative record. In all documentation leading to the Off-Post ROD the 4.0 mg/L human health-based criterion for fluoride was consistently presented. Given the evolving land use patterns and the absence of risk to livestock documented in the Off-Post Endangerment Assessment/Feasibility Study (HLA 1992) and again in the ROD, the 2 mg/L agricultural fluoride standard to a standard that reflects current use patterns. Since the groundwater north of RMA has never been formally designated by the Water Quality Control Commission and the area is undergoing extensive development, a change to the human health CBSG will be made.	A change in the fluoride CSRG from the agricultural limit of 2 mg/L to the human health limit 4.0 mg/L will be made for the OGITS and NBCS operations.
4	On-Post Surface Water Monitoring	On-post surface water quality monitoring is no longer necessary as contaminated soil excavation for the on-post remedy has been completed.	On-post surface water quality monitoring will be discontinued with the implementation of this LTMP.

* These program changes do not go into effect until the formal ROD change documents have been approved (shut-off criteria and fluoride standard).

3.2 Monitoring Categories

In the 1999 LTMP, seven monitoring categories were defined to meet the ROD requirements for monitoring and to support data evaluation. These categories were amended by the WRCP (FWENC 2003a). The categories developed for monitoring the performance of the containment and mass removal systems are discussed under system monitoring in Section 3.2.1. The other monitoring categories are grouped under site-wide monitoring and discussed in Section 3.2.2. These sections describe the monitoring activities performed for the LTMP monitoring categories, and describes the changes resulting from the implementation of the monitoring programs and networks established in this LTMP. Any future needs for changes to the LTMP monitoring networks will be addressed through a consultative process with the Regulatory Agencies and documented in updates to the LTMP.

3.2.1 System-Related Monitoring Categories

The 1999 LTMP (FWENC 1999) defined four different monitoring categories for containment and treatment system monitoring, i.e., compliance, conformance, shut-off monitoring, and operational monitoring. The effluent compliance monitoring and operational monitoring categories for the on-post and off-post containment, mass removal, and treatment systems are retained without any change in application, but the definition of the operational monitoring has been simplified. So far, performance monitoring has only been associated with the conformance monitoring downgradient of the system. With the revised monitoring program, the performance monitoring concept is being expanded to include other monitoring to evaluate system performance. The 2005 FYRR (PMRMA 2007a) recommended that more detailed and objective extraction well and system shut-off criteria be proposed as part of the revisions to the LTMP. In response to this recommendation, the shut-off monitoring definition was revised. Two categories were added: a pre-shut-off monitoring category to assist in the shut-off decision and a post-shut-off monitoring category to ensure that potential changes in water quality after shut-off would be detected. Another change to the existing program is the elimination of the potential shut-off monitoring wells category. Wells previously included in this category have been included in other LTMP monitoring categories. The following revised system-related monitoring categories will become effective upon implementation of this revised LTMP:

- *Compliance Monitoring*: Effluent water quality monitoring conducted to confirm that CSRGs are met by on-post and off-post treatment systems.
- *Performance Monitoring*: Water level and water quality monitoring performed to measure performance against specific criteria. The new category includes the previous conformance monitoring category.
- *Operational Monitoring*: Monitoring of containment system extraction wells and monitoring wells located near the systems to optimize system performance and ensure that RAOs are met. The operational monitoring program is flexible with respect to monitoring locations, frequencies, and chemical analyses to allow for quick operational responses to changing needs. The operational monitoring programs are updated through the respective system Operations and Maintenance (O&M) Plans and are not included in the LTMP.
- *Pre-Shut-Off Monitoring*: Monitoring or operational activities to confirm that shut-off should proceed and that the shut-off monitoring program should be initiated. Program will be designed for each specific system.
- *Shut-Off Monitoring*: Water quality monitoring at or near systems that have met shut-off criteria. Program will be designed for each specific system.

- *Post-Shut-Off Monitoring*: Monitoring to track groundwater levels, flow directions, and contaminant trends after successful completion of the shut-off monitoring program and termination of system operation. Program will be designed for each specific system.

3.2.2 On-Post and Off-Post Site-Wide Monitoring Categories

The on-post and off-post site-wide monitoring categories included in the long-term monitoring program and performed to support the RMA remedy are described below. These were identified in the 1999 LTMP with the exception of water quality tracking, a category that was added during the development of the WRCP (FWENC 2003a). All the existing site-wide monitoring categories are retained. However, the former tracking category is renamed water level tracking to distinguish this category from water quality tracking that was added in the WRCP (FWENC 2003a). Also, the definition of the water level tracking has been revised to distinguish between the on-post and off-post programs and reflect the fact that the lake level maintenance requirement for South Lakes was removed through an ESD (TtEC 2006b). The revised site-wide monitoring categories are as follows:

- *Water Level Tracking*: On-post water level monitoring used to track the effects of the soil remedy to groundwater in the On-Post OU.
- *Water Quality Tracking*: On-post water quality monitoring of indicator analytes to track contaminant migration in and downgradient of source areas within the identified plumes. (See Section 6.1 for details on indicator analytes)
- *Confined Flow System Monitoring*: Monitoring as required by the On-Post ROD requirement to continue to monitor water quality in the confined aquifer in three areas—Basin A, South Plants, and Basin F.
- *Exceedance Monitoring*: Long-term water quality monitoring of off-post groundwater to assess contaminant concentration reduction and remedy performance and to create groundwater CSRG exceedance area maps to support well permit institutional controls.
- *Off-Post Water Level Monitoring*: Water level monitoring off post conducted in support of the exceedance monitoring to assess flow paths for contaminant migration in the exceedance areas.
- *Surface Water Monitoring*: Off-post and on-post surface water monitoring to assess changes in surface water quality related to the RMA remedy.

3.3 Consultative Process

In many cases a consultative process between the RVO and the Regulatory Agencies will be used in the decisions related to the monitoring programs. One of the purposes of the consultative process is to ensure that the parties are aware of detrimental or potentially detrimental conditions and agree upon the actions required. If such a condition is identified, the RVO will initiate the consultative process with communication to the Regulatory Agencies. If any of the Regulatory Agencies identify such a condition, they may also initiate the consultative process with the other parties. The consultation may be an exchange of e-mails, written notification, or a meeting that may include a site inspection, followed up with written documentation for the record. Non-routine actions will be performed after the parties agree on the action. Examples of scenarios that call for application of the consultative process are as follows:

- **Effluent CSRG Exceedance:** Agencies will be notified of any effluent CSRG exceedance.
- **Major Non-Routine Events:** These are events, such as missed sample collection, inability to collect data, data quality problems, missed report deadlines, or extended system breakdowns, that have the potential for affecting effluent compliance.
- **Unresolved Performance Issues:** The Regulatory Agencies will be notified of problems with meeting the applicable performance criteria for each extraction and treatment system.
- **System Shut-Off:** The consultative process will be applied to reach the shut-off decision and in developing the pre-shut-off, shut-off, and post-shut-off monitoring programs.

Specific scenarios that call for consultation are identified for each system and monitoring program in the respective subsections within Sections 4, 5, and 6. Consultation triggers are presented in tables that include notification schedules and identify the type of consultation.

If the parties cannot reach consensus, the Dispute Resolution Process will be utilized consistent with the Federal Facility Agreement.

4.0 SYSTEM-RELATED MONITORING PROGRAMS

This section presents the groundwater monitoring plan for the RMA containment and mass removal systems. Section 3.2 defined the system-related monitoring categories for the systems. There are three routine monitoring categories associated with the systems, i.e., compliance, performance, and operational monitoring. Additionally, pre-shut-off monitoring, shut-off monitoring, and post-shut-off monitoring apply to systems that are considered for or have been shut off. The relationship between and requirements for the routine monitoring categories can be summarized as follows:

- **Compliance Monitoring**: Effluent water quality monitoring conducted to confirm that CSRGs are met by on-post and off-post treatment systems.
  - Compliance will be based on running averages for the last four quarters or one annual sample for those analytes that are not sampled quarterly.
  - The effluent data are presented in Quarterly Effluent Reports and Annual Summary Reports.
  - Any effluent Exceedance would result in initiation of the consultative process.
- **Performance Monitoring**: Water level and water quality monitoring performed to measure performance against specific performance criteria defined for each system.
  - System performance evaluations are performed annually and reported in Annual Summary Reports.
  - Some performance information, such as reverse hydraulic gradient data, will be presented in the Quarterly Effluent Reports.

- Performance issue notifications will occur and be reported according to the schedules outlined by the consultative process. All performance issues will be summarized in the Annual Summary Reports.
- If measures to address the performance issues fail or if none of the primary or secondary performance criteria are met, the consultative process will be utilized according to the (revised) performance criteria.

- **Operational Monitoring**: Monitoring of extraction, recharge, and/or monitoring wells located near the systems to optimize system performance and ensure that system objectives are met.
  - Flexible operational monitoring programs developed separately from the LTMP allow for system adjustments in response to changing conditions and result in consistent, reliable performance.
  - Operational monitoring data were used in the selection of the Performance Monitoring Networks to ensure adequate coverage for assessing performance criteria.
  - Essential operational data, such as plant availability, major maintenance, and reverse hydraulic gradient information, are reported in the Quarterly Effluent Reports
  - Essential operational data, such as plant availability, major maintenance, and reverse hydraulic gradient information, and water quality data are reported in the Annual Summary Reports.

General descriptions of the routine system-related monitoring categories are presented in Section 4.1, which also includes a description of how and when the consultative process will be used in decision making. The criteria for development of a routine CSRG analyte list are presented in Section 4.2. System performance criteria and monitoring programs for the groundwater containment and mass removal systems are presented in Sections 4.3 through 4.8, where the development and application of criteria and monitoring well networks for each system are addressed in separate subsections. Each of these subsections includes the following additions, modifications, and revisions to the established requirements and criteria:

- Detailed performance criteria that meet the system objectives.
- Routine CSRG analyte list developed based on common criteria.

The system shut-off criteria, decision process, and monitoring categories are presented in Section 4.9 for both the containment and mass removal systems.

It should be noted that this plan does not include the operational monitoring programs that are included in the O&M manuals for the respective systems.

4.1 System Monitoring—General Approach

The system monitoring programs were developed to evaluate system performance against the ROD requirements and objectives. This LTMP provides system-specific criteria and decision processes that are used in annual and Five-Year Summary Report (FYSR) evaluations.

4.1.1 Consultative Process

As described in Section 3.3, a consultative process between the RVO and the Regulatory Agencies will be used to address non-routine events. Specific scenarios that call for consultation are identified for each system and monitoring program in the respective subsections. Consultation triggers are presented in tables that include notification schedules and specify the consultative process components.

4.1.2 Compliance Monitoring

Compliance monitoring is water quality monitoring performed for all treatment system effluents at RMA. Each system has a list of compliance analytes for which CSRGs were developed in the On-Post and Off-Post RODs. The system effluents will be analyzed quarterly using the routine CSRG analyte lists, described in Section 4.2, and annually using the complete ROD CSRG lists.

4.1.2.1 Compliance Objective and Criteria

The effluent compliance objective for the RMA treatment systems is as follows:

- The concentrations of the CSRG analytes in the treatment system effluent must not exceed the CSRGs and PQLs identified for the system.

The performance criterion for meeting the compliance objective is:

- Demonstrate effluent meets CSRGs or applicable PQLs for system-specific CSRG analytes.

4.1.2.2 Compliance Decision Rules

Running averages will be used to evaluate effluent compliance. The running averages for each analyte will be based on four consecutive sets of quarterly compliance data. An effluent exceedance is defined as follows:

- If the running average of four sets of quarterly data for a CSRG list analyte exceeds its CSRG or PQL, this calculated average constitutes an effluent exceedance.
- If the annual concentration for a non routine CSRG analyte exceeds its CSRG/PQL, this value constitutes an effluent exceedance.
- One-time exceedances of quarterly or annual sample data will trigger notification of the Regulatory Agencies in accordance with the consultative process identified for the treatment systems and will be addressed with the appropriate operational response including confirmatory sampling and system adjustments as necessary.

4.1.3 Performance Monitoring

Performance monitoring is conducted in wells upgradient and downgradient of the containment and mass removal systems to evaluate system performance against established performance criteria and objectives. The performance criteria are specific to each system and depend on whether it is a containment or mass removal system and the location of the system. Depending on the criteria, performance monitoring includes water quality monitoring for all systems and in most cases water level monitoring. In some cases operational wells are included in the performance monitoring networks as well, thereby serving a dual purpose.

4.1.4 Operational Monitoring

Operational water level and/or water quality monitoring is conducted in extraction, recharge, and monitoring wells located near the containment or mass removal systems under the O&M program. Operational water quality monitoring is also conducted for the system influent and at sampling points within the system. Operational monitoring is conducted to:

- Optimize system performance.
- Ensure that RAOs are achieved.

Most of the wells are used for water level monitoring to ensure proper extraction and recharge system operation; selected wells are also used for water quality monitoring of indicator analytes. These monitoring data are used to evaluate and adjust the system to ensure optimal operation for containment, capture, and treatment. As operating conditions change, the operational monitoring program may also change. Therefore, the operational monitoring program is flexible with respect to monitoring locations, frequencies, and chemical analyses and is not modified as part of the LTMP. Operational monitoring data will continue to be evaluated and presented in the Annual Summary Reports. Relevant information from these reports will be included or summarized in FYRRs.

4.2 Routine CSRG Analyte Selection Criteria

The ROD CSRG analyte lists comprise the compliance standard that the systems are measured against. However, since many of the analytes on these lists are no longer detected and have not been detected for some time at or near the systems, it was determined that monitoring for all CSRG analytes at the current frequency is unnecessary. A routine CSRG analyte list to be used for routine compliance monitoring at the current quarterly monitoring frequency was developed for each system. The same routine CSRG list is used for annual performance water quality monitoring. To ensure that CSRG analytes do not reappear and to confirm compliance, the entire CSRG analyte list will continue to be analyzed once a year. Analytes that reappear at levels above their CSRGs or PQLs will be added back into the routine CSRG analyte list. The routine CSRG analyte lists may be re-evaluated as part of the 5-year reviews. The evaluation will be presented in the FYSRs and summarized in the FYRR.

An extensive review of historical data was conducted for the groundwater mass removal and containment systems in this plan to determine whether any changes in groundwater quality composition that have occurred since the implementation of the RODs support changing the analytes used for routine compliance monitoring. The analyte selection process presented below was developed to ensure a consistent approach for the evaluation and selection of CSRG list analytes for routine monitoring. It includes the input parameters considered in the screening process, and outlines the data review and decision processes and the final selection and documentation of the routine CSRG analyte list. The screening process is applied for each of the systems described in Section 4. The following subsections identify the parameters used in the review and screening of the ROD CSRG lists as well as the decision process for developing the routine CSRG analyte lists.

The CSRG analyte selection process presented in this document was developed utilizing existing networks and monitoring data. The resulting routine CSRG analyte lists will be initiated by performing one sampling event that includes sampling for the entire CSRG analyte list in all the upgradient performance water quality wells for each of the systems. If the concentration of an analyte is above the CSRG then the routine CSRG analyte list will be revised to include the analyte.

If further changes to the routine CSRG analyte lists are to be considered in the future, a new approach that utilizes upgradient performance water quality data would be developed and the consultative process would be applied to the evaluation process. The LTMP would be updated to reflect any revisions to the analyte lists.

4.2.1 CSRG Analyte Screening Input Parameters

For the screening process used to develop the routine CSRG analyte lists presented in this document, input parameters were carefully selected to ensure a consistent approach for the CSRG analyte screening between the different containment and mass removal systems. For each system, the ROD CSRG list was the starting point for the review. Treatment plant influent data, extraction well data, and upgradient monitoring well data for each system from the 5-year period FY02–FY06 were evaluated to establish the respective routine CSRG lists. The resulting analyte lists are presented in the respective subsections for each system and the approach and evaluation and analyte selection process is documented in a White Paper (in preparation).

4.3 Northwest Boundary Containment System

The NWBCS is a containment system designed to prevent the off-post migration of contaminated groundwater (USACE 1985). The ROD established CSRGs for the NWBCS effluent for eight contaminants potentially present in the groundwater migrating toward the northwest boundary. The ROD CSRG analytes are presented in Table 2.3-1. In the discussion of performance objectives and criteria below, the NWBCS is divided into the following three components with different monitoring objectives:

- NWBCS Original System: The original extraction system and 1,425 ft of slurry wall installed in 1984.
- NWBCS Northeast Extension: The extraction wells and 665 ft of slurry wall installed in 1990 as part of the Short-Term Improvements IRA at the northeast end of the system (MK Environmental Services 1990b).
- NWBCS Southwest Extension: The extraction and recharge systems installed as part of the Short-Term Improvements IRA in 1991 to address dieldrin contamination southwest of the original containment system. An additional extraction well was installed in 1996. No slurry wall is present in this area.

The existing system performance objective for the NWBCS is defined as follows:

- Prevent off-post migration of contaminated groundwater through containment and capture of contaminated water migrating toward the northwest boundary.
- The performance criteria developed to ensure that each system component meets the NWBCS performance objectives are presented in Sections 4.3.1 through 4.3.3.

Refer to Section 4.9 regarding the inclusion of potential BANS modifications in the shut-off evaluation for NWBCS.

4.3.1 NWBCS Original System

The Original System consists of 15 extraction wells, 21 recharge wells, and a 1,425-ft-long slurry wall. The slurry wall extends across a portion of the system (from wells 22311 through 22315) and the hydraulic barrier only portion extends from wells 22301 through 22310. The recharge wells are located northwest (downgradient) of the extraction wells and slurry wall. The combined system creates a reverse (counter-regional) hydraulic gradient to contain the contaminant plumes.

Dieldrin and chloroform are the primary contaminants in the Original System. In FY06 dieldrin and chloroform were detected at or above the PQLs/CSRGs in seven of the nine operating extraction wells and isodrin was detected above the CSRG in one extraction well (22315) (PMRMA 2007a).

4.3.1.1 Performance Criteria and Consultation

The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for the NWBCS Original System were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 4.3-1. For the NWBCS Original System, the performance criteria are presented below.

Primary Performance Criteria:

- Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.
- Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

Secondary Performance Criterion:

- If unable to maintain reverse hydraulic gradient due to factors beyond RVO control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends, based on annual evaluations, over the previous period of at least 5 years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

4.3.1.2 Performance Monitoring Decision Rules

The performance monitoring decision rules that will be applied to the performance monitoring data are presented below.

Decision

- Are reverse hydraulic gradients maintained between the performance monitoring points in the extraction and recharge well alignments at levels greater than zero?
- Do flow directions and water quality data confirm that plume-edge capture is maintained?
- If either of the above is not achieved, are concentrations of CSRG analytes at or below CSRGs/PQLs or decreasing in downgradient performance wells?

Inputs to the Decision

Required information to support the decision elements includes the following:

- Water level data for the water level (including reverse gradient) performance wells
- Water quality data for downgradient performance wells
- Water quality and water level data from operational monitoring wells
- Statistical trend analysis using the Mann-Kendall test if conclusions cannot be drawn based on visual observations

Study Boundaries

- Spatial study boundaries are defined by the water level and water quality performance wells.
- Analytes are limited to the NWBCS ROD CSRG analyte list.
- Monitoring frequencies are quarterly for water level performance wells and annual for water quality performance wells.

Decision Rule

1. If the quarterly performance evaluation shows loss of reverse hydraulic gradient or plume-edge capture, the issue will be addressed through the consultative process identified in Table 4.3-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the quarterly performance evaluation shows that the primary performance criteria are met, i.e., the reverse hydraulic gradient and plume-edge capture criteria have been consistently met, and measured water levels and water quality in performance wells confirm plume-edge capture, the containment system is functioning as intended.
3. If the performance evaluation shows that either of the primary criteria is not met, the secondary criterion is used to assess system performance by evaluating water quality trends in downgradient performance wells over a minimum of 5 years. If the performance evaluation shows that the secondary performance criterion, i.e., decreasing concentration trends or concentrations are at or below CSRGs/PQLs in downgradient performance wells is met, the containment system is effective.

Limits on Decision Errors

Potential error tolerance, based on method errors, will be included in the data evaluation as needed. The Post-Laboratory Data Validation procedure will be applied to any outliers (RVO

2007). The cumulative errors involved in water level monitoring will be considered during evaluation and discussion of monitoring data.

Table 4.3-1. Application of Consultative Process for NWBCS Original System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs	Quarterly (water quality)	Within 30 days of data being accepted	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Quarterly, semiannual, annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—reverse hydraulic gradient for one quarter	Quarterly (water level)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, graphs, etc., actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, status of reverse hydraulic gradient, potential for additional reverse hydraulic gradient monitoring, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem. Third consecutive quarter: If reverse hydraulic gradient issue is not resolved through follow-up actions, and restoration of the reverse hydraulic gradient is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues. If consensus decision is that restoration of the reverse hydraulic gradient is beyond RVO control, a review of all performance criteria and potential revision to the associated performance monitoring programs will be triggered and included in a Non-Routine Action Plan with schedule to address the performance issue.

Table 4.3-1. Application of Consultative Process for NWBCS Original System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Loss of primary performance criterion—plume-edge capture	Quarterly (water level)/Quarterly (water quality)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, graphs etc., actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, status of plume-edge capture, potential for additional plume-edge capture monitoring, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem. Third consecutive quarter: If plume-edge capture issue is not resolved through follow-up actions, and restoration of the plume-edge capture is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues. If consensus decision is that restoration of the plume-edge capture is beyond RVO control, a review of all performance criteria and potential revision to the associated performance monitoring program will be triggered and included in a Non-Routine Action Plan and schedule to address the performance issue.
Loss of secondary performance criterion— downgradient concentration trends increasing while primary criteria are met	Annual (water quality)	Within 30 days of determination	Annual evaluation period: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, present supporting data (for example, confirmatory sampling), graphs, etc., potential causes, actions taken and results to date, status of reverse hydraulic gradient and plume-edge capture, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.

Table 4.3-1. Application of Consultative Process for NWBCS Original System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Treatment system issues that could potentially affect compliance Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Extraction or recharge system problems that could potentially affect system performance Examples of extraction/recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Indication of irreversible plugging of recharge system; evaluation period runs 6 weeks from problem identification.	Per event	Within 7 days of completion of process evaluation	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

4.3.2 NWBCS Northeast Extension

The Northeast Extension was installed in 1990 and consists of a 660-ft extension of the Original System slurry wall and extraction wells 22316 and 22317, which were installed to intercept a small northwest-trending alluvial channel. Additional recharge wells were not installed because the groundwater flow turns to the southwest and travels between the Original System recharge wells and slurry wall, and is captured at the southwest end of the slurry wall in well 22309 (MK Environmental Services 1990b, MK Environmental Services 1993b, PMRMA 2007a). Thus, maintaining a reverse hydraulic gradient is not required for this portion of the NWBCS. Dieldrin is the primary contaminant at the Northeast Extension. In FY06, only well 22317 was operating continuously and dieldrin and isodrin were detected in this well at concentrations above their respective CSRGs/PQLs. Well 22316 was operated intermittently at a low flow rate because the alluvial saturated zone is very thin or nonexistent.

4.3.2.1 Performance Criteria and Consultation

The Northeast Extension extraction wells of the NWBCS do not have corresponding recharge wells opposite the slurry wall; therefore, hydraulic capture is the performance measure instead of reverse hydraulic gradient. The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for the NWBCS Northeast Extension were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 4.3-2. The table also includes operational trigger events that could potentially result in a compliance or performance issue. The performance criteria for the NWBCS Northeast Extension are presented below.

Performance Criteria:

- Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.
- Demonstrate decreasing concentration trends or that concentrations are at or below CSRGs/PQLs in downgradient performance wells.

4.3.2.2 Performance Monitoring Decision Rules

Decision

- Do water levels and water quality in upgradient and downgradient performance wells confirm that plume capture is achieved?
- Are concentrations of CSRG analytes at or below CSRGs/PQLs or decreasing in downgradient performance wells?

Inputs to the Decision

Required information to support the decision elements includes the following:

- Water level data for upgradient and downgradient performance wells

- Water quality data for upgradient and downgradient performance wells
- Water quality and water level data from operational monitoring wells

Study Boundaries

- Study boundaries are defined by the water level and water quality performance wells.
- Analytes are limited to the NWBCS ROD CSRG analyte list.
- Monitoring frequencies are quarterly for water level performance wells and annual for water quality performance wells.

Decision Rule

1. If the quarterly performance evaluation shows lack of plume capture or downgradient concentration trends are increasing, the issue will be addressed through the consultative process identified in Table 4.3-2. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the quarterly performance evaluation shows that measured water levels and water quality data confirm plume capture AND
3. If the annual performance evaluation shows that the water quality in downgradient wells demonstrates decreasing concentration trends or that concentrations are at or below CSRGs/PQLs in downgradient performance wells, the containment system is functioning as intended.

Limits on Decision Errors

Potential error tolerance, based on method errors, will be included in the data evaluation as needed. The Post-Laboratory Data Validation procedure will be applied to any outliers (RVO 2007). The cumulative errors involved in water level monitoring will be considered during evaluation and discussion of monitoring data.

Table 4.3-2. Application of Consultative Process for NWBCS Northeast Extension

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs	Quarterly (water quality)	Within 30 days of data being accepted	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Quarterly, semiannual, annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—plume capture	Quarterly (water levels)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, graphs etc., actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, status of plume capture, potential for additional plume capture monitoring, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem. Third consecutive quarter: If plume capture issue is not resolved through follow-up actions, and restoration of the plume capture is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.

Table 4.3-2. Application of Consultative Process for NWBCS Northeast Extension

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Loss of primary performance criterion—downgradient concentration trends increasing	Quarterly (water quality)	Within 30 days of determination	First quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, present supporting data (for example, confirmatory sampling), graphs, etc., potential causes, actions taken and results to date, status of plume capture, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem, which may include increased sampling frequency. Second quarter: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.
Treatment system issues that could potentially affect compliance Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Extraction or recharge system problems that could potentially affect system performance Examples of extraction/recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Indication of irreversible plugging of recharge system; evaluation period runs 6 weeks from problem identification	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

Table 4.3-2. Application of Consultative Process for NWBCS Northeast Extension

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

4.3.3 NWBCS Southwest Extension

The Southwest Extension was installed in 1991 and consists of four extraction wells and four recharge wells located southwest of, and separate from, the Original System, which were installed to intercept a separate dieldrin plume. There is an uncontaminated zone between the Southwest Extension and Original System plumes. The recharge wells were installed in this uncontaminated zone cross-gradient of the extraction wells to prevent the Southwest Extension and Original System plumes from shifting away from their respective extraction systems. Consequently, the Southwest Extension has a hydraulic capture system design. Dieldrin is the only contaminant at the Southwest Extension, but dieldrin concentrations have been below the PQL in all four extraction wells and the associated upgradient and downgradient monitoring wells since 2004.

4.3.3.1 Performance Criteria and Consultation

The Southwest Extension of the NWBCS does not have downgradient recharge wells; therefore, hydraulic capture is the performance measure instead of reverse hydraulic gradient. The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for the NWBCS Southwest Extension were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 4.3-3. The table also includes operational trigger events that could potentially result in a compliance or performance issue. The performance criteria for the NWBCS Southwest Extension are presented below.

Performance Criteria:

- Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.
- Demonstrate decreasing concentration trends or that concentrations are at or below the CSRGs/PQLs in downgradient performance wells.

4.3.3.2 Performance Monitoring Decision Rules

Decision

- Do water levels and water quality in upgradient and downgradient performance wells confirm that plume capture is achieved?
- Does water quality in downgradient wells demonstrate decreasing concentration trends or that concentrations are at or below the CSRGs/PQLs?

Inputs to the Decision

- Required information to support the decision elements includes the following:
- Water level data for upgradient and downgradient performance wells
- Water quality data for upgradient and downgradient performance wells

- Water quality and water level data from operational monitoring wells

Study Boundaries

- Study boundaries are defined by the water level and water quality performance wells.
- Analytes are limited to the NWBCS ROD CSRG analyte list.
- Monitoring frequencies are quarterly for water level performance wells and annual for water quality performance wells.

Decision Rule

1. If the quarterly performance evaluation shows lack of plume capture or downgradient concentration trends are increasing, the issue will be addressed through the consultative process identified in Table 4.3-3. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the quarterly performance evaluation shows that measured water levels and water quality data confirm plume capture AND
3. If the annual performance evaluation shows that the water quality in downgradient wells demonstrates decreasing concentration trends or that concentrations are at or below CSRGs/PQLs in downgradient performance wells, the containment system is functioning as intended.

Limits on Decision Errors

Potential error tolerance, based on method errors, will be included in the data evaluation as needed. The Post-Laboratory Data Validation procedure will be applied to any outliers (RVO 2007). The cumulative errors involved in water level monitoring will be considered during evaluation and discussion of monitoring data.

Table 4.3-3. Application of Consultative Process for NWBCS Southwest Extension

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs	Quarterly (water quality)	Within 30 days of data being accepted	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Quarterly, semiannual, annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—plume capture	Quarterly (water levels) /Quarterly (water quality)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, graphs, etc., actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, status of plume capture, potential for additional plume capture monitoring, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem. Third consecutive quarter: If plume capture issue is not resolved through follow-up actions, and restoration of the plume capture is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.

Table 4.3-3. Application of Consultative Process for NWBCS Southwest Extension

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Loss of primary performance criterion—downgradient concentration trends increasing	Annual (water quality)	Within 30 days of determination	Annual evaluation period: E-mail notification that includes description of issue with supporting data (for example, confirmatory sampling), graphs, etc., potential causes, actions taken to date to correct problem, status of plume capture, and proposed actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.
Treatment system issues that could potentially affect compliance Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.

Table 4.3-3. Application of Consultative Process for NWBCS Southwest Extension

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Extraction or recharge system problems that could potentially affect system performance Examples of extraction or recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Indication of irreversible plugging of recharge system; evaluation period is 6 weeks of problem identification	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

4.3.4 NWBCS Monitoring Networks

The well networks and monitoring frequencies presented below are intended to provide data to evaluate system performance and changes in upgradient concentrations that could affect system performance, as well as provide data for shut-off evaluations. As discussed in Section 4.9, a consultative process between the RVO and Regulatory Agencies will be used to determine the shut-off monitoring requirements.

The monitoring needs for each of the NWBCS components identified in Section 4.3 are discussed separately below. Common features of the system monitoring programs are:

- Downgradient, cross-gradient, and upgradient water level and water quality performance monitoring.
- Upgradient water quality monitoring for plume tracking to monitor flowpaths directed toward the system.

The downgradient component of the performance monitoring category replaces and is similar to the conformance monitoring category included in the 1999 LTMP. The downgradient performance monitoring well networks were developed and are listed below for each component of the NWBCS and the monitoring frequency is annual for the analytes indicated.

The cross-gradient component of the performance monitoring category formerly was addressed solely by the Operational Monitoring Program. Cross-gradient wells are included in the performance category to aid the evaluation of plume capture.

The upgradient component of the performance monitoring category changes the current operational emphasis of monitoring the operating extraction wells, whose water quality may be affected by flow from the recharge wells in the hydraulic barrier portion of the Original System or dilution caused by the large area of influence of the Southwest Extension extraction wells, to monitoring upgradient monitoring wells that are more representative of upgradient plume concentrations where practical. Although the Northeast Extension extraction wells are not influenced by the recharge system, an upgradient monitoring well is selected for consistency with the other portions of the system. The operating extraction wells may be monitored under the Operational Monitoring Program to augment the information from the upgradient performance wells. The upgradient performance wells are listed in the sections below and the monitoring frequency is annual for the analytes indicated.

Wells included in the water quality tracking category upgradient of the NWBCS are used to track the concentrations in the plume as it approaches the system. The water quality tracking network has been modified with regard to wells and analytes where appropriate. The monitoring frequency is twice in 5 years for the analytes indicated.

4.3.4.1 Original System

Performance Monitoring

The primary performance criteria for the Original System are to demonstrate containment through plume-edge capture and reverse hydraulic gradient. These will be demonstrated through visual evaluation of potentiometric maps for plume-edge capture, and visual comparison of water elevations in monitoring wells along the extraction and recharge well alignments for reverse hydraulic gradient. Water elevations in downgradient wells and in wells between the recharge and extraction well alignments will also be evaluated. The performance monitoring water level wells used to monitor plume-edge capture and the hydraulic gradient are listed in Table 4.3-4. The NWBCS Original System performance water level network is a subset of the operational water level network. The performance network includes a larger group of wells than was used to monitor the reverse gradient previously. Refer to the OARs for detailed water table maps. The performance and operational water level monitoring networks are shown on Figure 4.3-1. The operational network shown is similar to the operational water level network included in the 1999 LTMP. This larger network will continue to be monitored annually to determine the flow directions and gradients in a larger area. The monitoring frequency for the performance water level network is quarterly.

Table 4.3-4. NWBCS Original System Performance Water Level Monitoring Network

Plume-edge Capture	Hydraulic Gradient	Hydraulic Gradient	Hydraulic Gradient	Hydraulic Gradient
	Extraction Well/Slurry Wall Alignment	Recharge Well Alignment	Wells Between Recharge and Extraction Wells/Slurry Walls	Downgradient
22008	22009	22056	22010	22003
22043	22061	22035	22016	22005
22500	22045	22078	22017	37330
22501	22062	22077	22018	37331
27010	22063	22057	22019	37332
27086	22064	22076	22021	37333
27090	22066	22075	22042	37600
27500	22069	22511	22065	
27503		22073	22067	
27504		22059	22070	

The secondary performance criterion is to demonstrate that concentrations are below CSRGs/PQLs or are decreasing in downgradient performance wells. The monitoring frequency is annual and the analyte list is the routine CSRG analyte list presented in Section 4.3.5. The wells and analytes included in the performance monitoring water quality well network for the Original System are listed below and included in summary Table 4.3-8 for the NWBCS:

- Wells downgradient of system: 37330, 37331, 37332, 37333, 37600
- Wells upgradient of system: 22008, 22043, 22053, 22081, 27500
- Well cross-gradient of the system: 27010

The upgradient performance monitoring wells were selected instead of the extraction wells because the water quality data for the extraction wells in the hydraulic barrier portion of the system are subject to dilution from the recharge well flows. The water quality data for the extraction wells in the slurry wall portion of the system may also be less representative than that from upgradient monitoring wells because of larger zones of influence during pumping. The five upgradient performance wells were selected to monitor several different flow paths upgradient of the system. These flow paths extend from the edge of the main alluvial channel intercepted by the Original System on the east to the edge of the capture zone on the west. The majority of the groundwater flows in a northerly direction in this area. Well 27500 is located in a flow path that is captured by the system and is included to monitor water quality for plume-edge capture.

Some of the upgradient performance wells have not been sampled recently. Where the upgradient performance wells have limited data, no shut-off decisions are imminent, and data collection in these wells will begin when this plan is implemented. A consultative process will be initiated if RVO believes any of the wells are not representative of upgradient plume concentrations.

Cross-gradient well 27010 is located outside the Original System capture zone and is not influenced by the recharge system, such that it monitors the effectiveness of plume capture.

Water Quality Tracking

Plume tracking upgradient of the system is conducted as part of the water quality tracking monitoring network, which is updated in this plan. Comparisons of the 1999 LTMP and proposed water quality tracking networks are made in Section 6.1.2. Well 27002 was added to monitor an additional flow path nearer the west edge of the plume and farther upgradient than the performance wells. It is located in the thick alluvial aquifer upgradient of the Original System.

Wells 03005, 27091, 34005, 34017, and 34508 provide additional monitoring farther upgradient of the NWBCS. Well 03005 is located 14,000 feet upgradient and nearer to sources in South Plants. Well 27091 is located approximately 2,800 ft upgradient of the system and provides additional plume-edge monitoring for the Original System in anticipation of shut-down of the Southwest Extension (located west of well 27091). This well is located in a flow path that is captured by the system. Well 34005 is located near the eastern edge of the main alluvial channel in the interior of the plume, approximately 8,500 ft upgradient. Well 34017 is in a similar flow path as wells 03005, 34005, and 34020. Well 34508 is located approximately 8,000 feet upgradient in a separate small alluvial channel that is downgradient of a Sand Creek Lateral plume source. This channel discharges into the main alluvial channel upgradient of the Original System.

The monitoring frequency for upgradient plume tracking is twice in 5 years for the analytes listed in Table 4.3-5.

Table 4.3-5. NWBCS Original System Water Quality Tracking Monitoring Network

03005 (Chloroform, dieldrin)	27002 (Chloroform, dieldrin)	27025 (Arsenic, chloroform, dieldrin, DIMP, NDMA)
27037 (Chloroform, dieldrin)	27079 (Arsenic, chloroform, dieldrin, DIMP)	27082 (Arsenic, chloroform, dieldrin, DIMP, NDMA)
27083 (Chloroform, dieldrin)	27091 (Chloroform, dieldrin)	34005 (Chloroform, dieldrin)
34017 (Chloroform, dieldrin)	34020 (Chloroform, dieldrin)	34508 (Chloroform, dieldrin)
35058 (Chloroform, dieldrin)		

4.3.4.2 Northeast Extension

Performance Monitoring

The primary performance criteria for the Northeast Extension are to 1) demonstrate plume capture through water level monitoring in performance wells and 2) demonstrate that concentrations are at or below CSRGs/PQLs or are decreasing in downgradient performance wells. The performance monitoring water level wells are listed in Table 4.3-6 and included in summary Table 4.3-8. The well position relative to the slurry wall is indicated. The monitoring frequency for the performance water level network is quarterly.

Table 4.3-6. NWBCS Northeast Extension Performance Water Level Monitoring Network

22001 (upgradient)	22060 (downgradient)	22506 (upgradient)
22007 (downgradient)	22071 (upgradient)	22508 (downgradient)
22015 (downgradient)	22072 (downgradient)	22512 (downgradient)
22044 (downgradient)	22504 (upgradient)	
22049 (upgradient)	22505 (upgradient)	

The wells and analytes included in the performance monitoring water quality well network for the Northeast Extension are listed below and included in summary Table 4.3-8 for the NWBCS. The downgradient wells listed below are downgradient of the Northeast Extension slurry wall, but upgradient of the recharge wells. Wells 22015 and 22512 were selected as the downgradient water quality performance wells because they are in the migration path that would indicate whether contamination is migrating off post. Additionally, Original System performance well 37332 is located off post, downgradient of well 22512, and provides an added measure of Northeast Extension performance. Well 22505 was selected as the upgradient performance well because it is located in the center of the northwest-trending alluvial channel on the upgradient side of the slurry wall. Well 22505 has similar water quality as extraction well 22317, and will be used for performance monitoring. Well 22506 is located near the edge of the channel, has a thinner saturated zone (less than 1 ft of saturated alluvium), and would not provide significantly different water quality information than well 22505. The performance wells are to be analyzed for the routine CSRG analyte list and monitoring frequency is annual.

- Downgradient wells: 22015, 22512
- Upgradient well: 22505

Water Quality Tracking

Well 22001 is the selected upgradient water quality well for plume tracking. The monitoring frequency for plume tracking is twice in 5 years for DIMP and OCPs.

4.3.4.3 Southwest Extension

Performance Monitoring

The water level performance wells listed in Table 4.3-7 will be used to demonstrate plume capture. The well position relative to the extraction well field/capture zone is indicated. The monitoring frequency for the performance water level network is quarterly.

Table 4.3-7. NWBCS Southwest Extension Performance Water Level Monitoring Network

27003 (upgradient)	27092 (upgradient)
27093 (upgradient)	27501 (downgradient)
27505 (downgradient)	27506 (downgradient)
27508 (upgradient)	27509 (upgradient)
27510 (upgradient)	27511 (upgradient)
27516 (cross-gradient)	27517 (upgradient)
27522 (downgradient)	27524 (cross-gradient)
27525 (upgradient)	27528 (upgradient)
27529 (cross-gradient)	27530 (upgradient)
27531 (upgradient)	27532 (upgradient)
27533 (upgradient)	28002 (cross-gradient)
28003 (cross-gradient)	28004 (cross-gradient)
28005 (cross-gradient)	28031 (upgradient)
28519 (upgradient)	28521 (cross-gradient)
28522 (upgradient)	

The wells and analytes included in the performance monitoring water quality well network for the Southwest Extension are listed below and included in summary Table 4.3-8 for the NWBCS. Downgradient water quality performance monitoring is based on the current conformance monitoring category in the 1999 LTMP. The monitoring frequency is annual and the downgradient well is to be analyzed for the routine CSRG analyte list while the upgradient and cross-gradient wells are analyzed for dieldrin only based on contaminant history.

The water quality performance monitoring wells are as follows:

- Downgradient well: 27522
- Upgradient well: 27517
- Cross-gradient wells: 27516, 28521

Water Quality Tracking

Wells 03015, 27043, 34008, and 34015 were added to the water quality tracking monitoring network in the 1999 LTMP to provide monitoring farther upgradient of the Southwest Extension extraction wells. The water quality monitoring frequency for wells 03015, 03016, 27043, 34008, and 34015 is twice in 5 years and dieldrin is the only analyte.

The monitoring wells for all three components of the NWBCS are summarized in Table 4.3-8 and shown on Figure 4.3-1.

4.3.5 NWBCS Routine CSRG Analyte List

The review conducted for the NWBCS ROD CSRG analytes is summarized in Table 4.3-9, which shows that chloroform, dieldrin, isodrin, NDMA, and arsenic were retained for the routine CSRG analyte list. Dieldrin, isodrin, and chloroform were retained for the CSRG analyte list because of two or more exceedances in multiple extraction wells and upgradient monitoring wells. NDMA was retained because there was limited analytical data from the wells, so additional information is needed to assess this analyte. Likewise, arsenic is retained because it was only sampled in 2004 in the Original System extraction wells. DIMP, endrin, and TCE are removed from the routine CSRG analyte list because there were no CSRG exceedances in the treatment plant influent, extraction wells, and upgradient performance, water-quality tracking, and operational wells.

The NWBCS routine CSRG analyte list is shown in Table 4.3-10.

4.4 North Boundary Containment System

The NBCS is a containment system designed to prevent contaminated groundwater from migrating off post (USACE 1985). The current NBCS consists of 1) a system of extraction wells that remove contaminated groundwater from the UFS, 2) a soil bentonite barrier that impedes migration of contaminated groundwater to the Off-Post OU, 3) a carbon-adsorption treatment system that removes organic contaminants from extracted groundwater, 4) an UV-oxidation system for treatment of NDMA, and 5) a system of recharge trenches that returns treated groundwater to the UFS north of the barrier wall. A reverse hydraulic gradient across the barrier is maintained to prevent contaminated groundwater from moving off post.

The containment system originally consisted of a slurry wall with extraction wells upgradient and injection wells downgradient of the slurry wall. This system was originally installed as a pilot project in 1979 and extended to its current extent in 1981. The system was unable to maintain a reverse hydraulic gradient and was modified by replacing the injection (recharge) wells with 15 recharge trenches. As a result of the changes, a reverse hydraulic gradient has been maintained across the entire alluvial part of the system and most of the Denver Formation system since 1992. A carbon-adsorption system has been used to remove organic compounds from the influent prior to recharge. A UV-oxidation treatment system installed at the NBCS has been treating NDMA since September 1997.

During the 2000–2005 FYR period, two actions were proposed to enhance the effectiveness of the NBCS. The actions, listed below, are documented in the NBCS Fact Sheet (RVO 2004b):

- Adding two groundwater extraction wells upstream of the existing NBCS well field
- Injecting HRC into the groundwater aquifer farther upstream from the existing NBCS extraction wells to enhance biodegradation of organic contaminants

The purpose of the additional extraction wells, which were installed in 2003, was to accelerate groundwater cleanup. The groundwater pumped from upgradient wells will also maintain a reverse hydraulic gradient at the NBCS.

The injection of biodegradation-enhancing HRC is an innovative technology that was tested in pilot studies conducted at RMA through the EPA Superfund Innovative Technology Evaluation program (TtEMI 2003). The location, approach, and design of the in situ treatment system were developed during the 2000–2005 FYR period and the injection of biodegradation-enhancing compounds started in May 2005. Operation and monitoring of this HRC injection system was discontinued in 2007, because the system was not achieving its contaminant reduction goals (DCN No. 4, 2007; NBE Termination Report, URS Washington Division 2009).

CSRGs for the NBCS effluent were established for 29 contaminants potentially present in the groundwater migrating toward the north boundary. Of these compounds, chloride and sulfate levels were to be reduced to CSRGs through attenuation over time periods of 30 and 25 years respectively. The RMA On-Post OU identified attenuation as a remedy for chloride and sulfate at NBCS, and a study of regional concentrations and flow rates upgradient of the NBCS was conducted to evaluate remediation goals as well as remediation timeframes for these compounds (MK Environmental Services and FWENC 1996). Based on this study, the CSRG for chloride was set at the CBSG of 250 mg/L, and the timeframe for achieving the CSRG in the NBCS effluent was predicted to be 30 years. For sulfate, the CSRG was set at 540 mg/L based on regionally high levels of sulfate in groundwater, and the timeframe for achieving this was predicted to be 25 years.

4.4.1 NBCS Performance Criteria and Consultation

The performance objective and associated criteria have been updated as described below to address future monitoring needs. The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for the NBCS were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 4.4-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue. For the NBCS, the performance criteria are presented below.

Primary Performance Criteria:

- Demonstrate containment through reverse hydraulic gradient by visual evaluation of potentiometric maps and visual comparison of paired well water levels. If visual inspection is unclear, statistical or other evaluation criteria will be considered.
- Demonstrate containment through plume-edge capture by visual evaluation of flow directions on potentiometric maps, and evaluation of water quality data from performance water quality wells. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

Historical water quality data are sufficient to demonstrate that the ends of the system are uncontaminated; thus, monitoring the flow directions at the ends of the system is sufficient to demonstrate plume-edge capture.

Secondary Performance Criterion:

- If unable to maintain reverse hydraulic gradient due to factors beyond RVO control, the performance evaluation will be based on demonstrating that concentrations in downgradient water quality performance wells are at or below CSRGs/PQLs or show decreasing concentration trends over the previous period of at least 5 years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

4.4.2 Performance Monitoring Decision Rules

The performance monitoring decision rules that will be applied to the performance monitoring data are presented below.

Decision

- Are reverse hydraulic gradients maintained between the paired performance monitoring points at levels greater than zero?
- Do flow directions and water quality data confirm that plume-edge capture is maintained?
- If either of the above is not achieved, are concentrations of CSRG analytes at or below CSRGs/PQLs or decreasing in downgradient performance wells?

Inputs to the Decision

Required information to support the decision elements includes the following:

- Water level data for the water level (including reverse gradient) performance wells.
- Water quality data for downgradient performance wells.
- Water level data from operational monitoring wells.
- Statistical trend analysis using the Mann-Kendall test if conclusions cannot be drawn based on visual observations.

Study Boundaries

- Spatial study boundaries are defined by the water level and water quality performance wells.
- Analytes are limited to the NBCS ROD CSRG analyte list.
- Monitoring frequencies are quarterly for water level performance and annual for water quality performance wells.

Decision Rule

1. If the performance evaluations show loss of reverse hydraulic gradient or lack of plume-edge capture, the issue will be addressed through the consultative process identified in Table 4.4-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the performance evaluations show that the primary performance criteria are met, i.e., the reverse hydraulic gradient criterion has been consistently met, and measured water levels confirm plume-edge capture, the containment system is functioning as intended.
3. If the performance evaluation shows that either of the primary criteria is not met, the secondary criterion is used to assess system performance by evaluating and comparing water quality data in downgradient performance wells over a minimum of 5 years. If the performance evaluation shows that the secondary performance criterion, i.e., decreasing concentration trends in downgradient performance wells or concentrations at or below CSRGs/PQLs, is met, the containment system is effective.

Limits on Decision Errors

Potential error tolerance, based on method errors, will be included in the data evaluation as needed. The Post-Laboratory Data validation procedure will be applied to any outliers (RVO 2007). The cumulative errors involved in water level monitoring will be considered during evaluation and discussion of monitoring data.

Table 4.4-1. Application of Consultative Process for NBCS

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs	Quarterly (water quality)	Within 30 days of data being accepted	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Quarterly, semiannual, annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—reverse hydraulic gradient for one quarter	Quarterly (water level)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, graphs, etc., actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, status of reverse hydraulic gradient, potential for additional reverse hydraulic gradient monitoring, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem. Third consecutive quarter: If reverse hydraulic gradient issue is not resolved through follow-up actions, and restoration of the reverse hydraulic gradient is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues. If consensus decision is that restoration of the reverse hydraulic gradient is beyond RVO control, a review of all performance criteria and potential revision to the associated performance monitoring programs will be triggered and included in a Non-Routine Action Plan with schedule to address the performance issue.

Table 4.4-1. Application of Consultative Process for NBCS

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Loss of primary performance criterion—plume-edge capture	Annual (water level)	Within 30 days of determination	First annual period: E-mail notification that includes description of issue with supporting data, graphs, etc., actions taken to correct problem, and proposed actions to correct problem. Within 90 days after first notification: Meeting(s) with Regulatory Agencies will be held to discuss results of actions taken and develop consensus for future actions to correct problem. Within 180 days after first notification: If plume-edge capture issue is not resolved through follow-up actions, and restoration of the plume-edge capture is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues. If consensus decision is that restoration of the plume-edge capture is beyond RVO control, a review of all performance criteria and potential revision to the associated performance monitoring program will be triggered and included in a Non-Routine Action Plan with schedule to address the performance issue.
Loss of secondary performance criterion—downgradient concentration trends increasing while primary criteria are met	Annual (water quality)	During annual evaluation period	Annual evaluation period: E-mail notification that includes description of issue with supporting data (for example, confirmatory sampling), graphs, etc., actions taken to date to correct problem, status of reverse hydraulic gradient and plume-edge capture, , potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and proposed actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.

Table 4.4-1. Application of Consultative Process for NBCS

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Treatment system issues that could potentially affect compliance Examples of treatment system problems and process evaluation periods: UV system downtime lasting more than 2 weeks GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Extraction or recharge system problems that could potentially affect system performance Examples of extraction/recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Indication of irreversible plugging of recharge system; evaluation period is 6 weeks of problem identification	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

4.4.3 Chloride and Sulfate Attenuation Performance and Compliance

The On-Post ROD specified that the CSRGs for chloride and sulfate were to be met at the NBCS treatment plant within 30 and 25 years, respectively, of the issuance of the On-Post ROD (FWENC 1996). This means that the CSRGs will have to be met at the NBCS by 2026 for chloride and 2021 for sulfate. The CSRGs are expected to be achieved through attenuation occurring upgradient of the NBCS. As described in Responses to EPA Comments on the 2005 FYRR and in the *Development of Chloride and Sulfate Remediation Goals for the North Boundary Containment System* (MK Environmental Services and FWENC 1996), chloride and sulfate CSRGs will be met in the NBCS effluent primarily by the decreasing volume of contaminated groundwater flow from the former Basin F area. The North of Basin F IRA extraction well was shut down in 2000 because this decrease in contaminated groundwater flow from the Basin F area made continued operation infeasible. The referenced chloride and sulfate analysis and compliance timeframe predictions for the ROD were conservative in that meeting the CSRG goals at the NBCS was not dependent on concentrations decreasing in upgradient wells. Even though upgradient concentrations may actually increase, the overall contaminant mass flowing toward the NBCS is expected to decline. As for the other NBCS CSRG analytes, shut-off decisions will be based on the chloride and sulfate concentrations in the upgradient wells.

4.4.4 NBCS Monitoring Networks

The well networks and monitoring frequencies presented below are intended to provide data to evaluate system performance and changes in upgradient concentrations that could affect system performance, as well as provide data for shut-off evaluations. Monitoring wells were selected as the upgradient performance wells instead of extraction wells. Although the NBCS slurry wall prevents effects on upgradient water quality by the recharge system, the larger area of influence of the extraction wells may affect the representativeness of the extraction well data. As discussed in Section 4.9, a consultative process between the RVO and Regulatory Agencies will be used to determine the shut-off monitoring requirements. Operational monitoring is addressed separately.

Performance Monitoring

The primary performance criterion is to demonstrate containment through a reverse hydraulic gradient. Reverse hydraulic gradient will be demonstrated through visual evaluation of potentiometric maps and visual comparison of paired well water levels. Plume capture at the ends of the system will be based on water level monitoring and demonstrated through visual evaluation of potentiometric maps. The ends of the slurry wall are keyed into bedrock highs where the alluvium is unsaturated and the flow directions are inward toward the system. Historical monitoring has demonstrated that the inward flow at the ends of the slurry wall is uncontaminated, thereby assuring plume-edge capture. The well network, including the individual wells that comprise the pairs used to monitor the hydraulic gradient adjacent to the slurry wall is listed below in Table 4.4-2.

The NBCS performance water level network is a subset of the operational water level network and consists of the monitoring well pairs used previously to monitor the reverse gradient. Refer to the OARs for detailed water table maps. The performance and operational water level monitoring networks are shown on Figure 4.4-1. The operational network shown is similar to the operational water level network included in the 1999 LTMP with wells added to the west and upgradient of the system. This larger operational network will continue to be monitored to determine the flow directions and gradients farther from the system. The monitoring frequency for the performance water level network will be quarterly and the potentiometric surface maps will be based on annual monitoring of the operational water level network.

Table 4.4-2. NBCS Performance Water Level Monitoring Network

Well Network		Well Pairs
23207	23208	23522/23208
23212	23214	23519/23207
23217	23510	23516/23214
23513	23516	23513/23533
23519	23522	23510/23534
23528	23529	23528/23535
23533	23534	23217/23212
23535	23544	23529/23544
24179	24180	24503/24522
24503	24506	24506/24523
24509	24512	24509/24179
24515	24518	24526/24527
24521	24522	24512/24180
24523	24526	24515/24528
24527	24528	24518/24529
24529	24530	24521/24530

The wells included in the performance monitoring water quality well network are listed in Table 4.4-3 and are included in summary Table 4.4-6 at the end of the section. The monitoring frequency is annual and the analyte list is the ROD CSRG for upgradient wells, and the routine CSRG analyte list presented in Section 4.4.5, plus DBCP, for the downgradient wells. The ROD CSRG list is used for the upgradient wells because the NBCS CSRG list evaluation for wells (Section 4.4.5) was based primarily on extraction well data, which may be affected by pumping. DBCP was added to the downgradient well analyte list because some of the performance wells have limited or no previous analytical data, and the DBCP concentration was above the CSRG when a well adjacent to one of the performance wells was last sampled in 1987.

A slurry wall is present for the entire length of the NBCS and essentially eliminates recycling of the recharge flow in the extraction wells. However, the extraction well water quality data may be affected by the larger area of influence of extraction wells caused by pumping. Thus, using upgradient monitoring wells in the performance monitoring category changes the current operational emphasis of monitoring the operating extraction wells. The operating extraction wells may be monitored under the Operational Monitoring Program to augment the information from the upgradient performance wells.

The secondary performance criterion is to demonstrate that concentrations are at or below CSRGs/PQLs or are decreasing in downgradient performance wells. The downgradient component of the performance monitoring category replaces and is similar to the conformance monitoring category included in the 1999 LTMP.

A need for re-evaluating the NBCS conformance well network was identified in the 2005 FYRR (PMRMA 2007a). Most of the wells in the proposed downgradient performance monitoring well network are different than the conformance wells because several conformance wells were determined to not be representative of system performance in the 2005 FYRR. This was due to the presence of residual contamination downgradient of the system in some wells and slow migration through fine-grained sediments in other wells. Also, most of the conformance wells are located within the area just south of 96th Avenue that no longer is on RMA property, which is less secure for the wells, and they may be affected by road construction. The corresponding conformance wells being replaced also are listed below. Some of the former conformance wells are transferred to the off-post CSRG exceedance network. The selected wells contain residual contamination or are affected by slow migration and include wells 23198, 24162, 24166, 37338, and 37339. Well 23198 also is located in the area downgradient of the bend in the slurry wall where there may be a small amount of underflow. The selected downgradient performance wells are closer to the slurry wall and outside of the 100-ft zone adjacent to 96th Avenue. Ownership of this zone has been transferred to Commerce City and is outside the RMA security fence. Additionally, the wells in this area may be subject to closure because of widening of 96th Avenue. Some of the new performance wells are former recharge wells and were sampled in 2003 and 2004 because they were selected as alternates to the conformance wells within the 100-ft zone. The selected performance wells are in similar flow paths as the former conformance wells. Well 23438 was selected instead of previously selected alternate well 23437 to more effectively monitor downgradient of the bend in the slurry wall where a small amount of underflow in the unconfined Denver Formation may be occurring. Wells 24418 and 24421 were added to monitor an area upgradient of wells 24163 and 24164. Wells 24163 and 24164 were not included as conformance wells in the 1999 LTMP because historical data showed that contaminant concentrations had decreased to below CSRGs in this area. Performance wells 24418 and 24421 were added to monitor this gap in the former conformance network and were selected because they are downgradient of gaps between recharge trenches 11, 12, and 13. For comparison, in FY10 the former conformance wells and downgradient performance wells will both be sampled. After FY10, the duration of sampling the former conformance wells will be evaluated through the consultative process with the Regulatory Agencies.

Two of the three unconfined Denver Formation conformance wells (i.e., 23235 and 24191) were moved to the Denver well performance network discussed below because it was determined in the 2005 FYRR that they are not suited for performance monitoring since migration in the Denver Formation sandstones in these wells is much slower than in the overlying alluvium, and is not indicative of current system effectiveness. The third Denver Formation conformance well (23226) cleaned up quickly and has remained uncontaminated since the recharge trenches were constructed and a reverse gradient was established. Consequently, monitoring of this well is to be discontinued.

Table 4.4-3. NBCS Performance Water Quality Monitoring Network

Well	Location	Comments
23405	Downgradient	Replaces conformance well 23253
23434	Downgradient	Replaces conformance well 37339
23436	Downgradient	Replaces conformance well 23198
23438	Downgradient	Replaces conformance well 23198
24004	Downgradient	Replaces conformance well 24166
24006	Downgradient	No replacement necessary
24415	Downgradient	Replaces conformance well 24162
24418	Downgradient	New
24421	Downgradient	New
24424	Downgradient	Replaces conformance well 37338
37362	Downgradient	New
23119	Upgradient	Monitoring well
23160	Upgradient	Monitoring well
23211	Upgradient	Monitoring well
24101	Upgradient	Monitoring well
24105	Upgradient	Monitoring well
24106	Upgradient	Monitoring well
24114	Upgradient	Monitoring well
24117	Upgradient	Monitoring well
24185	Upgradient	Monitoring well
24199	Upgradient	Monitoring well
24201	Upgradient	Monitoring well

Denver Well Performance Water Quality Monitoring

Monitoring of 17 UFS and 3 CFS Denver wells near the NBCS previously occurred under the conformance and operations monitoring programs. The NBCS Denver well monitoring will now be conducted under the NBCS performance category. Water quality monitoring of four UFS Denver well pairs adjacent to the slurry wall will be discontinued where a reverse hydraulic gradient is consistently present in the wells, and there is an upward hydraulic gradient (see paragraph below) in the upgradient well in each pair. These conditions apply to well pairs 23126/23138, 23242/23243, 23536/23537, and 23538/23539.

An upward hydraulic gradient is determined by measuring static water elevations in adjacent wells that are screened in different zones vertically. In this case, the two zones are the shallower alluvial and deeper unconfined Denver aquifers, both of which are in the UFS. The unconfined Denver zone generally has lower hydraulic conductivity than the shallower alluvial zone. Thus, differences in horizontal and vertical hydraulic gradients and contaminant migration commonly occur between the two zones. When the water elevation is higher in the lower zone well than in the upper zone well, the gradient is upward. If the water elevation in the shallower zone well is higher than in the lower zone well, the gradient is downward. An upward gradient indicates that any potential vertical flow of groundwater between the two zones will be upward. Since the contamination levels typically are higher in the shallow zone than in the deeper zone, an upward gradient is desirable because it prevents contamination from potentially migrating downward into the lower zone. It should be noted that a downward gradient only indicates a potential for downward migration. Lower hydraulic conductivity in a lower zone can reduce or prevent downward migration of contaminants even though a downward gradient exists.

Monitoring of these wells has shown that the unconfined Denver zone is uncontaminated or below CSRGs in three of the four well pairs. Only well pair 23242/23243 has contaminants present at levels above CSRGs. However, there is no potential for underflow of contaminants because a reverse hydraulic gradient is present in the wells, and there is an upward hydraulic gradient in the upgradient well in each pair. Since contaminant concentrations in the extraction wells, which are screened in the overlying alluvium, have demonstrated long-term decreasing trends, the concentrations in these Denver UFS wells are not expected to increase. Quarterly water level monitoring of these eight wells will continue under operational monitoring to demonstrate that the reverse and upward hydraulic gradients are maintained. If the reverse gradient is not maintained at well pair 23242/23243, sampling will be resumed as with the other Denver UFS wells described below. As previously indicated, water quality monitoring of UFS Denver conformance well 23226 will also be discontinued.

Monitoring of the remaining 11 Denver Formation wells (8 UFS and 3 CFS) will be conducted under the NBCS performance water quality category to monitor concentration trends upgradient and downgradient of the NBCS slurry wall. A small volume of potential contaminated underflow has only been identified at the well pair at the bend in the slurry wall (wells 23540/23541), where additional downgradient performance monitoring will occur. In many cases, more contaminants are detected and the concentrations are higher in the downgradient well than in the upgradient well, which is not consistent with an underflow scenario. Additionally, the contaminant concentrations in wells 23540/23541 are higher than in the upgradient extraction well (23335). Thus, the contamination appears to be older remnant contamination and not representative of current system effectiveness. Since migration in the Denver Formation is much slower than in the overlying alluvium, and the concentration trends have been determined previously (RVO 2007, RMA Environmental Database) and discussed with the Regulatory Agencies in 2008 and 2009 LTMP meetings, the monitoring frequency in the wells listed below in Table 4.4-4 is once in 5 years for the analytes indicated.

Table 4.4-4. NBCS Unconfined Flow System and Confined Flow System Denver Well Performance Water Quality Network

Well	Flow System/Location	Analytes
23194	UFS/downgradient	Carbon tetrachloride, chloride, chloroform, DIMP
23195	UFS/upgradient	Carbon tetrachloride, chloride, chloroform, DIMP
23235	UFS/downgradient	1,2-dichloroethane, chloride, DIMP
23540	UFS/downgradient	Chloride, dieldrin, DIMP
23541	UFS/upgradient	Chloride, dieldrin, DIMP
23542	UFS/downgradient	Chloride, chloroform, DIMP
23543	UFS/upgradient	Chloride, chloroform, DIMP
24191	UFS/downgradient	Chloride, DIMP
23161	CFS/downgradient	Chloride, DIMP
23200	CFS/downgradient	1,2-dichloroethane, chloride, DIMP, NDMA
24171	CFS/downgradient	Chloride, DIMP

Water Quality Tracking

Wells included in the water quality tracking category upgradient of the NBCS are used to track the concentrations in the plume upgradient of the system. This group, which is similar to the group in the 1999 LTMP, includes wells in Sections 23 and 24, but also wells in the North Plants area. Comparisons of the 1999 LTMP and proposed water quality tracking networks are made in Section 6.1.2. Well 23548, located downgradient of the HRC barrier, was added to the 1999 LTMP upgradient well network. Basin F has a project-specific monitoring program that is addressed elsewhere. Basin F wells 26015, 26017, 26157, and 26163, which were in the 1999 LTMP network, were incorporated in the Basin F Closure/Post Closure monitoring program (TtEC 2006a, 2009a). The monitoring frequency for NBCS water quality tracking is twice in 5 years, except for well 23548, for the analytes shown in Table 4.4-5. Well 23548 is completed in a Denver Formation sandstone, which has lower permeability than the overlying alluvium, and the sampling frequency is once in 5 years.

The monitoring wells for all components of the NBCS are summarized in Table 4.4-6 and shown in Figure 4.4-1.

Table 4.4-5. NBCS Upgradient Water Quality Tracking Monitoring Network

Well	Location	Analytes
23095	Upgradient	Arsenic, chloride, chloroform, dieldrin, DIMP, fluoride, NDMA, sulfate
23096	Upgradient	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA, sulfate
23142	Upgradient	Chloride, chloroform, dieldrin, DIMP, fluoride, sulfate
23548	Upgradient	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA
24081	Upgradient/North Plants	Carbon tetrachloride, chloride, chloroform, DIMP, fluoride, tetrachloroethylene
24092	Upgradient	Chloride, chloroform, DIMP, fluoride, sulfate
24094	Upgradient	Carbon tetrachloride, chloride, chloroform, DIMP, fluoride, sulfate
25059	Upgradient/North Plants	Chloride, chloroform, DIMP, fluoride, tetrachloroethylene

4.4.5 NBCS Routine CSRG Analyte List

The review conducted for the NBCS ROD CSRG analytes is summarized in Table 4.4-7, which shows that the following 15 analytes were retained for the routine CSRG analyte list:

- DIMP
- Aldrin
- Dieldrin
- Isodrin
- 1,2-Dichloroethane
- Carbon tetrachloride
- Chloroform
- Tetrachloroethylene
- TCE
- DCPD
- NDMA
- Chloride
- Fluoride
- Sulfate
- Arsenic

Fourteen of these analytes had two or more CSRG/PQL exceedances in the extraction wells, four had CSRG/PQL exceedances in upgradient monitoring wells, and nine were retained from the influent evaluation. Arsenic is retained due to a lack of analytical results. The NBCS routine CSRG analyte list is presented in Table 4.4-8.

4.5 Railyard Containment System

The RYCS (Rail Classification Yard [Railyard] Containment System) is designed as a capture system. When the Irondale and Motor Pool extraction systems were shut off, treatment of the remaining Railyard Plume was moved from the ICS to the new RYCS in July 2001 (see Section 2.3.3). Recharge of the treated water was also transferred from the ICS to the Railyard. Two Railyard extraction wells (03306 and 03307) located downgradient of the primary Railyard extraction well field were converted to recharge wells 03401 and 03402. The objective of the original Railyard system, which applies to the current system, was to contain and intercept the plume, as specified in the Decision Document, which states, "(a) groundwater interception/containment strategy fulfills all the assessment criteria for IRAs and has been selected as the preferred strategy for the Rail Classification Yard IRA" (MK Environmental Services 1990a).

4.5.1 RYCS Performance Criteria and Consultation

The performance objective and associated criteria have been updated as described below to address future monitoring needs. Since the RYCS is a plume capture system, hydraulic capture is the performance measure instead of reverse hydraulic gradient. The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for the RYCS were established based on system compliance requirements and the performance criteria. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 4.5-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue. The performance criteria are for the RYCS are presented below.

Performance Criteria:

- Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.
- Demonstrate decreasing concentration trends or that concentrations are at or below CSRGs in downgradient performance wells.

4.5.2 Performance Monitoring Decision Rules

The performance monitoring decision rules that will be applied to the performance monitoring data during the FYR are presented below.

Decision

- Do water levels in water level performance wells and water quality in upgradient and downgradient performance wells confirm that plume capture is achieved?
- Are concentrations of CSRG analytes at or below CSRGs or decreasing in downgradient performance wells?

Inputs to the Decision

Required information to support the decision elements includes the following:

- Water level data for the water level performance wells
- Water quality data for upgradient and downgradient performance wells
- Water quality and water level data from operational monitoring wells
- Statistical trend analysis using the Mann-Kendall test if conclusions cannot be drawn based on visual observations

Study Boundaries

- Spatial study boundaries are defined by the water level and water quality performance wells.
- Analytes are limited to the ROD CSRG analyte list for RYCS.
- Monitoring frequencies are quarterly for water level performance wells and annual for water quality performance wells.

Decision Rule

1. If the quarterly performance evaluation shows lack of plume capture or downgradient concentration trends are increasing, the issue will be addressed through the consultative process identified in Table 4.5-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the quarterly performance evaluation shows that measured water levels and water quality data confirm plume capture AND
3. If the annual performance evaluation shows that the water quality in downgradient wells demonstrates decreasing concentration trends or that concentrations are at or below CSRGs/PQLs in downgradient performance wells, the containment system is functioning as intended.

Limits on Decision Errors

Potential error tolerance, based on method errors, will be included in the data evaluation as needed. The Post-Laboratory Data Validation procedure will be applied to any outliers (RVO 2007). The cumulative errors involved in water level monitoring will be considered during evaluation and discussion of monitoring data.

Table 4.5-1. Application of Consultative Process for RYCS

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs	Quarterly (water quality)	Within 30 days of data being accepted	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Quarterly, semiannual, annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—plume capture	Quarterly (water levels) Quarterly, Annual (water quality)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, graphs, etc., actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, status of plume capture, potential for additional plume capture monitoring, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem. Third consecutive quarter: If plume capture issue is not resolved through follow-up actions, and restoration of the plume capture is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.

Table 4.5-1. Application of Consultative Process for RYCS

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Loss of primary performance criterion—downgradient concentration trends increasing	Annual (water quality)	Within 30 days of determination	Annual evaluation period: E-mail notification that includes description of issue with supporting data (for example, confirmatory sampling), graphs, etc., potential causes, actions taken to date to correct problem, status of plume capture, and proposed actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.
Treatment system issues that could potentially affect compliance Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.
Extraction or recharge system problems that could potentially affect system performance Examples of extraction or recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Indication of irreversible plugging of recharge system; evaluation period runs 6 weeks from problem identification	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with a description of any corrective measures to prevent recurrence.

Table 4.5-1. Application of Consultative Process for RYCS

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

4.5.3 Railyard Monitoring Networks

The well networks and monitoring frequencies presented below are intended to provide data to evaluate system performance, changes in upgradient concentrations that could affect system performance, as well as provide data for shut-off evaluations. As discussed in Section 4.9, a consultative process between the RVO and Regulatory Agencies will be used to determine the shut-off monitoring requirements.

Performance Monitoring

The primary performance criterion is to demonstrate containment through plume capture. This will be demonstrated through visual evaluation of potentiometric maps. The performance monitoring water level wells used to monitor water levels to demonstrate plume capture are listed in Table 4.5-2. The RYCS performance water level network is similar to the operational water level network and consists of all monitoring wells near the extraction and recharge systems that are used to map the capture zone. The performance and operational water level monitoring networks are shown on Figure 4.5-1. The operational network shown is similar to the operational water level network included in the 1999 LTMP. Refer to the OARs for detailed water table maps. The monitoring frequency for the performance water level network will be quarterly.

Table 4.5-2. Railyard Performance Water Level Monitoring Network

03001	03010
03017	03301
03302	03303
03304	03305
03501	03502
03503	03505
03506	03507
03508	03509
03510	03511
03512	03513
03522	03527
03528	03529
03530	03531
03532	03533
03534	03535
03536	03537
03538	04506

Monitoring of water quality in upgradient, cross-gradient, and downgradient wells also is necessary to demonstrate reductions in concentrations and plume capture. The performance wells used to monitor water quality are listed below in Table 4.5-3. The extraction wells were not selected as upgradient performance wells because the DBCP plume has been demonstrated to be vertically stratified, occurring in the upper part of the aquifer (MK Environmental Services 1989). The extraction wells are screened across the entire saturated thickness of the alluvium, which is approximately 35 ft. Thus, the water quality data for the extraction wells may not represent the plume concentrations in a conservative manner. The selected upgradient performance monitoring wells are screened in the upper 15–20 ft of the aquifer. Wells 03501, 03503, 03529, 03530, and 03538 will be sampled annually for the routine CSRG analyte list, which consists of DBCP. The remaining performance wells will be sampled biannually for DBCP; wells 03001, 03507, 03509, and 03527 will be sampled during even years; and wells 03508 and 04506 will be sampled during odd years.

Table 4.5-3. Railyard Performance Water Quality Monitoring Network

Well	Location
03001	Cross-gradient
03501	Upgradient of extraction wells
03503	Upgradient of extraction wells
03507	Downgradient of recharge wells
03508	Downgradient of recharge wells
03509	Downgradient of recharge wells
03527	Cross-gradient
03529	Downgradient of extraction wells
03530	Downgradient of extraction wells
03538	Upgradient of extraction wells
04506	Downgradient of recharge wells

Upgradient Water Quality Tracking

Upgradient water quality tracking will consist of monitoring well 03523, which is located approximately 800 ft upgradient of the extraction system. Well 03523 is located nearest to the DBCP source and historically has contained the highest concentrations in the plume. The monitoring frequency for RYCS water quality tracking is twice in 5 years for DBCP.

The monitoring wells for all components of the Railyard monitoring networks are summarized in Table 4.5-4 and shown in Figure 4.5-1.

4.5.4 Railyard Routine CSRG Analyte List

The RYCS ROD CSRG analytes are shown in Table 2.3-3. A review of the RYCS analytes resulted in the elimination of TCE from the routine CSRG analyte list. DBCP was retained because it had two or more CSRG/PQL exceedances in the plant influent, extraction wells, or upgradient performance/shut-off monitoring wells and is the only analyte on the RYCS routine CSRG analyte list.

4.6 Basin A Neck System

The BANS consists of seven alluvial extraction wells, a slurry wall, an air stripper, a GAC adsorption system for treatment, and five gravel-filled recharge trenches.

The mass removal objective of the BANS was clarified in a September 28, 2004, Memorandum for Record. The purpose of the memorandum was "to re-state and clarify the requirements for the BANS in the Record of Decision for the On-Post Operable Unit" (RVO 2004a). The system is operated so that a reverse hydraulic gradient is maintained in the middle of the system, but the recharge trenches do not extend to the ends of the slurry wall where a reverse gradient is not achieved.

Since the soil containment remedy in the Basin A area has not yet been implemented, it was considered premature to consider a reduced routine BANS CSRG analyte list.

Refer to Section 4.9 regarding the inclusion of potential BANS modifications in the NWBCS shut-off evaluation.

4.6.1 Performance Criteria and Consultation

The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for BANS were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria are presented in Table 4.6-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue. Mass removal performance will be evaluated based on total mass removed relative to the estimated mass approaching the BANS extraction system. The extracted water streams from the BRES and Complex Trenches, which are treated at BANS, will be excluded from the BANS mass removal performance calculations. Mass removal graphs, mass vs. time, will be prepared to determine whether mass removal reaches asymptotic conditions. The performance criteria for BANS are presented below.

Performance Criteria:

- Demonstrate effective mass removal through comparison of calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by standardized approach.
- Demonstrate that concentrations in downgradient performance wells are stable or decreasing.

It should be noted that the BRES and Complex Trenches dewatering systems from which water is piped to BANS for treatment have separate performance and shut-off criteria, presented in Sections 4.7 and 5.1.

4.6.2 Performance Monitoring Decision Rules

The performance monitoring decision rules that will be applied to the performance monitoring data during the FYR are presented below.

Decision

- Are mass removal goals achieved by the BANS extraction and treatment systems?
- Are downgradient concentrations decreasing or stable?

Inputs to the Decision

Required information to support the decision elements includes the following:

- Influent and effluent water quality data
- BANS extraction well water quality data
- Water quality data for upgradient performance wells
- Water quality data for downgradient performance wells
- Performance water level data
- Statistical trend analysis using the Mann-Kendall test for concentration trend analysis if conclusions cannot be drawn based on visual observations

Study Boundaries

- Spatial study boundaries are defined by the influent, effluent, extraction wells, and water level and quality performance wells.
- Analytes are limited to the BANS ROD CSRG analytes and DIMP, which is not included in the BANS CSRG list.
- Monitoring frequencies are quarterly for the effluent, and annual for the water level and water quality performance wells. Influent and extraction well monitoring is performed in accordance with operational requirements.

Decision Rule

1. If the performance evaluation shows that either of the primary criteria is not met, i.e., mass removal is less than 75 percent of the mass flux approaching the system or downgradient concentration trends are increasing, the issue will be addressed through the consultative process identified in Table 4.6-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the annual performance evaluation shows that the primary mass removal performance criterion is met, i.e., the mass removed by the system is at least 75 percent of the mass flux approaching the system, AND
3. If the annual performance evaluation shows that the primary downgradient concentration trend performance criterion is met, i.e., concentrations in downgradient performance wells are stable or decreasing, the system is functioning as intended.

Limits on Decision Errors

Potential error tolerance, based on method errors, will be included in the data evaluation as needed. The Post-Laboratory Data Validation procedure will be applied to any outliers (RVO 2007). The cumulative errors involved in water level monitoring will be considered during evaluation and discussion of monitoring data.

Table 4.6-1. Application of Consultative Process for BANS Mass Removal System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs	Quarterly (water quality)	Within 30 days of data being finalized	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (Water Quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—mass removed by the system is less than 75 percent[1] of the mass flux approaching the system on an annual basis	Annual (water quality)	Within 30 days of determination	Annual evaluation period: E-mail notification that includes description of issue with supporting data (e.g., confirmatory sampling), graphs etc., actions taken to date to correct problem, and proposed actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.
Loss of primary performance criterion—downgradient concentration trends increasing	Annual (water quality)	Within 30 days of determination	Annual evaluation period: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, present supporting data (for example, confirmatory sampling), graphs, etc., potential causes, actions taken and results to date, and develop consensus for future actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.

Notes:
[1] Trigger removal percentage set at 75 percent for this LTMP; potential adjustment pending data review after 5-year data collection period.

Table 4.6-1. Application of Consultative Process for BANS Mass Removal System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Treatment system issues that could potentially affect compliance Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week Decrease in treatment capacity that affects system-specific extraction rates at BANS, BRES, Complex Trenches, or Lime Basins	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.

Notes:
[1] Trigger removal percentage set at 75 percent for this LTMP; potential adjustment pending data review after 5-year data collection period.

Table 4.6-1. Application of Consultative Process for BANS Mass Removal System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Extraction or recharge system problems that could potentially affect system performance Examples of extraction/recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Decrease in recharge capacity that affects system-specific extraction rates at BANS, BRES, Complex Trenches or Lime Basins Indication of irreversible plugging of recharge system; evaluation period runs 6 weeks from problem identification	Per event	Notification within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

Notes:
[1] Trigger removal percentage set at 75 percent for this LTMP; potential adjustment pending data review after 5-year data collection period.

4.6.3 BANS Monitoring Networks

Performance Monitoring

The performance water quality monitoring network shown below in Table 4.6-2 consists of four upgradient monitoring wells and four downgradient monitoring wells. The wells will be sampled annually for the BANS CSRG analyte list. A slurry wall is present at the BANS that separates the recharge and extraction systems and reduces the volume of water treated. The slurry wall is keyed into a subcropping Denver sandstone in the central portion of the system. Thus, reverse underflow (from the recharge side to the extraction side) affects the water quality data for some of the extraction wells. Due to the narrow alluvial channel at the BANS, the four upgradient monitoring wells provide a representative cross section of the plume for estimating upgradient mass flux. Mass flux will be estimated using annual average flow rates and contaminant concentrations. The seven extraction wells will be sampled annually under the operations monitoring program for comparison with the mass flux calculations based on the performance wells. The downgradient concentration trends will be evaluated in the four downgradient monitoring wells. Downgradient water quality tracking wells 26006, 27025, and 27082 provide data on the contaminant concentration trends farther downgradient from the BANS.

Table 4.6-2. BANS Performance Monitoring Network

Well	Location	Type
26507	Upgradient	Monitoring
35512	Upgradient	Monitoring
35514	Upgradient	Monitoring
35516	Upgradient	Monitoring
26501	Downgradient	Monitoring
26505	Downgradient	Monitoring
35505	Downgradient	Monitoring
35525	Downgradient	Monitoring

Since the BANS is a mass removal system, performance water level monitoring will be used to determine the upgradient cross-sectional area of the saturated alluvium and the hydraulic gradient for calculating the groundwater flow approaching the system and evaluate mass flux. The hydraulic performance of the system will also be evaluated. Water level monitoring will also occur under the operations program to optimize system operation for as long as the system is operating. The performance water level network is in Table 4.6-3 below and the monitoring frequency is annual.

Table 4.6-3. BANS Performance Water Level Monitoring Network

Well	Location	Type
26096	Downgradient	Monitoring
26501	Downgradient	Monitoring
26502	Downgradient	Monitoring
26503	Downgradient	Monitoring
26504	Downgradient	Monitoring
26505	Downgradient	Monitoring
26506	Upgradient	Monitoring
26507	Upgradient	Monitoring
26509	Downgradient	Monitoring
26510	Upgradient	Monitoring
26511	Downgradient	Monitoring
26512	Upgradient	Monitoring
35012	Downgradient	Monitoring
35018	Downgradient	Monitoring
35079	Upgradient	Monitoring
35304	Upgradient	Extraction
35305	Upgradient	Extraction
35306	Upgradient	Extraction
35505	Downgradient	Monitoring
35509	Downgradient	Monitoring
35510	Downgradient	Monitoring
35511	Upgradient	Monitoring
35512	Upgradient	Monitoring
35513	Upgradient	Monitoring
35514	Upgradient	Monitoring
35515	Upgradient	Monitoring
35516	Upgradient	Monitoring
35518	Downgradient	Monitoring
35519	Upgradient	Monitoring
35520	Downgradient	Monitoring
35521	Upgradient	Monitoring
35522	Downgradient	Monitoring
35523	Upgradient	Monitoring
35525	Downgradient	Monitoring
35526	Upgradient	Monitoring
35544	Upgradient	Monitoring
35549	Upgradient	Monitoring

Water Quality Tracking

Upgradient wells monitored in and near Basin A include wells 35065, 36627, 36629, 36630, 36631, 36632, and 36633. Downgradient wells include 26006, 27025, and 27082. Wells 26006, 27025, 27082, and 35065 are sampled twice in 5 years, and wells 36627, 36629, 36630, 36631, 36632 and 36633 are sampled once in 5 years. The rationale for the reduced monitoring frequency for the Basin A wells is provided in Section 6.1.2.3. The indicator analytes and monitoring frequencies for the wells are shown in Table 6.1-6.

The monitoring wells for all components of the BANS are summarized in Table 4.6-4 and shown on Figure 4.6-1.

4.7 Bedrock Ridge Extraction System

The BRES was designed as a capture system and installed in 2000. Evaluation of the BRES led to the decision to modify the system to improve plume capture. Extraction well 36306 was installed and became operational in 2005.

The CCR for this project was approved in September 2008 and the system was determined to be completed in accordance with the ROD, to have successfully attained capture of the plume and to be operating as designed (Washington Group International 2008). In the concurrence letter, the EPA determined the system was operational and functional (O&F) (EPA 2008).

Long-term operations and maintenance of the Bedrock Ridge extraction system and monitoring wells is presented in the Basin A Neck Treatment System Operational and Maintenance Manual (Washington Group International 2003).

Refer to Section 4.9 regarding the inclusion of potential BANS modifications in the NWBCS shut-off evaluation.

4.7.1 Performance Criteria and Consultation

The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for BRES were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 4.7-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue. The performance criteria for the BRES, are presented below.

Performance Criteria:

- Demonstrate plume capture through visual evaluation of flow directions on potentiometric maps and evaluation of water quality data from performance and operational monitoring wells. If visual inspection is unclear, statistical and other evaluation criteria will be considered.
- Demonstrate decreasing or stable concentration trends or that concentrations are at or below CSRGs in downgradient performance wells.

4.7.2 Performance Monitoring Decision Rules

Decision

- Do water levels in water level performance wells and water quality in upgradient, downgradient, and plume-edge performance wells confirm that plume capture is achieved?
- Does water quality in downgradient wells demonstrate decreasing concentration trends or that concentrations are at or below the CSRGs/PQLs?

Inputs to the Decision

Required information to support the decision elements includes the following:

- Water level data for the water level performance wells
- Water quality data for the upgradient, downgradient, and plume-edge performance wells
- Water quality and water level data from operational monitoring wells
- Statistical trend analysis using the Mann-Kendall test if conclusion cannot be drawn based on visual observations

Study Boundaries

- Study boundaries are defined by the water level and water quality performance wells.
- Analytes are limited to the BANS ROD CSRG list and DIMP, which is not included in the BANS CSRG list.
- Monitoring frequencies are quarterly for water level performance wells and annual for water quality performance wells.

Decision Rule

1. If the quarterly performance evaluation shows lack of plume capture or downgradient concentration trends are increasing, the issue will be addressed through the consultative process identified in Table 4.7-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the quarterly performance evaluation shows that measured water levels and water quality data confirm plume capture AND
3. If the annual performance evaluation shows that the water quality in downgradient wells demonstrates decreasing concentration trends or that concentrations are at or below CSRGs/PQLs in downgradient performance wells, the containment system is functioning as intended.

Table 4.7-1. Application of Consultative Process for BRES[1]

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs[1]	Quarterly (water quality)	Within 30 days of data being finalized	First event: E-mail notification that includes analyte concentration, description of potential cause, actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection[1]	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Quarterly, semiannual, annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—plume capture	Quarterly (water levels) Quarterly, annual (water quality)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, graphs etc., actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, status of plume capture, potential for additional plume capture monitoring, potential evaluation of volume pumped vs. contaminated aquifer flow, extraction well capture zones, and develop consensus for future actions to correct problem. Third consecutive quarter: If plume capture issue is not resolved through follow-up actions, and restoration of the plume capture is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.

Notes:
1 Treatment system and recharge system issues are addressed as BANS triggers in Table 4.6-1.
2 Trigger will go into effect after five sampling events performed to establish trend after implementation of this version of the LTMP.

Table 4.7-1. Application of Consultative Process for BRES[1]

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Loss of primary performance criterion—downgradient concentration trends increasing[2]	Annual (water quality)	Within 30 days of determination	Annual evaluation period: E-mail notification that includes description of issue with supporting data (for example, confirmatory sampling), graphs etc., potential causes, actions taken to date, status of plume capture, and proposed actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.
Treatment system issues that could potentially affect compliance[1] Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week Decrease in treatment capacity at BANS that affects BRES extraction rates	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.

Notes:
1 Treatment system and recharge system issues are addressed as BANS triggers in Table 4.6-1.
2 Trigger will go into effect after five sampling events performed to establish trend after implementation of this version of the LTMP.

Table 4.7-1. Application of Consultative Process for BRES[1]

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Extraction or recharge[1] system problems that could potentially affect system performance Examples of extraction or recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Decrease in recharge capacity at BANS that affects BRES extraction rates. Indication of irreversible plugging of recharge system; evaluation period runs 6 weeks from problem identification.	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

Notes:
1 Treatment system and recharge system issues are addressed as BANS triggers in Table 4.6-1.
2 Trigger will go into effect after five sampling events performed to establish trend after implementation of this version of the LTMP.

4.7.3 BRES Monitoring Networks

Performance Monitoring

The primary performance criterion is to demonstrate plume capture. This will be demonstrated through visual evaluation of potentiometric surface maps. The wells used to monitor water levels to demonstrate plume capture are listed in Table 4.7-2. The monitoring frequency is quarterly.

Table 4.7-2. BRES Performance Water Level Monitoring Network

25503	25504
25505	25506
36302	36303
36304	36306
36502	36555
36556	36557
36558	36559
36561	36562
36563	36564
36565	36566
36567	36568
36569	36570
36571	36572
36573	36574
36575	36576
36577	36578
36579	36580

Monitoring of water quality in upgradient, downgradient, and plume-edge performance monitoring wells also is used to demonstrate plume capture. Wells will be sampled for the Bedrock Ridge-specific analytes in the BANS CSRG list and DIMP. These BRES analytes include benzene, chloroform, carbon tetrachloride, DIMP, tetrachloroethylene, and TCE and were identified in the Bedrock Ridge Design Document (Morrison Knudsen Corporation 1999). Organosulfur compounds and organochlorine pesticides have been detected in wells farther upgradient and are included in the BRES performance well analyte list. The performance wells used to monitor water quality are listed below. The Bedrock Ridge Design Document (Morrison Knudsen Corporation 1999) concluded that given the slow migration and low permeability in the Denver Formation, the downgradient wells would be expected to clean up very slowly and not indicate system effectiveness. Thus, no performance criteria were required for the downgradient wells in the design document. However, decreasing concentration trends have been observed in downgradient water quality tracking wells 25503 and 25504. Thus, four downgradient monitoring wells have been included in the performance network. Since little or no water quality data have been collected from these wells, the wells will be monitored for five sampling events to assess the trends before any performance conclusions are drawn. Consequently, plume capture is demonstrated by viewing the potentiometric surface maps, monitoring water quality in plume-edge wells, and consideration of the downgradient well data.

The performance water quality wells are listed in Table 4.7-3 and the monitoring frequency is annual.

Table 4.7-3. BRES Performance Water Quality Network

Well	Location	Type
36555	Downgradient	Monitoring
36565	Upgradient/plume edge	Monitoring
36566	Downgradient	Monitoring
36567	Upgradient	Monitoring
36571	Downgradient	Monitoring
36572	Downgradient	Monitoring
36575	Upgradient/plume edge	Monitoring
36578	Upgradient	Monitoring

Upgradient and Downgradient Water Quality Tracking

Upgradient water quality tracking wells consist of monitoring wells 36552 and 36594. One downgradient well (25502) is included in the water quality tracking network to track the downgradient concentration trends. The monitoring frequencies are twice in 5 years and the indicator analytes are listed in Table 6.1-6. With the addition of four downgradient performance monitoring wells, it no longer is necessary to monitor 1999 LTMP water quality tracking wells 25503 and 25504, and they were deleted from the network.

The monitoring wells for all components of the BRES are summarized in Table 4.7-4 and shown on Figure 4.7-1.

4.8 Off-Post Groundwater Intercept and Treatment System

The OGITS consists of two extraction systems, located in the First Creek Pathway and Northern Pathway, and a treatment plant where the extracted water is treated by carbon adsorption. The First Creek paleochannel system consists of five extraction wells and six recharge trenches. The Northern Pathway System (NPS), which is located near Highway 2 and bisected by Peoria Street and north of 104th Avenue, consisted of 12 extraction wells and 24 recharge wells and pipelines for conveyance of water to the treatment plant at Peoria Street and from the treatment plant to the recharge wells. The NPS has been operating since 1993. Both the groundwater contaminant concentrations and the areal extent of groundwater contamination have significantly decreased since operation of the NPS began. Four of the NPS extraction wells were turned off on July 1, 2004 (PMRMA 2005c). Two First Creek System (FCS) extraction wells were turned off in September 2003 (PMRMA 2005b).

The modifications to the OGITS affect the NPS and the associated recharge wells used for reinjection of treated groundwater, as described in the Conceptual Design Document prepared for Amber Homes, Inc. (George Chadwick Consulting 2005). It is expected that the modified system will expedite cleanup of alluvial groundwater between the original and new Northern Pathway extraction wells. The new NPS extraction wells will be operated concurrently with the remaining original NPS extraction wells until the latter meet the ROD-specified shut-off criteria.

The NPS modifications were initiated in spring 2006 and include the following:

- Abandonment of eight existing recharge wells.
- Abandonment of three of the four existing extraction wells that have been turned off. The fourth well will be abandoned at a future date.
- Installation of six upgradient extraction wells near Highway 2 in the solvent, dieldrin, and DIMP plumes.
- Installations of five recharge trenches near Highway 2. These are in-line with and on both sides of each new extraction well in the dieldrin and DIMP plumes.

The original extraction wells and the new extraction wells will be operated until they meet the ROD shut-off requirements.

Specific criteria for monitoring performance relative to the OGITS objectives and for shutting off the system are presented in the sections below.

4.8.1 Performance Criteria and Consultation

The performance objective and associated performance criteria have been updated to address future monitoring needs and facilitate the system performance evaluation. Consultation trigger events for OGITS were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria are presented in Table 4.8-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue.

Mass removal performance will be evaluated based on total mass removed relative to the estimated mass approaching the extraction system. Mass removal graphs, mass vs. time, will be prepared to determine whether mass removal reaches asymptotic conditions. The performance criteria for the OGITS are presented below.

Performance Criteria:

- Demonstrate effective mass removal through comparison of total calculated mass removed by the system for each of the CSRG analytes and mass flux approaching the system estimated by standardized approach.
- Demonstrate that concentrations in downgradient performance wells are stable or decreasing.

4.8.2 Performance Monitoring Decision Rules

The performance monitoring decision rules that will be applied to the performance monitoring data during the FYR are presented below.

Decision

- Are mass removal goals achieved by the OGITS extraction and treatment systems?
- Are downgradient concentrations decreasing or stable?

Inputs to the Decision

Required information to support the decision elements includes the following:

- Influent and effluent water quality data
- OGITS extraction well water quality data
- Water quality data for upgradient performance wells
- Water quality data for downgradient performance wells
- Statistical trend analysis using the Mann-Kendall test for concentration trends if conclusions cannot be drawn based on visual observations
- Performance water level data

Study Boundaries

- Spatial study boundaries are defined by the influent, effluent, extraction wells, and water level and water quality performance wells.
- Analytes are limited to the OGITS ROD CSRG list.
- Monitoring frequencies are quarterly for the effluent, and annual for performance wells. Influent monitoring is performed in accordance with operational requirements.

Decision Rule

1. If the performance evaluation shows that either of the primary criteria is not met, i.e., mass removal is less than 75 percent of the mass flux approaching the system or downgradient concentration trends are increasing, the issue will be addressed through the consultative process identified in Table 4.8-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.
2. If the annual performance evaluation shows that the primary mass removal performance criterion is met, i.e., the mass removed by the system is at least 75 percent of the mass flux approaching the system, AND
3. If the annual performance evaluation shows that the primary downgradient concentration trend performance criterion is met, i.e., concentrations in downgradient performance wells are stable or decreasing, the system is functioning as intended.

Limits on Decision Errors

Potential error tolerance, based on method errors, will be included in the data evaluation as needed. The Post-Laboratory Data Validation procedure will be applied to any outliers (RVO 2007). The cumulative errors involved in water level monitoring will be considered during evaluation and discussion of monitoring data.

Table 4.8-1. Application of Consultative Process for OGITS Mass Removal System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs	Quarterly (water quality)	Within 30 days of data being finalized	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data	Annual (water level, water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Analytical data quality problems in finalized data	Quarterly, annual (Water Quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of primary performance criterion—the mass removed by the system is less than 75 percent[1] of the mass flux approaching the system on an annual basis	Annual (water quality)	Within 30 days of determination	Annual evaluation period: E-mail notification that includes description of issue with supporting data (e.g., confirmatory sampling), graphs etc., actions taken to date to correct problem, and proposed actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.

Notes:
[1] Trigger removal percentage set at 75 percent for this LTMP; potential adjustment pending data review after 5-year data collection period.

Table 4.8-1. Application of Consultative Process for OGITS Mass Removal System **Page 2 of 3**

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Loss of primary performance criterion—downgradient concentration trends increasing	Annual (water quality)	Within 30 days of determination	Annual evaluation period: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, present supporting data (for example, confirmatory sampling), graphs, etc., potential causes, actions taken and results to date, and develop consensus for future actions to correct problem, which may include increased sampling frequency. Second consecutive performance sampling event of trend increase: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.
Treatment system issues that could potentially affect compliance Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.
Extraction or recharge system problems that could potentially affect system performance Examples of extraction/recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Indication of irreversible plugging of recharge system; evaluation period runs 6 weeks from problem identification	Per event	Notification within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.

Notes:
[1] Trigger removal percentage set at 75 percent for this LTMP; potential adjustment pending data review after 5-year data collection period.

Table 4.8-1. Application of Consultative Process for OGITS Mass Removal System

Trigger Event	Associated Monitoring /Inspection Frequency	Notification Schedule	Consultation Required
Quarterly Effluent Report not issued by scheduled date (6 months following the reporting period)	Quarterly	No later than the Effluent Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

Notes:
[1] Trigger removal percentage set at 75 percent for this LTMP; potential adjustment pending data review after 5-year data collection period.

4.8.3 Chloride and Sulfate Attenuation Performance and Compliance

The On-Post ROD specified that the CSRGs for chloride and sulfate were to be met at the NBCS treatment plant within 30 and 25 years, respectively, of the issuance of the On-Post ROD (FWENC 1996). This means that the CSRGs will have to be met at the NBCS by 2026 for chloride and 2021 for sulfate. The CSRGs are expected to be achieved through attenuation occurring upgradient of the OGITS as the NBCS effluent concentrations decrease, consistent with the on-post remedy. The conclusions concerning meeting the CSRGs at the OGITS will be based on effluent concentrations in accordance with the Off-Post ROD. However, the Off-Post RS/S (Table 2.1) acknowledged that the background concentration for sulfate at OGITS was not determined and may be higher than at NBCS where the CSRG was based on the background concentration of 540 mg/L. The timeframes for meeting chloride and sulfate CSRGs specified for the NBCS in the On-Post ROD will also apply to OGITS. Consistent with the other OGITS CSRG analytes, shut-off decisions will be based on the concentrations in the upgradient and downgradient wells.

4.8.4 OGITS Monitoring Networks

4.8.4.1 Performance Monitoring

The performance water quality monitoring network shown below consists of downgradient monitoring wells and upgradient monitoring wells. As discussed above, one of the performance criteria is to compare upgradient mass flux to mass removed by the treatment plant. The operating extraction wells are sampled under the operational monitoring program for calculating mass flux and mass removal because some of the analytes are not detected in the treatment plant influent, but are detected in extraction wells. Upgradient mass flux will be calculated for each CSRG analyte detected in each extraction well, and compared to the mass flux estimated in upgradient monitoring wells using a Darcy's Law approach. For the extraction wells, average annual flow rates and concentrations will be used. The upgradient monitoring wells were selected to provide a cross-section of the plume upgradient of the extraction systems. The annual average alluvial saturated thickness and available hydraulic conductivity/transmissivity data will be used to estimate the annual mass flux. Simplifying assumptions, such as uniform concentrations with depth, no flow in the bedrock, uniform lateral concentrations to the mid-points between wells, etc. will be used in the estimates.

The performance criterion of demonstrating decreasing concentrations in downgradient wells will be accomplished with the downgradient wells listed in Table 4.8-2.

Table 4.8-2. OGITS Performance Water Quality Monitoring Network

Well	Location	Type
First Creek Pathway		
37084	Downgradient	Monitoring
37110	Downgradient	Monitoring
37343	Downgradient	Monitoring
37074	Upgradient	Monitoring
37075	Upgradient	Monitoring
37076	Upgradient	Monitoring
37083	Upgradient	Monitoring
37370	Upgradient	Monitoring
37373	Upgradient	Monitoring
Northern Pathway		
37008	Downgradient	Monitoring
37009	Downgradient	Monitoring
37010	Downgradient	Monitoring
37011	Downgradient	Monitoring
37012	Downgradient	Monitoring
37013	Downgradient	Monitoring
37027	Cross-gradient	Monitoring
37039	Cross-gradient	Monitoring
37452	Cross-gradient	Monitoring
37094	Upgradient	Monitoring
37095	Upgradient	Monitoring
37395	Upgradient	Monitoring
37404	Upgradient	Monitoring
37457	Upgradient	Monitoring
37458	Upgradient	Monitoring
37469	Upgradient	Monitoring
37471	Upgradient	Monitoring
37473	Upgradient	Monitoring
37474	Upgradient	Monitoring
EPA-4	Upgradient	Monitoring

Since the OGITS has a mass removal objective, performance water level monitoring will be used to determine the upgradient cross-sectional area of the saturated alluvium and hydraulic gradient for calculating the groundwater flow approaching the system and evaluate mass flux. The hydraulic performance of the system is also evaluated. Water level monitoring will also occur under the operations program to optimize system operation for as long as the system is operating. The performance water level network is shown in Table 4.8-3 and the monitoring frequency is annual.

Table 4.8-3. OGITS Performance Water Level Monitoring Network

Well	Location	Type
First Creek Pathway		
37045	Upgradient	Monitoring
37048	Upgradient	Monitoring
37050	Upgradient	Monitoring
37054	Upgradient	Monitoring
37058	Downgradient	Monitoring
37059	Downgradient	Monitoring
37060	Upgradient	Monitoring
37061	Upgradient	Monitoring
37062	Upgradient	Monitoring
37063	Upgradient	Monitoring
37064	Upgradient	Monitoring
37065	Upgradient	Monitoring
37066	Upgradient	Monitoring
37067	Upgradient	Monitoring
37068	Upgradient	Monitoring
37069	Upgradient	Monitoring
37071	Upgradient	Monitoring
37072	Upgradient	Monitoring
37073	Upgradient	Monitoring
37074	Upgradient	Monitoring
37075	Upgradient	Monitoring
37076	Upgradient	Monitoring
37083	Upgradient	Monitoring
37084	Downgradient	Monitoring
37090	Upgradient	Monitoring
37105	Cross-gradient	Monitoring
37106	Cross-gradient	Monitoring
37107	Upgradient	Monitoring
37110	Downgradient	Monitoring
37116	Cross-gradient	Monitoring
37117	Cross-gradient	Monitoring
37118	Upgradient	Monitoring
37127	Upgradient	Monitoring
37128	Upgradient	Monitoring
37130	Upgradient	Monitoring
37131	Downgradient	Monitoring
37132	Downgradient	Monitoring

Table 4.8-3. OGITS Performance Water Level Monitoring Network

Well	Location	Type
37133	Cross-gradient	Monitoring
37135	Upgradient	Monitoring
37136	Cross-gradient	Monitoring
37137	Cross-gradient	Monitoring
37138	Downgradient	Monitoring
37139	Upgradient	Monitoring
37140	Upgradient	Monitoring
37141	Downgradient	Monitoring
37142	Upgradient	Monitoring
37313	Downgradient	Monitoring
37343	Downgradient	Monitoring
37370	Upgradient	Monitoring
37373	Upgradient	Monitoring
37396	Downgradient	Monitoring
37407	Downgradient	Monitoring
37419	Upgradient	Monitoring
37422	Upgradient	Monitoring
37426	Upgradient	Monitoring
37427	Upgradient	Monitoring
37800	Upgradient	Extraction
37803	Upgradient	Extraction
37804	Upgradient	Extraction
Northern Pathway		
37008	Downgradient	Monitoring
37009	Downgradient	Monitoring
37010	Downgradient	Monitoring
37011	Downgradient	Monitoring
37012	Downgradient	Monitoring
37013	Downgradient	Monitoring
37014	Between recharge and extraction well alignments	Monitoring
37015	Between recharge and extraction well alignments	Monitoring
37016	Between recharge and extraction well alignments	Monitoring
37017	Between recharge and extraction well alignments	Monitoring
37018	Between recharge and extraction well alignments	Monitoring
37019	Between recharge and extraction well alignments	Monitoring
37020	Between recharge and extraction well alignments	Monitoring
37021	Between recharge and extraction well alignments	Monitoring
37022	Between recharge and extraction well alignments	Monitoring

Table 4.8-3. OGITS Performance Water Level Monitoring Network

Well	Location	Type
37023	Between recharge and extraction well alignments	Monitoring
37024	Between recharge and extraction well alignments	Monitoring
37025	Between recharge and extraction well alignments	Monitoring
37026	Between recharge and extraction well alignments	Monitoring
37027	Cross-gradient	Monitoring
37028	Upgradient	Monitoring
37029	Upgradient	Monitoring
37030	Upgradient	Monitoring
37031	Upgradient	Monitoring
37032	Upgradient	Monitoring
37033	Upgradient	Monitoring
37034	Upgradient	Monitoring
37035	Upgradient	Monitoring
37037	Upgradient	Monitoring
37038	Upgradient	Monitoring
37039	Cross-gradient	Monitoring
37080	Upgradient	Monitoring
37094	Upgradient	Monitoring
37095	Upgradient	Monitoring
37098	Recharge well alignment	Monitoring
37099	Recharge well alignment	Monitoring
37100	Recharge well alignment	Monitoring
37101	Recharge well alignment	Monitoring
37102	Upgradient	Monitoring
37103	Upgradient	Monitoring
37111	Recharge well alignment	Monitoring
37112	Recharge well alignment	Monitoring
37113	Recharge well alignment	Monitoring
37114	Recharge well alignment	Monitoring
37115	Recharge well alignment	Monitoring
37368	Upgradient	Monitoring
37395	Upgradient	Monitoring
37397	Cross-gradient	Monitoring
37404	Upgradient	Monitoring
37405	Downgradient	Monitoring
37451	Cross-gradient	Monitoring
37452	Cross-gradient	Monitoring
37453	Upgradient	Monitoring

Table 4.8-3. OGITS Performance Water Level Monitoring Network

Well	Location	Type
37454	Upgradient	Monitoring
37455	Upgradient	Monitoring
37456	Upgradient	Monitoring
37457	Upgradient	Monitoring
37458	Upgradient	Monitoring
37459	Upgradient	Monitoring
37460	Cross-gradient	Monitoring
37461	Cross-gradient	Monitoring
37462	Cross-gradient	Monitoring
37463	Upgradient	Monitoring
37464	Upgradient	Monitoring
37465	Upgradient	Monitoring
37469	Upgradient	Monitoring
37470	Upgradient	Monitoring
37471	Upgradient	Monitoring
37472	Cross-gradient	Monitoring
37473	Upgradient	Monitoring
37474	Upgradient	Monitoring
37475	Upgradient	Monitoring
37476	Upgradient	Monitoring
37477	Upgradient	Monitoring
37478	Upgradient	Monitoring
37479	Upgradient	Monitoring
37480	Upgradient	Monitoring
37481	Upgradient	Monitoring
37482	Upgradient	Monitoring
37484	Upgradient	Monitoring
37485	Upgradient	Monitoring
37487	Upgradient	Monitoring
37488	Upgradient	Monitoring
37494	Upgradient	Monitoring
37495	Upgradient	Monitoring
37496	Upgradient	Monitoring
37811	Upgradient	Extraction
37817	Upgradient	Extraction
37818	Upgradient	Extraction
37819	Upgradient	Extraction
37820	Upgradient	Extraction

Table 4.8-3. OGITS Performance Water Level Monitoring Network

Well	Location	Type
37821	Upgradient	Extraction
37822	Upgradient	Extraction
EPA-4	Upgradient	Monitoring

The monitoring wells for all components of the OGITS monitoring networks are summarized in Table 4.8-4 and shown in Figure 4.8-1.

4.8.4.2 Upgradient Water Quality Monitoring

Upgradient water quality wells in the off-post CSRG exceedance monitoring network include 37150, 37151, 37320, and 37367 in the NPS, and 37081, 37328, and 37369 in the FCS. The complete upgradient and downgradient CSRG exceedance monitoring network is described in Section 6.2.

4.8.5 CSRG Routine Analyte List

The review conducted for the OGITS ROD CSRG analytes is summarized in Table 4.8-5 which shows that the following 13 analytes were retained for the routine CSRG analyte list:

- 1,2-Dichloroethane
- Carbon tetrachloride
- Chloroform
- DBCP
- DCPD
- Dieldrin
- DIMP
- NDMA
- Tetrachloroethylene
- Chloride
- Fluoride
- Sulfate
- Arsenic

All of these analytes were detected at levels above the respective CSRGs or PQLs in the monitoring wells: nine were detected two or more times in extraction wells and two were detected two or more times in the influent. The revised routine CSRG analyte list is presented in Table 4.8-6.

4.9 System Shut-Off

The RMA On-Post and Off-Post RODs established general shut-off monitoring requirements following the shut-off of groundwater extraction wells or extraction systems (HLA 1995, FWENC 1996). However, it became apparent during the 2005 FYRR resolution process that there is a need to tailor the shut-off decision process, including the requirement for shut-off monitoring programs, to the type of system and its associated purpose and objectives. As discussed in Section 3.1.3, a consultative process with the Regulatory Agencies shall be applied to the shut-off decision and to the development of monitoring programs associated with shut-off.

The current RODs shut-off criteria allowed for different interpretations of when shut-off monitoring should begin; therefore, revised shut-off criteria are being recommended by this LTMP, and will not become effective until formally modified through a ROD Change Document. As part of these recommendations, ROD-required shut-off monitoring shall start after the entire extraction system, or a discrete portion of an extraction system, has been shut off. Operational shut-off monitoring shall be conducted from the time an extraction well is shut-off until system shut-down to ensure that the operational objectives of the system continue to be met. The procedure developed for the operational shut-off monitoring will be issued prior to the implementation of this LTMP. The following changes to the shut-off monitoring approach constitute ROD changes that will be documented separately:

- Shut-off of individual extraction wells will be addressed under the operational monitoring program for each system according to a new operational shut-off procedure.
- The revised ROD shut-off monitoring requirements will apply only to shut-off of entire systems or discrete portions of systems. A discrete portion of an extraction system is defined as a branch of an extraction system that serves a specific purpose within a system, such as capture of a specific plume or analyte, and can be easily distinguished from the rest of the system with regard to operation and monitoring. Specific examples of discrete portions of systems include the:
  - Hydraulic barrier portion of the NWBCS Original System
  - Western portion of the NBCS, west of Peoria Street

The recommendation to initiate the shut-off process for a system or portion of a system will be based on the concentrations in the upgradient and cross-gradient water quality performance wells reported below their respective ARARs. System shut-off initiation may be recommended when:

- The concentrations of CSRG analytes in all upgradient and cross-gradient water quality performance wells have been below ARARs for a minimum of two consecutive routine sampling events and the system has been evaluated to be ready for shut-off by the program manager. The Regulatory Agencies will be notified of the intent to shut the system off, and provided with the monitoring results and justification for system shut-off.

The consultative process will be applied to decide if shut-off should proceed and if and what pre-shut-off monitoring activities should be performed before shutting the system off.

- When the established shut-off criteria for a system have been met, the consultative process will be initiated. The Regulatory Agencies will be informed and a pre-shut-off monitoring program will be developed, if appropriate, in cooperation with the Regulatory

Agencies. This program may include additional confirmatory monitoring and/or short-term system shut-off. A signed Decision Document with an approved Sampling and Analysis Plan (SAP) will govern the pre-shut-off monitoring program. At the end of the pre-shut-off period the Parties will develop a formal decision through the consultative process as to whether system shut-off and shut-off monitoring should proceed.

- When the system shut-off decision has been reached the consultative process will be applied to develop a shut-off monitoring program. Shut-off monitoring wells may be selected from the performance, tracking, and operational wells. An approved SAP will govern the shut-off monitoring program.
- The ability to restart extraction and treatment during the shut-off monitoring period will be ensured through preservation of extraction wells, recharge wells/trenches, associated piping, and any requisite utilities, combined with either mothballing of the existing treatment system or arranging for alternate treatment that can be implemented within 6 months of determining that the system may be restarted.

The BANS (Section 4.6) will continue to be operated as a mass removal system until an agreement to shut off the NWBCS (Section 4.3) has been reached. At that time potential modifications to BANS will be considered to ensure that the remedy remains protective and that groundwater contamination above CSRGs does not migrate past the RMA boundary. The potential BANS modifications will be based on the flow and contaminant conditions at the time of NWBCS shut-off and will be implemented within a year after completion of the NWBCS shut-off monitoring program. BANS will continue to treat any water extracted by the BRES, Complex Trenches, and Lime Basins extraction systems. The shut-off criteria for BANS will be developed through consultation with the Regulatory Agencies after agreement regarding the potential system modifications and revised performance criteria has been reached.

The system shut-off process, starting with the recommendation to initiate the shut-off process and ending with the post-shut-off monitoring phase, is illustrated in Table 4.9-1.

4.9.1 Pre-Shut-Off Evaluation

When the RVO believes shut-off criteria for a system have been met, consultation with the Regulatory Agencies will be initiated and a pre-shut-off monitoring program will be developed. This program may include additional confirmatory monitoring and/or short-term system shut-off based upon the factors listed below. A signed Decision Document with an approved SAP will govern the pre-shut-off monitoring program. The Regulatory Agencies will be notified if any changes to the approved SAP monitoring requirements or significant changes in system operation occur during the pre-shut-off period.

Factors that should be considered in developing the pre-shut-off monitoring programs for the systems include:

- Locations of sources
- Distance to source
- Travel time to source
- Concentration trends prior to shut-off

- Historical concentration levels
- Fate and transport properties of contaminants
- Attenuation of concentrations between sources and system

After successful completion of the pre-shut-off monitoring program and Regulatory Agency Approval to Proceed with system shut-off, a SAP for the shut-off monitoring program will be developed for Regulatory Agency review and approval. The SAP will be incorporated into a formal Decision Document identifying if system shut-off and system shut-off monitoring should proceed.

4.9.2 Shut-Off Monitoring Criteria

Shut-off monitoring will be conducted for a minimum of 5 years, with quarterly monitoring during the first and last years and annual monitoring in the intervening years for all analytes on the applicable CSRG analyte list. The reason for performing quarterly monitoring during the first year is to address potential rebound, which is most likely to occur immediately after the system has been shut off. The final year of quarterly monitoring is intended to confirm that it is appropriate to proceed with system shut-off.

The extraction wells, recharge wells/trenches, associated piping, and any requisite utilities will be preserved for potential restart during the shut-off monitoring period. The existing treatment system will either be mothballed or demolished. If the treatment system is demolished, contractual arrangements will be made prior to demolition to ensure that treatment using a portable system is implemented within 6 months of determining that the system must be restarted. The consultative process will be applied to decide if the system can be shut off permanently at the end of the shut-off monitoring period. The criteria that apply to the shut-off monitoring program are as follows:

1. Once the system or a discrete portion of a system has met the pre-shut-off criteria and has been turned off, the shut-off monitoring program will be used to confirm that the groundwater remedy goal has been successfully achieved. These performance criteria may be re-instated if shut-off criteria are not achieved and the system/subsystem is re-started.
2. Shut-off monitoring wells may be selected from the performance, tracking, and operational wells.
3. Monitoring will be performed for a minimum period of 5 years with quarterly monitoring for the first and final years, and annual monitoring for the intervening years. The duration of the monitoring program will be determined during the consultative process and documented in the approved SAP.
4. ARAR exceedances during the shut-off monitoring period in any well within the shut-off monitoring network of a system/subsystem will trigger a restart of the shut-off monitoring period for all system/subsystem wells in the shut-off monitoring network if the exceedance occurs during year one or year two of the shut-off monitoring period. Restart of the monitoring will include quarterly monitoring during the first year followed by at least three years of annual monitoring followed by a final year of quarterly monitoring. If the exceedance(s) occur during the third, fourth, fifth, or later years, the

consultative process shall be initiated to determine an alternative shut-off monitoring schedule that will achieve the shut-off monitoring objectives.

5. Exceedance of the ARARs for two consecutive sampling years (any exceedance during a quarterly monitoring year or an exceedance during an annual monitoring year) will require the system/subsystem to be restarted.
6. In case of a missed sampling event, consultation will be initiated to decide whether the sampling program will have to be restarted.
7. The Regulatory Agencies will be notified and consultation initiated in case chemical data are rejected to determine if the sampling program needs to be modified.

4.9.3 Permanent System Shut-Off Decision

The decisions and decision rules for system shut-off are presented below.

Decision

- Have concentrations of all ROD CSRG analytes in all shut-off monitoring wells been below all ARARs for the duration of the shut-off monitoring period and do the data indicate that they will continue to meet the ARARs in the future?

Decision Rule

- If concentrations of all ROD CSRG analytes in all shut-off monitoring wells have been below ARARs for the duration of the shut-off monitoring period and other data indicate ARARs will continue to be met in the future, the Regulatory Agencies will be notified of the plans to permanently shut off the system, and the Regulatory Agencies will be provided with all of the monitoring results and justification for permanent system shut-off for review and approval. A signed Decision Document will be issued to document the shut-off decision. Upon approval by the Regulatory Agencies, a post-shut-off monitoring plan will be developed and the permanent system shut-off will be implemented.

4.9.4 Post-Shut-Off Monitoring

The post-shut-off monitoring network will be selected from the available shut-off, performance, water level tracking, water quality tracking, and operational monitoring wells as appropriate. The monitoring program will be designed for a system-specific duration and frequency.

After successful completion of the shut-off monitoring program, a post-shut-off monitoring program will be developed for Regulatory Agency review and approval. The SAP will be incorporated into a formal Decision Document identifying that the permanent system shut-off should proceed, and the monitoring program will be incorporated in the LTMP. A CCR will be developed to document completion of each groundwater treatment system remedy.

Table 4.9-1. System Shut-Off Activities, Documentation and Decision Process

System Shut-Off Phase	Shut-Off Recommendation[1]	Pre-Shut-Off Monitoring[1]	Shut-Off Monitoring[1]	Post-Shut-Off Monitoring
Monitoring Categories	Input data categories: • Performance Monitoring • Operational Monitoring • Tracking	Well selection categories: • Performance Monitoring • Operational Monitoring • Tracking	Well selection categories: • Performance Monitoring • Operational Monitoring • Tracking	Well selection categories: • Performance Monitoring • Operational Monitoring • Tracking
System Status	• System is operating	• System is operating; intermittent shut-off possible	• System is not operating but treatment can be restarted	• System abandoned/removed
Monitoring Programs	Decision based on: • Concentrations less than ARARs in upgradient and cross-gradient water quality performance wells for minimum of two routine sampling events	• Properly designed sampling program is a potential combination of performance, operational, and tracking monitoring developed through consultation • Operational program (monitoring and operations) open to Regulatory Agencies in order to minimize operational changes that could affect the data collected • All CSRG analytes analyzed	• Minimum 5 years; first year and last year quarterly events; intervening years annual • All CSRG analytes analyzed • Restart monitoring if concentrations in years 1 and 2 are above ARARs or significant data quality issues occur • Restart treatment if concentrations in two consecutive years are above ARARs • Consult in years 3–5 if concentrations are above ARARs or significant data quality issues occur	1. Post-shut-off monitoring program based on consultative process
Plans/Reports	• Formal recommendation with supporting data to initiate shut-off	• Decision Document to document agreement to proceed with pre-shut-off phase combined with SAP for pre-shut-off monitoring and activities • Pre-Shut-Off Monitoring Report	• Decision Document that documents agreement to proceed with shut-off combined with SAP for shut-off monitoring program • Data summaries in quarterly effluent reports and annual summary reports • CCR if program requirements met	2. Decision Document that reflects agreement to permanently shut off system 3. SAP for post-shut-off monitoring program 4. Updates in annual summary report 5. MCR at completion of program

Notes:
[1] Consultation and decision required to proceed.

4.10 Termination of System Operation

As system operation proceeds, regulatory options allowing termination of system operation prior to achieving ROD shut-off criteria may become available. The decision and the decision rule for that situation are presented below.

Decision

- Do termination conditions (e.g., deminimis mass removal or risk range considerations) exist allowing shut-off in a manner consistent with both CERCLA as amended by SARA, the NCP, and associated guidance and the Colorado Hazardous Waste Act?

Decision Rule

- If RVO believes that termination conditions exist that allow shut-off in a manner consistent with both CERCLA as amended by SARA, the NCP, and associated guidance and the Colorado Hazardous Waste Act, the Regulatory Agencies will be provided with all of the monitoring results and justification for termination of system operation prior to achieving ROD shut-off criteria for review and approval. Formal documentation, with any post-shut-off monitoring plan, will be issued to the Regulatory Agencies for approval prior to termination of the system operation.

5.0 PROJECT-SPECIFIC MONITORING PROGRAMS

Several portions of the RMA remedy have specific groundwater monitoring requirements that are not subject to change through the LTMP processes, for example, analytes, frequency, and monitoring network. Any changes to these project-specific monitoring programs must be formally detailed in a Decision Document approved by the Regulatory Agencies. Once a Decision Document is final, changes to the monitoring network will be tracked through the LTMP.

Groundwater monitoring associated with containment areas that fall under CERCLA are included in the LTMP as specific remedy monitoring components integrated within the water level or water quality tracking programs. The Complex Trenches, Shell Trenches, and Lime Basins remedies include slurry walls and dewatering components to enhance containment in addition to RCRA-equivalent covers. For these sites, water level monitoring is conducted to evaluate the effectiveness of each remedy.

The South Plants Central Processing Area; South Plants Balance of Areas, SPSA-2d Ditch; and Basin A remedies utilize caps and covers for soil containment. For these remedies, water level and water quality monitoring are conducted to evaluate the effectiveness of each remedy. To distinguish the different monitoring requirements, these three sites are grouped under Source Monitoring, and monitoring is integrated within the water level and water quality tracking categories. The CERCLA monitoring programs related to soil containment areas are addressed as follows in this LTMP.

5.1 Complex Trenches Dewatering System

Refer to Section 4.9 regarding the inclusion of potential BANS modifications in the NWBCS shut-off evaluation.

5.1.1 Performance Criteria and Consultation

The performance criteria for the Complex Trenches dewatering system are based on achieving water elevation goals (i.e., below the bottoms of the disposal trenches), not water quality or mass flux goals. Quarterly water level monitoring is conducted in 11 wells to monitor the hydraulic gradient across the slurry wall, and water levels inside the slurry-wall enclosure, to assess progress toward meeting the dewatering goals. The groundwater pumped by the Complex Trenches dewatering system is treated at the BANS to meet CSRGs and reinjected in the BANS recharge trenches. Consultation trigger events for the Complex Trenches were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria are presented in Table 5.1-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue. The performance criteria established in the approved design document (RVO 1997a) for the Complex Trenches are presented below.

Performance Criteria:

- Demonstrate groundwater elevations in compliance monitoring wells 36216 and 36217 are below the target elevations of 5226 and 5227 ft, respectively.
- Maintain positive gradient from the outside to the inside of the barrier wall (for as long as active dewatering is occurring).

5.1.2 Performance Monitoring Decision Rules

1. If groundwater elevations in both of the compliance monitoring wells are at or below the target groundwater elevations, this component of the Complex Trenches remedy is functioning as intended.
2. If a positive gradient is maintained from the outside to the inside of the barrier wall (for as long as active dewatering is occurring), this component of the Complex Trenches remedy is functioning as intended.
3. If the performance evaluation shows that one or both of the dewatering goals are not met, the issue will be addressed through the consultative process identified in Table 5.1-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.

Meeting the dewatering goals likely will not be achieved until the Integrated Cover System is completed and the vegetation has been established. The cover is designed to reduce the infiltration of precipitation, which will reduce the volume of water that must be pumped to achieve the dewatering goals. The vegetation plays a critical role in the effectiveness of the cover, but first must be established, which requires irrigation. For cover compliance, the vegetation is expected to be established 5 years after the cover is constructed and seeded. Irrigation of the cover for establishing the vegetation may cause recharge inside the slurry-wall enclosure and increase the volume of water that must be pumped to meet the dewatering goals. Therefore, meeting the dewatering goals will not be required until the end of the 5-year period when the vegetation is established and irrigation has ended. Cover construction, revegetation, and initial irrigation for the Complex Trenches portion of the Integrated Cover System was completed on September 9, 2009. Consequently, achievement of the dewatering goals is expected to occur by September 9, 2014, after the 5-year period required to establish vegetation.

5.1.3 System Shut-Off

The requirement for maintaining an inward hydraulic gradient ends when the dewatering goal of lowering the groundwater elevations in both of the compliance monitoring wells below the target elevations has been maintained and dewatering is no longer required. The decision process for discontinuing extraction from the Complex Trenches will be developed through application of the consultative process and based on the ongoing performance evaluation.

Table 5.1-1. Application of Consultative Process for Complex Trenches

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Individual effluent sample above CSRGs[1]	Quarterly (water quality)	Within 30 days of data being accepted	First event: E-mail notification that includes analyte concentration, description of potential cause, and actions taken to date or proposed actions to correct problem. Second consecutive event: Meetings scheduled to review trigger event, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem.
Missed effluent data collection[1]	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data for dewatering system	Quarterly (water level)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect monitoring data for BANS treatment plant[1]	Quarterly, semiannual, annual (water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
BANS treatment plant analytical data quality problems in finalized data[1]	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
One or both dewatering goals have not been achieved within 5 years of cover completion and revegetation (i.e., by September 9, 2014) After the performance goal has been achieved, loss of performance criterion—groundwater elevations in one or both of the compliance monitoring wells are above the target groundwater elevations, which are 5226 ft for well 36216 and 5227 ft for well 36217[2]	Quarterly (water levels)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem. Third consecutive quarter: If issue is not resolved through follow-up actions, and restoration of the dewatering goal is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.

Notes:
[1] Treatment system and recharge system issues are addressed as BANS triggers in Table 4.6-1.
[2] Until dewatering goals are achieved and maintained, quarterly groundwater level data will be presented in the Quarterly Effluent Data Report.

Table 5.1-1. Application of Consultative Process for Complex Trenches

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Loss of performance criterion—dewatering does not maintain positive gradient from the outside to the inside of the barrier wall (for as long as active dewatering is occurring).	Quarterly (water levels)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem. Third consecutive quarter: If issue is not resolved through follow-up actions, and loss of dewatering goal is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.
Treatment system issues that could potentially affect compliance[1] Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week Decrease in treatment capacity at BANS that affects Complex Trenches extraction rate	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.

Notes:
[1] Treatment system and recharge system issues are addressed as BANS triggers in Table 4.6-1.
[2] Until dewatering goals are achieved and maintained, quarterly groundwater level data will be presented in the Quarterly Effluent Data Report.

Table 5.1-1. Application of Consultative Process for Complex Trenches

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Extraction or recharge[1] system problems that could potentially affect system performance Examples of extraction or recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification Decrease in recharge capacity at BANS that affects Complex Trenches extraction rate Indication of irreversible plugging of recharge system[1]; evaluation period runs 6 weeks from problem identification	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.
Annual Summary Report not issued by scheduled date (September 30^{th}, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

Notes:
[1] Treatment system and recharge system issues are addressed as BANS triggers in Table 4.6-1.
[2] Until dewatering goals are achieved and maintained, quarterly groundwater level data will be presented in the Quarterly Effluent Data Report.

5.1.4 Water Level Monitoring Program

Quarterly performance water level monitoring will be conducted to monitor the hydraulic gradient and gradient direction across the slurry wall, and to determine whether the water levels are below the bottoms of the disposal trenches. The summary of wells in the Complex Trenches can be found in Table 5.1-2 and shown on Figure 5.1-1.

Table 5.1-2. Complex Trenches Water Level Monitoring Network

Well	Well Type
36215	Dewatering Trench Piezometer
36216	Water Level Compliance Well
36217	Water Level Compliance Well
36218	Monitoring Well
36219	Monitoring Well
36220	Monitoring Well
36221	Monitoring Well
36080	Monitoring Well
36189	Monitoring Well
36301	Monitoring Well
36305	Dewatering Well

5.2 Shell Trenches

5.2.1 Performance Criteria and Consultation

The performance criteria for the Shell Trenches are based on achieving water elevation goals (i.e., below the bottoms of the disposal trenches) (RVO 1997a). Quarterly water level monitoring is conducted in 14 wells to monitor the hydraulic gradient across the slurry wall, and water levels inside the slurry-wall enclosure, to assess progress toward meeting the dewatering goals. Consultation trigger events for Shell Trenches were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues. These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 5.2-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue. The performance criterion established in the approved design document (RVO 1997a) for the Shell Trenches is presented below.

Performance Criterion:

- Demonstrate groundwater elevations are below the disposal trench bottom elevations within the slurry wall enclosure listed in Table 5.2-2.

5.2.2 Performance Monitoring Decision Rules

1. If groundwater elevations are below the disposal trench bottom elevations within the slurry wall enclosure, this component of the Shell Trenches remedy is effective.

2. If the performance evaluation shows that the dewatering goal is not met, the issue will be addressed through the consultative process identified in Table 5.2-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.

5.2.3 Performance Evaluation

- The locations for determining whether water levels are below the trench bottoms are the six boring locations listed in Table 5.2-2. The trench bottom elevations were determined in these boreholes.
- The performance criterion will be accomplished by visual inspection of water elevation contours drawn using the wells in the Shell Trenches water level monitoring network and the resulting interpreted water elevations at the boring locations.
- Linear interpolation between data points will be used to draw the water elevation contours between wells.
- As discussed in the 2005 FYRR (PMRMA 2007a), meeting the dewatering goal likely will not be achieved until the Integrated Cover System is completed and the vegetation has been established. The cover is designed to reduce the infiltration of precipitation, which will reduce the volume of water that could affect achievement of the dewatering goal. The vegetation plays a critical role in the effectiveness of the cover, but first must be established, which requires irrigation. For cover compliance, the vegetation is expected to be established 5 years after the cover is constructed and seeded. Irrigation of the cover for establishing the vegetation may cause recharge inside the slurry-wall enclosure. Therefore, meeting the dewatering goal will not be required until the end of the 5-year period when the vegetation is established and irrigation has ended. Cover construction, revegetation, and initial irrigation for the Shell Trenches portion of the Integrated Cover System was completed on September 15, 2007. The final inspection for the cover revegetation was held on October 2, 2007. Consequently, achievement of the performance goal is expected to occur by October 2, 2012, after the 5-year period required to establish vegetation.

Table 5.2-1. Application of Consultative Process for Shell Trenches

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Inability to collect compliance and performance water level monitoring data	Quarterly (water level)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
The dewatering goal has not been achieved within 5 years of cover completion and revegetation (i.e., by October 2, 2012). After the performance goal has been achieved, loss of performance criterion—groundwater water levels in compliance wells above target elevations; i.e., groundwater elevations are above the disposal trench bottom elevations within the slurry-wall enclosure. The lowest trench bottom elevation is 5237.7 ft in borehole 3453 (LTMP Table 5.2-2). The water elevations at the borehole locations listed in Table 5.2-1 are determined by linear interpolation of water elevations between monitoring wells as described in LTMP Section 5.2.2.	Quarterly (water levels)	Within 30 days of determination	First quarter: E-mail notification that includes description of issue with supporting data, actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter: Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem. Third consecutive quarter: If issue is not resolved through follow-up actions, and groundwater elevations remain above target levels, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

Table 5.2-2. Elevation of Shell Trenches Bottoms

Bore ID	Original Ground Elevation (ft)	Depth to Bottom of Trench (ft)	Trench Bottom Elevation (ft)
3178	5251.02	9	5242.02
3444	5248.1	4	5244.1
3445	5248.5	8	5240.5
3446	5248.6	8	5240.6
3453	5246.7	9	5237.7
3457	5249.8	9	5240.8

Water Level Monitoring Program

Quarterly performance water level monitoring will be conducted to monitor the hydraulic gradient and gradient direction across the slurry wall, and to determine whether the water levels are below the bottoms of the disposal trenches. The summary of wells in the Shell Trenches network can be found in Table 5.2-3 and shown on Figure 5.2-1.

Table 5.2-3. Shell Trenches Water Level Monitoring Network

36222	36223
36224	36225
36226	36528
36529	36530
36531	36532
36533	36535
36536	36537

5.3 Lime Basins Dewatering System

The Lime Basins soil remedy was changed in the 2005 Section 36 Lime Basins Remedy ROD Amendment (TtEC 2005) to include an encircling slurry wall and dewatering well system to lower water levels below the Lime Basins waste and create an inward hydraulic gradient across the slurry wall. The groundwater pumped by the Lime Basins dewatering system is treated at the CWTP and reinjected in the Lime Basins recharge trenches until the CWTP is decommissioned in 2010. After shutdown of the CWTP, it is planned to treat the Lime Basins groundwater at the BANS to meet CSRGs and reinject the treated water in the BANS recharge trenches.

5.3.1 Performance Criteria and Consultation

The performance criteria for the Lime Basins dewatering system are based on achieving water elevation goals. Consultation trigger events for Lime Basins were established based on system compliance requirements, performance criteria, and non-routine operational events that might lead to performance or compliance issues (TtEC 2007). These triggers, along with notification requirements, type of consultation, and follow-up criteria, are presented in Table 5.3-1. The table also includes operational trigger events that could potentially result in a compliance or performance issue. The performance criteria for the Lime Basins are presented below.

Performance Criteria:

- Maintain a positive gradient from the outside to the inside of the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).
- Maintain a groundwater level below the elevation of the Lime Basins waste (5242 ft) inside the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).

The target elevation for lowering the water levels below the waste inside the slurry-wall enclosure is 5242 ft. Six monitoring wells located inside the slurry-wall enclosure will be used as the compliance wells.

5.3.2 Performance Monitoring Decision Rules

1. If dewatering maintains positive gradient from the outside to the inside of the barrier wall (for as long as the surrounding local groundwater table is in the alluvium), AND
2. If dewatering maintains a groundwater level below the elevation of the Lime Basins waste (5242 ft) inside the barrier wall, this component of the Lime Basins remedy is functioning as intended.
3. If the performance evaluation shows that one or both of the dewatering goals are not met, the issue will be addressed through the consultative process identified in Table 5.3-1. Any performance trigger event will be addressed according to the process outlined in the table and included in the annual performance evaluation.

Although achieving the Lime Basins dewatering goals does not rely on installation of the cover, the associated revegetation and irrigation may affect the timeframe for meeting the dewatering goals. The cover is designed to reduce the infiltration of precipitation, which will reduce the volume of water that must be pumped to achieve the dewatering goals. The vegetation plays a critical role in the effectiveness of the cover, but first must be established, which requires irrigation. For cover compliance, the vegetation is expected to be established 5 years after the cover is constructed and seeded. Irrigation of the cover for establishing the vegetation may cause recharge inside the slurry-wall enclosure and increase the volume of water that must be pumped to meet the dewatering goals. Therefore, meeting the dewatering goals will not be required until the end of the 5-year period when the vegetation is established and irrigation has ended. Cover construction, seeding, and irrigation for the Lime Basins portion of the Integrated Cover System were completed on September 9, 2009. Consequently, achievement of the dewatering goals is expected to occur by September 9, 2014, after the 5-year period required to establish vegetation.

Table 5.3-1. Application of Consultative Process for Lime Basins Dewatering System

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Missed effluent data collection[1]	Quarterly (water quality)	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect performance monitoring data for dewatering system	Quarterly (water level)[2]	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Inability to collect monitoring data for treatment plant[1]	Quarterly, semiannual, annual (water quality)	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
Treatment plant analytical data quality problems in finalized data[1]	Quarterly, annual (water quality)	Within 30 days of discovery	E-mail notification that includes description of issue and cause, extent of data problems, actions taken to correct problem, and corrective measures to prevent recurrence.
Loss of performance criterion—dewatering does not maintain positive gradient from the outside to the inside of the barrier wall (for as long as the surrounding local groundwater table is in the alluvium)[4]	Quarterly (water levels)[2] Annual water level monitoring after the groundwater table drops below the level of the alluvium inside the barrier wall	Within 30 days of determination	First quarter:[3] E-mail notification that includes description of issue with supporting data, actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter:[3] Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem. Third consecutive quarter:[3] If issue is not resolved through follow-up actions, and loss of dewatering goal is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.

Notes:
1 Treatment system and recharge system issues are addressed under the CERCLA system and the Underground Injection Control for the Mass Removal/Lime Basins project. Treatment and recharge location will change to BANS in 2010.
2 Performance water level monitoring frequency is quarterly during the first year of operation and then will be re-evaluated. Any subsequent change in the monitoring frequency will be subject to Regulatory Agency approval.
3 Notification changes to match changes in the monitoring frequency.
4 Trigger will take effect after the dewatering goal of creating an inward hydraulic gradient across the barrier wall has been achieved for two consecutive quarters.
5 Trigger will take effect after the dewatering goal of lowering the water level below the Lime Basins waste inside the barrier wall has been achieved for two consecutive quarters.
6 Until dewatering goals are achieved and maintained, quarterly groundwater level data will be presented in the Quarterly Effluent Data Report.

Table 5.3-1. Application of Consultative Process for Lime Basins Dewatering System

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Loss of performance criterion— dewatering does not maintain groundwater level below the elevation of the Lime Basins waste (5242 ft) inside the barrier wall[5]	Quarterly (water levels)[2] Annual water level monitoring after the groundwater table drops below the level of the alluvium inside the barrier wall	Within 30 days of determination	First quarter:[3] E-mail notification that includes description of issue with supporting data, actions taken to correct problem, and proposed actions to correct problem. Second consecutive quarter:[3] Meeting(s) with Regulatory Agencies will be scheduled to review trigger events, potential causes, actions taken and results to date, and develop consensus for future actions to correct problem. Third consecutive quarter:[3] If issue is not resolved through follow-up actions, and loss of the dewatering goal is within RVO's control, the Regulatory Agencies will be notified within 2 weeks of determination, and a proposed Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.
One or both dewatering goals have not been achieved within 5 years of cover completion and revegetation (i.e., by September 9, 2014)[6]	Quarterly (water levels)	Within 30 days of determination	E-mail notification and meeting(s) with Regulatory Agencies to review trigger events, potential causes, actions taken and results to date. A proposed Non-Routine Action Plan will be developed within 30 days of meeting for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to resolve issues.
Treatment system issues that could potentially affect compliance[1] Examples of treatment system problems and process evaluation periods: GAC performance issues not corrected within 4 weeks of operational adjustments Power outage lasting more than 1 week Decrease in treatment capacity at BANS that affects Lime Basins extraction rate	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, potential increased process monitoring, and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.

Notes:

1 Treatment system and recharge system issues are addressed under the CERCLA system and the Underground Injection Control for the Mass Removal/Lime Basins project. Treatment and recharge location will change to BANS in 2010.

2 Performance water level monitoring frequency is quarterly during the first year of operation and then will be re-evaluated. Any subsequent change in the monitoring frequency will be subject to Regulatory Agency approval.

3 Notification changes to match changes in the monitoring frequency.

4 Trigger will take effect after the dewatering goal of creating an inward hydraulic gradient across the barrier wall has been achieved for two consecutive quarters.

5 Trigger will take effect after the dewatering goal of lowering the water level below the Lime Basins waste inside the barrier wall has been achieved for two consecutive quarters.

6 Until dewatering goals are achieved and maintained, quarterly groundwater level data will be presented in the Quarterly Effluent Data Report.

Table 5.3-1. Application of Consultative Process for Lime Basins Dewatering System

Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Extraction or recharge[1] system problems that could potentially affect system performance Examples of extraction or recharge system problems and process evaluation periods: Extraction well damage that has a significant impact on extraction rate and requires extensive repairs; evaluation period runs 1 week from problem identification. Indication of irreversible plugging of recharge system[1]; evaluation period runs 6 weeks from problem identification Decrease in recharge capacity at BANS that affects Lime Basins extraction rate	Per event	Within 7 days of process evaluation completion	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem and schedule for system restoration. Once system is operational an e-mail will be sent to the Regulatory Agencies along with any corrective measures to prevent recurrence.
Annual Summary Report not issued by scheduled date (September 30th, of each year)	Annual	No later than the Annual Summary Report due date	E-mail followed by formal letter that includes notification of missed deadline and the actual issuance date along with explanation for delay and a summary of major report findings.

Notes:
1 Treatment system and recharge system issues are addressed under the CERCLA system and the Underground Injection Control for the Mass Removal/Lime Basins project. Treatment and recharge location will change to BANS in 2010.
2 Performance water level monitoring frequency is quarterly during the first year of operation and then will be re-evaluated. Any subsequent change in the monitoring frequency will be subject to Regulatory Agency approval.
3 Notification changes to match changes in the monitoring frequency.
4 Trigger will take effect after the dewatering goal of creating an inward hydraulic gradient across the barrier wall has been achieved for two consecutive quarters.
5 Trigger will take effect after the dewatering goal of lowering the water level below the Lime Basins waste inside the barrier wall has been achieved for two consecutive quarters.
6 Until dewatering goals are achieved and maintained, quarterly groundwater level data will be presented in the Quarterly Effluent Data Report.

5.3.3 Water Level Monitoring Network

The Lime Basin dewatering system began operation on March 30, 2009. During the first year of operation, quarterly water level monitoring will be conducted in 13 monitoring wells (2 existing and 11 new wells), and the 6 new dewatering wells listed in Tables 5.3-2 and 5.3-3, to monitor water elevations inside the slurry-wall enclosure and the hydraulic gradient across the slurry wall. These wells are shown on the BANS well location map (Figure 4.6-1). After the first year of operation, the water level monitoring frequency will be re-evaluated. Data from the first year of monitoring will be summarized and reviewed with the Regulatory Agencies during project status meetings. Any changes to the monitoring frequency will be formally documented in a Decision Document approved by the Regulatory Agencies.

Table 5.3-2. Lime Basins Water Level Monitoring Network—Existing and New Monitoring Wells

36054	36212
36231 (MW-1)	36232 (MW-2)
36233 (MW-3)	36234 (MW-4)
36235 (MW-5)	36236 (MW-6)
36237 (MW-7)	36238 (MW-8)
36239 (MW-9)	36240 (MW-10)
36241 (MW-11)	

Table 5.3-3. Lime Basins Water Level Monitoring Network—Dewatering Wells

36315 (DW-5)
36316 (DW-6)
36317 (DW-7)
36318 (DW-8)
36319 (DW-9)
36320 (DW-10)

5.3.4 Long-Term Monitoring

As stated in the ROD Amendment, long-term water level monitoring will be conducted to document that water levels remain below the waste material and an inward hydraulic gradient is maintained as long as the surrounding local groundwater table is in the alluvium.

Monitoring data collected prior to turning off the dewatering wells will be used to determine whether the annual water level monitoring event should be conducted during a specific quarter. Additionally, quarterly water level monitoring will be conducted during the first year after the dewatering wells are turned off to further assess the seasonal variation and select the most appropriate quarter for conducting the annual water level monitoring event. Regardless, after the RCRA-equivalent soil covers are installed, seasonal variations in groundwater levels near the Lime Basins site are expected to be insignificant.

After water levels fall below the alluvium, the ROD Amendment specifies that water levels will be monitored annually to confirm that they stay below the alluvium. The decision to terminate dewatering will be formally documented in a Decision Document approved by the Regulatory Agencies.

5.4 North Plants LNAPL

In 2008, a Pilot LNAPL Removal System Action Plan (TtEC 2008b) was prepared and is currently being used to determine the extent to which removal of LNAPL is practicable using a well recovery skimming system. A total of 22 piezometers and 2 recovery wells have been installed in the North Plants LNAPL plume. Since the installation of piezometers in 2003, water levels and product levels have been measured to establish LNAPL thickness and extent.

As part of the pilot study, operation of the well skimming system will be in accordance with the schedule presented in the Pilot LNAPL Removal System Action Plan (TtEC 2008b). The pilot LNAPL removal system will be operated to the extent necessary to gather data in support of the final action, if any, for the North Plants LNAPL Plume (TtEC 2008b).

Information gathered from pilot system operation will be provided in Water Team meetings or through e-mail transmittals. Two recovery wells and 10 piezometers were installed in February 2009, and monitoring began in March 2009. Through January 2010, no LNAPL has accumulated in the recovery wells or new piezometers, so LNAPL recovery operations have not yet begun. After 1 year of operating the pilot system, or until sufficient data are collected to design the final remedial action, RVO will prepare a pilot system evaluation report that summarizes the results, evaluates performance in meeting the pilot study objectives, and makes recommendations based on these results. This pilot system report will serve as a decision-making document for potential future actions. The pilot system report will be prepared and provided to the Regulatory Agencies for review within 60 days of ending the pilot study. The report will include data evaluation from the pilot system operation and discussion of any future actions for the LNAPL based on the results of the pilot system operation. Criteria for completion of any LNAPL recovery operation will also be developed in the pilot study report. The completion criteria and the potential need for post-shut-off monitoring or periodic operation of the system will also consider the water-level effects on the LNAPL accumulation (TtEC 2008b).

5.5 Source Monitoring

Water level and water quality tracking are conducted to track the effects and progress of the on-post remedy. For long-term operations, the ROD states, "Where human health exceedance soils are left in place at soil sites, groundwater will be monitored, as necessary, to evaluate the effectiveness of the remedy." On-post monitoring relies on water level tracking as the primary means of tracking the effects of remedies on water levels and flow paths/flow directions. Water quality tracking is conducted to track contamination in and downgradient of source areas within the identified plumes. As stated in Section 2.4, project-specific monitoring is handled separately from the LTMP.

Source monitoring is conducted in the South Plants Central Processing Area; South Plants Balance of Areas, SPSA-2d Ditch; and Basin A to evaluate effectiveness of the remedies. The objectives of the source-monitoring component of on-post water level and quality tracking are as follows:

- Conduct water level monitoring to assess the impact of the on-post remedy implementation on water levels, flow, and contaminant migration pathways in plume source areas.
- Conduct water quality monitoring for key indicator compounds to support contaminant concentration tracking in source areas where human health exceedance soils are left in place.

The source monitoring details are provided in Sections 6.1.1 and 6.1.2.

5.6 Other Monitoring Programs

Other RMA Programs are not considered part of the LTMP as monitoring and reporting is conducted in accordance with RCRA and CERCLA requirements. These monitoring programs include monitoring of the HWL, ELF, Basin F, and LWTS and are summarized below. Any changes in these monitoring programs are not tracked in the LTMP.

Hazardous Waste Landfill/Enhanced Landfill—The HWL cap is complete, pending Regulatory Agency approval. Groundwater beneath the HWL is currently monitored under the requirements of the HWL Post-Closure Groundwater Monitoring Plan (TtEC 2009b). Groundwater beneath the ELF is currently monitored under the requirements of the ELF Closure Groundwater Monitoring Plan (TtEC 2008a). HWL has ceased operations and the final cap is completed and is currently in post closure (TtEC 2007). The ELF cap construction started in October 2008 and is expected to be complete in 2010.

Monitoring is conducted in upgradient and downgradient wells to detect any migration of landfill contaminants into the groundwater. The monitoring network consists of several two-well clusters that monitor separate sandstone intervals in the weathered Denver Formation. Separate monitoring systems have been installed around the LWTS basins west of the HWL.

Post-closure and closure monitoring of the HWL and ELF wells, respectively, are conducted quarterly, with analytical results presented to the Regulatory Agencies on an annual basis. If a significant increase in analyte concentration is detected in downgradient wells, then steps will be taken to determine potential leakage from the landfill, including review of data packages, comparison of upgradient to downgradient analyte concentrations, comparison of downgradient analytes to sump data, and resampling of subject monitoring wells.

If groundwater is found to be adversely affected by a leak from the landfill, then a groundwater assessment program will be initiated and developed. The Regulatory Agencies will be notified of any significant increase in analyte concentrations above prediction limits (TtEC 2009b, TtEC 2008a).

Basin F—Groundwater beneath Basin F is currently monitored under the requirements of the Basin F Closure/Post-Closure Groundwater Monitoring Plan (TtEC 2006a). This plan is designed to monitor general trends and provide information on water quality. Monitoring is conducted in upgradient and downgradient wells for both the Basin F Wastepile and Basin F principal threat areas within Basin F. The monitoring network consists of several wells designed to monitor groundwater flow and water quality within the saturated alluvium and upper Denver Formation, and the deeper weathered Denver Formation.

The monitoring schedule provided in the Basin F Closure/Post-Closure Groundwater Monitoring Plan included semiannual baseline sampling for the Wastepile wells in April and October 2006, followed by semiannual closure (post-liner removal) sampling for 1 year, and annual sampling thereafter. The Principal Threat excavation monitoring program included semiannual baseline sampling in April and October 2007, followed by semiannual post-excavation sampling in wells for 1 year, and annual sampling thereafter.

General trends in water quality and prediction limits are monitored for qualitative remedy effectiveness evaluations. If detections are above Basin F reporting limits, concentrations for selected chemicals of concern will be plotted, tracked, and compared to contaminants associated with Basin F. Water levels will be measured, plotted, and contoured after each sampling event and compared to previous monitoring events to determine changes in groundwater flow conditions (TtEC 2006a).

Water quality results will be submitted annually to the Regulatory Agencies. In 2009, the first annual Basin F Groundwater Monitoring Report (TtEC 2009a) was generated, comparing data from baseline monitoring to closure monitoring. Water quality and water level monitoring data will also be available from the RMA Environmental Database.

Landfill Wastewater Treatment System—Groundwater beneath the LWTS is being monitored pursuant to Appendix A of the Draft Final Landfill Wastewater Treatment System Closure Plan (URS Washington Division and TtEC 2009). This plan is designed to monitor wells upgradient and downgradient of the LWTS to assess potential releases of hazardous constituents from the LWTS to groundwater.

6.0 SITE-WIDE MONITORING PROGRAMS

The site-wide monitoring programs incorporate on-post and off-post groundwater monitoring not included with the system-related monitoring as well as on-post and off-post surface water monitoring. The following monitoring categories are described in subsections below:

- Water level tracking
- Water quality tracking
- CFS monitoring
- Off-post exceedance monitoring
- Surface water monitoring

Water quality samples collected under the water quality tracking, CFS, and surface water monitoring programs will continue to be analyzed for indicator analytes that are representative of the respective monitoring areas. This approach is consistent with EPA guidance (EPA 1995) which supports the use of a shorter list of indicator analytes for remedy monitoring.

The selection of indicator analytes is based on evaluations of contaminant sources and historical trends associated with major contaminants, the concern attributed to specific contaminants, and physical/chemical properties that determine their migration rates. The following factors were considered in the selection process:

- Presence (and contaminant history) in area soil, waste, or groundwater
- Physical/chemical properties that affect contaminant migration rate (i.e., solubility and mobility)
- Concentrations
- CSRG analytes for downgradient systems
- ARARs
- Treatability of compounds at the respective treatment system

Indicator analytes will be tracked between source areas where they originate and the systems where they are treated.

As described in Section 3.3, a consultative process between the RVO and the Regulatory Agencies will be used to address non-routine events related to the performance and quality objectives of these programs. Common and category-specific triggers for consultation are identified in Table 6.1-1 for all the site-wide monitoring categories. The category-specific triggers are related to monitoring objectives and performance criteria discussed in the subsections that follow. The consultative process tables include notification schedules and specify the consultation process components.

Table 6.1-1. Application of Consultative Process for Site-Wide LTMP Monitoring Programs

Monitoring Category	Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
All[1]	Inability to collect monitoring data	Per event	Within 30 days of identifying that there will be or was a missed event	E-mail notification that includes description of issue and cause, actions taken to correct problem, and corrective measures to prevent recurrence.
All[1], except surface water	Well damage that could affect data collection	Per event	Within 30 days of identifying well damage	E-mail notification (with option to meet) that includes description of problem, actions taken to correct problem, and schedule for well restoration.
Water Level Tracking/Off-Post Water Level Monitoring	Missed water level data collection	Annual	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
Water Level Tracking/Off-Post Water Level Monitoring	Change in flow direction that could affect mass removal or containment objectives	Annual	Within 30 days of determination	First corresponding annual evaluation period: E-mail notification that includes description of issue with supporting data (for example, confirmatory water level monitoring), graphs etc., actions taken to date to correct problem, and proposed actions to correct problem, which may include increased monitoring frequency. Second consecutive evaluation period: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.
Water Quality Tracking	Changes in water quality trends that could affect containment, mass removal, or treatment objectives	Once in 5 years, twice in 5 years	Within 30 days of determination	First corresponding evaluation period: E-mail notification that includes description of issue with supporting data (for example, confirmatory sampling), graphs etc., actions taken to date to correct problem, and proposed actions to correct problem, which may include increased sampling frequency. Second consecutive evaluation period: The Regulatory Agencies will be notified within 2 weeks of determination, and an assessment of the problem will be provided. If deemed necessary, a Non-Routine Action Plan will be developed within 30 days of notification for review and approval by the Regulatory Agencies. Meetings will be held with Regulatory Agencies to develop consensus and resolve issues on the Action Plan.

Notes:
[1] Categories are water level tracking, water quality tracking, CFS monitoring, off-post exceedance monitoring, and surface water monitoring.

Table 6.1-1. Application of Consultative Process for Site-Wide LTMP Monitoring Programs

Monitoring Category	Trigger Event	Associated Monitoring/ Inspection Frequency	Notification Schedule	Consultation Required
Water Quality Tracking	Missed water quality data collection	Once in 5 years, twice in 5 years	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
CFS Monitoring	Concentration increase in CFS well. Examples include: Detection of previously undetected organic indicator analyte Greater than 50% concentration increase for organic indicator analyte Order of magnitude increase in inorganic indicator analyte	Twice in 5 years	Within 60 days of determination	First event: E-mail notification that includes description of issue and potential causes and any follow-up. Second event: E-mail notification followed by meeting with Regulatory Agencies to review available data and assess the need for additional sampling.
Off-Post Exceedance Monitoring	Concentration increase (above CSRGs/PQLs) in exceedance well. Examples include: Concentration increase from levels below to levels above the CSRG/PQL Greater than 50% concentration increase for analyte present at levels above CSRG/PQL	Twice in 5 years	Within 60 days of determination	First event: E-mail notification that includes description of issue and potential causes and any follow-up. Second event: E-mail notification followed by meeting with Regulatory Agencies to review available data and assess the need for additional sampling and/or network change.
Surface Water Monitoring	Missed water quality data collection	Annual	Within 30 days of discovery of missed event	E-mail notification that includes description of issue, actions taken to correct problem, and corrective measures to prevent recurrence.
	Concentration increase (above CBSMSWs or CSRGs) at surface water monitoring location	Annual	Within 60 days of determination	First event: E-mail notification that includes description of issue and potential causes and any follow-up. Second event: E-mail notification followed by meeting with Regulatory Agencies to review available data and assess the need for additional sampling.

Notes:
[1] Categories are water level tracking, water quality tracking, CFS monitoring, off-post exceedance monitoring, and surface water monitoring.

6.1 On-Post Monitoring Programs

The site-wide long-term monitoring program defined in this section is designed to evaluate the performance of each remedy component outlined in Section 2.0. In keeping with EPA guidance on performance monitoring (EPA 1995), the 1999 LTMP on-post monitoring networks were selected using data collected during the extensive characterization of groundwater contamination at RMA during the RI and FS. These data were used to define baseline conditions, and the long-term monitoring program was designed to evaluate the overall performance of the remedy rather than continue the comprehensive evaluation of water quality. The long-term groundwater monitoring program described in this LTMP revision is based mainly upon the continuation and modification of existing monitoring programs. Consistent with EPA guidance, the monitoring program relies upon water level measurement to monitor contaminant plume migration and capture; water quality data are collected less frequently and in fewer locations to confirm the interpretation of the water level results. Additionally, on-post and off-post bedrock paleochannels create preferential migration pathways that prevent significant changes in flow directions. Thus, the hydrogeology helps facilitate the monitoring approach used in the LTMP. Most of the groundwater flow occurs in the saturated alluvium in these bedrock paleochannels, with much less flow where the alluvium is unsaturated (Figure 2.2-1).

6.1.1 Water Level Tracking

Water level and water quality tracking are conducted to track the effects and progress of the on-post remedy. Water level tracking is the primary means of tracking the effects of remedies on water levels and flow/flow directions on post. Both water level and water quality tracking will be used to monitor contaminant migration. Water level tracking is divided into two subgroups: source monitoring and monitoring upgradient and downgradient of sources. Source monitoring is identified as a separate component of water level tracking because of the On-Post ROD requirement for groundwater monitoring in source areas where human health exceedance soils are left in place. Outside of the source areas, the additions to the water level tracking network are addressed under miscellaneous additions.

6.1.1.1 Monitoring Criteria

Objective:

- Conduct water level monitoring to assess the impact of the on-post remedy implementation on water levels, flow, and contaminant migration pathways between the plume source areas and the RMA boundary.

Criteria:

- Develop and maintain water level tracking network that tracks the impacts of on-post remedy implementation on water levels, flow direction, and contaminant migration pathways in previously identified plumes between on-post source areas and the RMA boundary.
- Evaluate water level data to assess if lowering of the water table is occurring where soil covers and caps are installed. Use visual time-trend comparisons of water level contours to assess if there are any changes that could impact flow, flow directions, and contaminant migration pathways.

The consultation triggers specific to water level tracking are identified in Table 6.1-1 as:

- Missed water level data collection
- Change in flow direction that could affect mass removal or containment objectives

The table identifies the consultative processes that will be triggered by these events.

6.1.1.2 Data Evaluation

Data evaluation for the annual water level tracking monitoring events will entail 1) incorporation of all contemporaneous monitoring data and contour maps, 2) plotting the current and previous year contours on the same map for comparison to aid the consistency in interpreting the data and help to identify outliers, 3) an elevation difference map will be generated for the current and previous year maps to identify outliers and areas of potential recharge and discharge, 4) significant changes in water elevations will be identified, 5) applicable precipitation data will be evaluated, and 6) significant changes in flow directions that could impact the effectiveness of the remedy will also be identified.

The on-post water level tracking data will be used to monitor changes in aquifer conditions during and after implementation of soil remedies. Installation of soil covers and caps in soil remedy areas will reduce infiltration and groundwater recharge and thereby cause passive dewatering and affect groundwater flow. The water level tracking maps will be provided in the Annual Summary Reports and significant trends in tracking data will be summarized in the FYSR, along with comparison water level maps that will show any changes that have occurred during the 5-year period.

6.1.1.3 Monitoring Network

The on-post network of wells selected for water level tracking, both in and beyond the areas of the systems, includes 295 wells. The water level tracking wells are shown along with the 88 off-post water level monitoring wells in Figure 6.1-1, and a complete listing of these wells is presented in Table 6.1-2.

A quantitative analysis was used to develop the water level tracking network in the 1999 LTMP. Conducting a similar analysis for this document was not necessary because the previous network was adopted. The only deletions included wells that have been closed and those in Table 6.1-3 below. Wells were added in areas where new wells were installed for project-specific monitoring programs, such as in the Lime Basins and STF areas. The list was also updated to reflect changes implemented in the Well Networks Update (FWENC 2003b). In a few cases, wells were added where the water levels have fallen and original tracking wells are dry or have much less than 5 ft of water in the well screens. Table 3-4 in the 1999 LTMP included temporary well numbers for wells that were to be installed in the future. All of these wells have been installed or assigned permanent well numbers and added to the current water level tracking network. The additions to the network are discussed below. In this LTMP 342 wells have been identified for performance water level monitoring, and 295 and 88 wells have been identified for on-post water level tracking and off-post water level monitoring, respectively. As of October 2007 an additional 829 wells are currently monitored for water levels in operational and project-specific monitoring programs. The locations of the operational and project-specific water level wells, which are not included in the LTMP, are shown on Figure 6.1-1.

Table 6.1-3. Deletions from the Water Level Tracking Network

Deleted Well	Location	Rationale
23226 23235	NBCS Denver UFS	Included in the NBCS operational/performance networks
25503 25504	BRES	Transferred to the Bedrock Ridge performance network
37077 37085 37365	FCS Denver UFS	Included in the OGITS FCS operational network

6.1.1.4 Additions to Water Level Tracking Network

Source Monitoring

South Plants Central Processing Area

Well 01656 will be added to the water level tracking network in South Plants as a replacement for well 01511.

South Plants Balance of Areas, SPSA-2d Ditch

Two wells (01669 and 01670) were added as upgradient wells for South Plants SPSA-2d Ditch source monitoring.

Basin A

Sampling and evaluation of the designated Basin A project monitoring program (RMA Decision Document DD-BasinA-16 [RVO 2010]) is conducted as part of the LTMP. Fourteen UFS and two CFS wells were specified for annual water level monitoring during the construction and consolidation phase of the Basin A remedy in the Basin A Consolidation and Remediation Design Document (RVO 1997c). Two of the 14 UFS wells (36513 and 36540) were closed due to interference with soil excavation. Well 36513 was closed in 2002 and well 36540 was closed in 2006. Seven replacement UFS wells were to be added to the Basin A water level network after cover construction. The seven replacement wells were installed in 2007 and 2008. The remaining 12 Basin A construction and consolidation phase UFS wells and 7 replacement UFS wells listed in Table 6.1-4 comprise the Basin A water level monitoring network and are included in the LTMP water level tracking network, which is monitored annually.

CFS monitoring is addressed in Section 6.1.3, and one of the two Basin A CFS water level wells (36171) was incorporated in the CFS monitoring program. The second well (36170) was not included because it is part of the same well cluster as 36171, it was not constructed properly, and it does not contribute to Basin A or CFS monitoring needs.

Table 6.1-4. Basin A Water Level Network

Construction/Consolidation Phase UFS Wells	Replacement UFS Wells
36052	36627
36054	36628
36077	36629
36089	36630
36092	36631
36094	36632
36112	36633
36123	
36142	
36168	
36169	
36210	

Miscellaneous Additions

Table 6.1-5 summarizes other additions to the water-level tracking network. Eight wells are located near the STF Mass Removal Project system. A small groundwater mound is present in the STF Plume area that was not observed when water levels previously were higher in South Plants. The STF groundwater mound now appears to be the high point in the water table in South Plants. Project-specific monitoring will also be conducted in this area until the system shuts down in 2010. Two wells near Lake Ladora are added to the water level tracking network because they were also added to the water quality tracking network.

Some of the wells listed in Table 6.1-4 are either upgradient or downgradient of the Lime Basins site. In addition to the wells listed in Table 6.1-4 for Basin A, well 36212 will be added to the water level tracking network. Operational water level monitoring for the Lime Basins Mass Removal and Dewatering Projects will also be conducted as discussed in the design documents that were issued prior to implementation of this LTMP. Project-specific monitoring for Lime Basins Mass Removal Project will end after the system shuts down in 2010, but monitoring for the Lime Basins Dewatering Project will continue after 2010. The Lime Basins Dewatering Project monitoring program is presented in Section 5.3.

Table 6.1-5. Miscellaneous Additions to Water Level Tracking Network

Well	Location/Explanation
01407	South Tank Farm. Added to water level tracking network.
01408	South Tank Farm. Added to water level tracking network.
01681	South Tank Farm. Added to water level tracking network.
01685	South Tank Farm. Added to water level tracking network.
01686	South Tank Farm. Added to water level tracking network.
01687	South Tank Farm. Added to water level tracking network.
02522	South Tank Farm. Added to water level tracking network.
02523	South Lakes. Added to water quality tracking network.
02597	South Lakes. Added to water quality tracking network.
02683	South Tank Farm. Added to water level tracking network.
04029	Downgradient RYCS area. Added to water level tracking network.
04080	Western Tier/Motor Pool area. Added to water level tracking network.
07139	Southern Tier. Added to water level tracking network.
11023	Southern Tier. Added to water level tracking network.
23053	North of Basin F. Added to help map the water table where the gradient is very flat
23548	HRC area. Added to water quality tracking network
24003	NBCS. Added to water level tracking network.
24098	NBCS. Added to water level tracking network.
24126	NBCS. Replaces closed well 24063.
27002	NWBCS. Added to water quality tracking network.
27043	NWBCS. Added to water quality tracking network.
27066	NWBCS. Added to water level tracking network.
27077	NWBCS. Added because nearby well 27078 is nearly dry.
34015	NWBCS. Added to water quality tracking network.
36212	Lime Basins. Added to water level tracking network.
36217	Complex Trenches compliance well.

6.1.2 Water Quality Tracking

Water quality tracking is conducted in conjunction with water level tracking to track contamination in and downgradient of source areas within the identified plumes. Water quality tracking is divided into two subgroups: source monitoring and monitoring downgradient of sources. Source monitoring is identified as a separate component of water quality tracking because of the On-Post ROD requirement for groundwater monitoring in source areas where human health exceedance soils are left in place. Monitoring downgradient of sources pertains to sources where human health exceedance soils are left in place and other sources.

6.1.2.1 Source Monitoring

Source monitoring is conducted in South Plants; South Plants Balance of Areas, SPSA-2d Ditch; and Basin A to evaluate effectiveness of the remedies. The objective of the source-monitoring component of on-post water quality tracking is as follows:

- Conduct water quality monitoring for key indicator compounds to support contaminant concentration tracking in source areas where human health exceedance soils are left in place.

6.1.2.2 Monitoring Downgradient of Sources

The objective of the on-post water quality tracking downgradient of sources is as follows:

- Monitor concentrations between source areas and the RMA boundary, and to evaluate long-term trends in these areas.

6.1.2.3 Performance Criteria

- Conduct monitoring for indicator analytes in source areas and within historically defined plumes for contaminant tracking purposes.
- Evaluate water quality data to assess concentration trends and address potential needs for changes to the monitoring program. Use water level data and historical chemical data to identify monitoring locations and indicator analytes.

6.1.2.4 Data Evaluation

Concentration trends are tracked to monitor the effects of the remedy and to provide concentration data for plumes upgradient of the internal and boundary mass removal or containment systems. Consequently, the data are analyzed by graphing the data and qualitatively evaluating the trends by visual inspection.

The consultation triggers specific to water quality tracking are identified in Table 6.1-1 as:

- Missed water quality data collection
- Changes in water quality trends that could affect containment, mass removal, or treatment objectives

The table identifies the consultative processes that will be triggered by these events.

On-post plume extent mapping will be used to evaluate the long-term progress of the remedy; therefore, beginning in 2014, on-post plume extent mapping for selected indicator analytes will be conducted on a 20-year frequency. The indicator analytes are listed below:

On-post plume extent mapping indicator analytes:

- DIMP
- Dieldrin
- Chloroform
- Benzene

- NDMA
- Carbon tetrachloride
- Dithiane
- Arsenic

6.1.2.5 Monitoring Network

The water quality tracking network developed in the 1999 LTMP still meets the data needs for monitoring the effectiveness of the remedy and most of the wells were incorporated in the revised network. This conclusion is based on the fact that the assumptions used to develop the network in the 1999 LTMP are still valid. Monitoring of South Plants; South Plants Balance of Areas, SPSA 2-d Ditch; and Basin A has been grouped under Source Monitoring to distinguish these sites from other areas because of the requirement to monitor groundwater where human health exceedance soil is left in place. A few changes in the network and analyte lists have been made where the remedy was changed or where project-specific monitoring wells have been installed. In some areas, monitoring wells were added to provide additional data between sources and containment systems to evaluate concentration trends and future system shut-off. Other network or analyte changes were made based on evaluation of the water quality tracking data. While changes in the plumes have occurred since 1994 when pre-ROD baseline plume mapping was conducted, on-post plume mapping is not needed to evaluate short-term remedy effectiveness. The RVO is not planning to delete plumes, so plume mapping is not needed for this purpose. Where monitoring changes in the plumes is important, such as at the pump and treat systems, operational and performance monitoring is conducted.

The 1999 LTMP water quality tracking indicator analyte lists were reviewed and revised based on the recent and historical results. EPA 1995 guidance supports the use of a shorter list of indicator analytes for remedy monitoring in areas upgradient and downgradient of containment and treatment systems and in source areas, with a more complete analyte list near the systems. The indicator analyte selection criteria were developed in the 1999 LTMP. Analytes were deleted from the indicator analyte list if they have not been detected historically, and added to the indicator analyte list if they were detected at significant concentrations. The water quality network, indicator analytes, and sampling frequency for each well are listed in Table 6.1-6.

Water quality tracking wells associated with the groundwater containment and mass removal systems are discussed separately in the respective sections for these systems, but included in the water quality tracking network presented in Table 6.1-6 and shown on Figure 6.1-2. Monitoring in the other remedy areas identified in Section 2.4 is described in the subsections below. Other operational and project-specific water-quality monitoring besides that specified in the LTMP is conducted at RMA. Figures 6.1-2 and 6.2-1 show the locations of these operational and project-specific water quality wells.

6.1.2.6 Source Monitoring

South Plants Central Processing Area

Wells 01078 and 01525 are retained from the 1999 LTMP. Wells 01078 and 01525 are located in the South Plants North Plume within the Central Processing Area. Wells 01078 and 01525 are to be sampled once in 5 years because of the flat hydraulic gradient and slow groundwater migration in South Plants. The frequencies and analytes are listed in Table 6.1-6.

South Plants Balance of Areas—SPSA-2d Ditch

Wells 01101, 01044, 01047, 01582, 01669, and 01670 were added as source monitoring wells because human health exceedance soil was discovered east of the STF and consequently, the South Plants 3-ft soil cover was extended. Monitoring of these wells was included in a DCN for the ICS project (DCN-ICSC-69) and is implemented by the LTMP. These wells are to be sampled once in 5 years for aldrin and dieldrin (Table 6.1-6). Chloride is included for well 01101 because it is adjacent to CFS well 01109.

Wells 01669 and 01670 are located near the edge of the STF benzene plume and had relatively high benzene concentrations in 2005 (12,400 and 3,040 µg/L, respectively), which may fluctuate over time. The benzene concentrations in these wells may affect the aldrin/dieldrin analytical results due to interferences or increase the reporting limits for aldrin/dieldrin if dilution is necessary to conduct the aldrin/dieldrin analyses. Although detection of aldrin or dieldrin is not expected, if it occurs it likely would be of extremely low concentrations (< 0.1 µg/L). Thus, low reporting limits for aldrin and dieldrin are needed. If the aldrin/dieldrin analyses cannot be conducted for these wells because of benzene interferences or if sufficiently low reporting limits cannot be achieved, the sampling of these wells will be re-evaluated.

Basin A

As designated in the RMA Decision Document DD-BasinA-16 (RVO 2010), six of seven wells (36627, 36629, 36630, 36631, 36632, and 36633) will be monitored for the indicator analytes listed in Table 6.1-6. A seventh well (36628) is in a similar flowpath as other wells and was deleted.

As specified in the Basin A Consolidation and Remediation Project Design Document (RVO 1997c) and reiterated in the Decision Document, a sampling frequency of once in 5 years is appropriate to monitor water quality in Basin A. In the design document, groundwater velocity of 0.16 to 0.25 ft/day and groundwater travel of 300 to 500 ft in 5 years were estimated. This estimated travel over 5 years represents only about 10 percent of the length of the Basin A groundwater flow path of approximately 4,500 ft. In the future, as remediation is completed and the Integrated Cover System is installed and the vegetation becomes established, local recharge feeding the Basin A aquifer is expected to be significantly reduced, resulting in flattening of the hydraulic gradient in the Basin A aquifer and further reducing the groundwater velocity and contaminant migration rates.

The indicator analyte lists for the Basin A have been revised to include additional relevant compounds of interest, such as arsenic to monitor the effects of the Lime Basins mass removal and dewatering systems, NDMA, and dithiane, which is a control compound for the BANS treatment plant.

6.1.2.7 Other Areas

Former Basin F and Basin F Wastepile

Groundwater monitoring for the Basin F remedy is conducted under a separate RCRA monitoring program (TtEC 2006a) that is coordinated with the LTMP. Long-term monitoring will continue for 1999 LTMP wells 26015, 26017, 26157, and 26163, and the wells have been incorporated into the Basin F post-closure monitoring program.

North Boundary Enhancement

One well, 23548, has been added to the water quality tracking network downgradient of the NBE HRC barrier north of Basin F to track potential long-term residual effects of the in situ injection and natural attenuation in this area. It will be sampled once in 5 years for the analytes listed on Table 6.1-6. Well 23548 is completed in a Denver Formation sandstone, which has lower permeability than the overlying alluvium, and thus, the sampling frequency is once in 5 years.

North Plants

The 1999 LTMP source area monitoring well for North Plants, 25059, will continue to be monitored. Well 24081 is located downgradient of North Plants and is added to the network. The North Plants wells are to be sampled twice in 5 years for the analytes listed in Table 6.1-6.

Lime Basins

Well 36210 was added to the network to monitor the Lime Basins area. The monitoring frequency for well 36210 is also twice in 5 years.

Downgradient of Basin A

Downgradient of Basin A, 1999 LTMP wells 26500 and 35069 had not been sampled prior to including them in the 1999 LTMP. They were uncontaminated (or well below CSRGs) in 2002, 2004, 2007, and 2009, and are therefore located outside of the Basin A plume flow path and were deleted from the current network.

Water quality tracking well 35065, which is located downgradient from Basin A and upgradient of the BANS, is sampled with a frequency of twice in 5 years to provide additional data for groundwater plumes approaching the BANS. The groundwater travel time from this well to the BANS is approximately 1.8 years based on the summer 2006 hydraulic gradient of 0.0195 foot/foot, an average hydraulic conductivity of 31.05 ft/day from three alluvial pumping or injection tests in wells 26503, 35509, and 36123, and an assumed effective porosity of 0.25. The indicator analyte list for well 35065 was revised to include additional relevant compounds of interest, such as arsenic to monitor the effects of the Lime Basins mass removal and dewatering systems, NDMA, and dithiane, which is a control compound for the BANS treatment plant.

Bedrock Ridge

Wells 25502, 36552, and 36594 are retained from the 1999 LTMP and will be sampled twice in 5 years for the analytes indicated on Table 6.1-6. Well 25502 is located downgradient of the BRES and the Section 36 wells are located upgradient. Wells 25503 and 25504 were deleted from the water quality tracking network because four adjacent wells were added to the BRES performance network.

South Plants Balance of Areas

Wells 02065 and 36181 were added in the South Plants area to augment the 1999 LTMP network and add monitoring in the South Plants Southwest and South Plants North Plumes. Wells 02065 and 36181 are to be sampled once in 5 years because of the flat hydraulic gradient and slow groundwater migration in the South Plants area. The frequencies and analytes are listed in Table 6.1-6.

South Tank Farm

Well 01534 is retained from the 1999 LTMP and is located within the STF Plume. It will provide long-term monitoring after the STF mass removal project ends. Well 01534 will be sampled twice in 5 years because it is within the STF Plume and closer to the South Lakes. The frequency and analytes are listed in Table 6.1-6.

South Lakes Area

As discussed in Section 2.3.5, the ROD requirement for lake-level maintenance or other means of hydraulic containment or plume control was removed with an ESD (TtEC 2006b). Groundwater monitoring will be conducted as part of the long-term monitoring program for groundwater to assess any change in future conditions. Wells 02034, 02505, 02512, 02524, and 02525 are retained from the 1999 LTMP for monitoring downgradient of the STF benzene plume and near Lakes Ladora and Mary. Well 02056 was deleted because of the consistent absence of contamination. Wells 02523 and 02597 were added to augment the well network near Lake Ladora.

Western Plume Group

This plume group includes the Railyard, Motor Pool, and Western Plumes. Since shut-off monitoring was completed for the ICS and Motor Pool System, post-shut-off monitoring will be developed separately from the LTMP.

- Railyard

  Well 03523 is retained from the 1999 LTMP and will be sampled twice in 5 years for DBCP as indicated on Table 6.1-6. Well 03503 was deleted because it was included in the RYCS performance network.

- Motor Pool

  Well 04535 is included in the water level and water quality tracking networks. It will be sampled twice in 5 years until the Motor Pool Monitoring Completion Report (MCR) is completed, which will also determine any post-shut-off monitoring needs.

- Western Plume

  Well 33341 is deleted from the water quality tracking network. The TCE concentrations in this well have shown a decreasing trend and in 2004 and 2007 were below the MCL/CBSG of 5 μg/L.

NWBCS

Wells 03016, 27025, 27037, 27079, 27082, 27083, 34020, and 35058 are retained from the 1999 LTMP and will be sampled twice in 5 years for the analytes indicated in Table 6.1-6. Wells 03005, 03015, 22001, 27002, 27043, 27091, 34005, 34008, 34015, 34017, and 34508 were added to the water quality tracking monitoring network to provide additional monitoring farther upgradient of the NWBCS, closer to sources. These wells will also be sampled twice in 5 years for the analytes indicated in Table 6.1-6.

Since the NWBCS has three components, which intercept contaminated groundwater flow from multiple source areas, the wells are discussed below in relation to the sources and NWBCS components.

- Well 22001 is located 1,000 ft upgradient of the Northeast Extension and monitors flow in a small alluvial channel downgradient of Basin F.
- Wells 03015, 03016, 27043, 34008, and 34015 are upgradient of the Southwest Extension and monitor a dieldrin plume that originates in South Plants.
- Wells 03005, 27002, 27037, 27083, 27091, 34005, and 34017 are upgradient of the Original System in the major alluvial channel located on the west side of RMA. Well 27091 is located approximately 2,800 ft upgradient of the system and provides additional plume-edge monitoring in anticipation of shutdown of the Southwest Extension (located west of well 27091). Well 34005 is located in the interior of the plume, 8,500 ft upgradient of the system.
- Wells 27025 and 27082 are upgradient of the Original System in the Basin A Neck paleochannel and downgradient of the BANS.
- Wells 34508 and 35058 are upgradient of the Original System in a separate small alluvial channel downgradient of a Sand Creek Lateral source. Groundwater in this separate channel discharges into the main alluvial channel upgradient of the NWBCS.
- Well 27079 is upgradient of the Original System in a small paleochannel and downgradient of former Basin F.

NBCS

Wells 23095, 23096, 23142, 24092, and 24094 are retained from the 1999 LTMP and will be sampled twice in 5 years for the analytes indicated on Table 6.1-6.

6.1.3 Confined Flow System Monitoring

The On-Post ROD describes the CFS monitoring component of the ROD remedy as follows:

- Monitoring of the CFS is to be conducted in the South Plants area, the Basin A area, and close to Basin F. Data from these wells are assessed to determine whether contaminant levels within the CFS are increasing or migrating significantly with time.
- Specific monitoring wells will be selected during remedial design.

The ROD requirement was based on pre-ROD studies conducted by the Army and Shell to evaluate the water quality of the deeper, confined aquifer at RMA (HLA 1994, MK

Environmental Services 1994). These studies indicated that a small number of confined wells show consistent patterns of contamination in the South Plants, Basin A, Section 26 (Basins C and F), and North Boundary (Sections 23 and 24) areas. As stated in the Detailed Analysis of Alternatives Report (1995), there is no evidence of widespread contamination in the confined aquifer. Leakage of contaminants from the UFS to the deeper CFS only occurs locally where conditions favor vertical migration. Lateral migration of contaminants that have been detected in the CFS is limited and will occur at very slow rates. The planned capping of Basin A and South Plants will reduce downward vertical gradients through reduction of water levels in the UFS, thereby reducing the spread of contaminants to and within the CFS.

Based on the ROD requirement, the following monitoring objective was identified for the CFS:

- Conduct CFS monitoring in the South Plants, the Basin A, and Basin F areas to assess whether contaminants are migrating from the UFS to the CFS and if there is lateral migration within the CFS.

North Boundary CFS monitoring is conducted and evaluated as part of the NBCS performance monitoring program in Section 4.4.4.

6.1.3.1 Performance Criteria and Consultation

The purpose of the CFS monitoring network is to provide data to assess whether contaminant levels in the CFS are increasing or migrating significantly with time. Throughout most of RMA the hydraulic gradient is downward indicating the potential for downward migration of contamination from the UFS to the CFS. The impacts of infiltration of precipitation are expected to be significantly reduced as a result of installation of soil covers and caps, with corresponding declines in water levels in the UFS. The CFS is separated from the UFS by low permeability siltstone and claystone aquitards; therefore, water levels in the CFS are not anticipated to be affected significantly by cap and cover installation. The associated reduction in hydraulic gradient will significantly slow the flow of groundwater from source areas, and lower water levels in the UFS will reduce the driving force for downward vertical migration of contaminants from the UFS to the underlying CFS. The vertical hydraulic gradients in some areas may change from downward to upward. If this occurs, the potential for downward migration will be significantly reduced.

Performance Criteria:

- Provide data that can be used to determine whether downward hydraulic gradients are present indicating the potential for downward contaminant migration.
- Maintain monitoring program to determine whether contaminant concentrations in the CFS are increasing or migrating significantly with time.

Input Parameters

1. CFS well network specified in the 1999 LTMP for South Plants, Basin A, and Basin F areas.
2. Analytes to review: LTMP-specified indicator analytes, including chloride, for each CFS and adjacent UFS well (specified for the individual CFS wells in Table 6.1-8).

3. Groundwater elevation data for each CFS well and for adjacent UFS wells for evaluation of vertical gradients (Table 6.1-7).

The consultation triggers specific to CFS monitoring are identified in Table 6.1-1 as:

- Concentration increase in CFS well, as indicated by the following examples:
- Detection of previously undetected organic indicator analyte
- Greater than 50 percent concentration increase for organic indicator analyte
- Order of magnitude increase in inorganic indicator analyte

The table identifies the consultative processes that will be triggered by these events.

6.1.3.2 Data Evaluation

Since the implementation of the 1999 LTMP, 20 CFS wells have been sampled to monitor concentrations of indicator analytes and migration potential in the confined aquifer. Most of the wells in the CFS network have been monitored for nearly 20 years and a reduction in contaminants has been observed in many of these wells. Indicator analytes for each well were selected and listed in the 1999 LTMP based on historical data and expected contaminants at each location.

Data from wells in these areas are assessed to determine whether contaminant levels within the CFS are increasing or migrating significantly with time. Water level monitoring results are also evaluated for the CFS and adjacent UFS wells. This evaluation includes comparisons of CFS water level data with UFS water level data to assess the potential for downward migration.

Analytical results for CFS wells are presented in a series of concentration vs. time plots (Appendix B, Figures B-1 through B-23). Water level data and hydraulic gradients for CFS and corresponding UFS wells are presented in Table 6.1-7. No increasing trends in organic analytes have been observed in the CFS monitoring network in the past 10 years. Organic analytes have been detected sporadically at very low concentrations in three wells. Benzene was detected below CSRGs near the detection limit in 2002, and less than the detection limit in 2004 and 2007, in well 01102. Benzene concentrations were approximately 9,000 µg/L shortly after the well was installed. The strong downward trend in benzene concentrations over time indicate that the original high concentrations were introduced during well installation and then attenuated. Chlorobenzene and 1,1-dichloroethane were detected at concentrations below 1 µg/L in well 02057 in the past 10 years. Both of these analytes show decreasing trends in well 02057 since 1989. Dieldrin was detected once below the PQL in well 26153 in 1997, but this detection was not repeated in four more recent sampling events.

Chloride concentrations are decreasing in four of seven CFS wells in the South Plants area. Slight increases have been observed in wells 01067 and 01102, but at very low levels that are not indicative of contamination. The reported chloride concentrations in well 35083 in 2002 and 2004 were anomalously high (810,000 and 940,000 µg/L) and are significantly higher than concentrations in shallower UFS wells and upgradient CFS wells. In 2007, the chloride concentration decreased to more typical levels (i.e., 51,700 µg/L), but in 2009, the chloride concentration in well 35083 was 1,500,000 µg/L, which warrants further evaluation.

Chloride concentrations in the Basin A area are generally stable to slightly decreasing. One notable exception is well 35067 where chloride concentrations have trended upwards since 1989. Well 35067 has a potentially questionable aquitard (HLA 1996a). Thus, well 35067 may be semi-confined instead of confined. These data support the hypothesis that no contaminant migration pathway exists in the CFS beneath the major source areas of RMA.

6.1.3.3 CFS Monitoring Network

Based on the low potential for contaminant migration within the CFS illustrated by the data presented in this section and very slow groundwater flow rates within the CFS, the monitoring frequency will be twice in 5 years with the implementation of this revised program. The CFS and associated UFS paired wells and indicator analytes are listed in Table 6.1-9 and the well locations are shown in Figure 6.1-3. The UFS paired wells indicated in Table 6.1-9 will be sampled and analyzed for chloride.

The CFS monitoring results and network will be evaluated as part of the FYSR.

6.1.3.4 Discontinuation of CFS Monitoring

When the ROD requirement of post-remedy monitoring has been met, then the discontinuation of the CFS monitoring network will be considered. The RVO will make a recommendation to discontinue the program based on a review of historical data that RVO believes that there is no CFS contamination of concern, and enter into consultation with the Regulatory Agencies.

The following factors may be considered when evaluating whether CFS monitoring can be discontinued:

1. Have all indicator analytes decreased to very low concentrations with no evidence of migration?
2. Do chloride concentrations indicate a stable or decreasing trend that has been equal to or below historic levels for the last 5 years?
3. Do analyte concentrations indicate an increasing trend regardless of concentration level?
4. Is the groundwater elevation in a CFS well greater than in the overlying UFS, indicating a permanent upward hydraulic gradient?
5. Have any organic target analytes been detected during the past 10 years?
6. Have wells with leaking seals been identified?

If agreement is reached that discontinuation of CFS monitoring can proceed, a Decision Document that specifies a confirmatory sampling program will be developed for signature by all parties. If it is determined that long-term monitoring should be resumed, the well(s) and analytes will be identified in the LTMP, which will be updated to reflect the change in the monitoring program.

6.2 Off-Post Groundwater Monitoring Programs

6.2.1 Exceedance Monitoring

Off-post water quality monitoring is conducted to assess contaminant concentration reduction and remedy performance, and to support the IC component of the off-post remedy. The Off-Post ROD (HLA 1995) stated,

> *[T]he preferred alternative includes long-term monitoring of offpost groundwater and surface water to assess contaminant concentration reduction and remedy performance. Groundwater monitoring will continue utilizing both monitoring wells and private drinking water wells.*

The Off-Post RS/S added that the purpose of the off-post regional monitoring program is to provide data to:

> *(1) assist in the assessment of the effectiveness of the remedy,*
> *(2) assist in the assessment of contaminant concentration reduction,*
> *(3) prepare the CSRG exceedance area map, and*
> *(4) assist in the assessment of groundwater flow direction and hydraulic gradient.*

This is accomplished by monitoring water quality in a network of off-post monitoring wells and private wells. The regional monitoring category in the RS/S is now called Exceedance monitoring in the LTMP. Exceedance monitoring wells are sampled twice in 5 years. Water levels also are monitored annually in the monitoring wells.

Exceedance monitoring is also conducted in support of the IC component of the off-post remedy. The purpose of the ICs is to restrict the use of contaminated groundwater, in particular the installation of new wells, within identified plume areas. This restriction is implemented in areas with contaminant levels that potentially exceed the CSRGs presented in Tables 2.3-1 and 2.3-5. According to the Off-Post ROD, Appendix B (HLA 1995):

> "The Army has provided the Office of the State Engineer, State of Colorado, a map identifying areas in the Off-Post Study Area where groundwater could potentially exceed CSRGs. This map will be updated based on each sampling round."

The maps are intended for use by the State Engineer in the Well Notification Program. The CSRG exceedance area maps will continue to be submitted in the year following sample collection, as described in the Off-Post RS/S, and samples will be collected twice in each 5-year period (HLA 1996b).

The off-post CSRG exceedance data will also be used to monitor the extent and concentration trends of plumes upgradient and downgradient of the OGITS. These data will also be used to evaluate the OGITS monitoring networks, and will be considered during OGITS shut-off decisions.

6.2.1.1 Exceedance Network and Analyte Evaluation Criteria

The RVO conducts CSRG exceedance monitoring twice in 5 years. The CSRG exceedance monitoring network presented in this plan has been revised to ensure that proper wells and analytes are monitored so that the most accurate CSRG Exceedance areas can be drawn.

The exceedance monitoring network and analytes will be re-evaluated over time in response to changing conditions off post. The following criteria, which were developed to assess the existing network, will be used as guidelines for potential future network revisions:

- If an exceedance monitoring well has not had any CSRG exceedances during at least three consecutive sampling events, is located in area where there were no exceedances during the last FYR period and where there is no evidence of migration of an upgradient exceedance toward a well, the exceedance monitoring well will be considered for removal from the exceedance monitoring network.

Consultation with the Regulatory Agencies will be initiated if the RVO determines, based on the criteria presented above, that a reduction in the exceedance monitoring network might be feasible. Likewise, consultation may be initiated if any of the parties, determine, based on available data, that additions to the exceedance monitoring network may be necessary.

The analyte list for each well in the Off-Post CSRG Exceedance network includes analytes with CSRG/PQL exceedances in the well that occurred during the past 5 years (i.e., FY02 through FY06) in addition to DIMP, which is the primary indicator of off-post contamination, even if it is below the CSRG in the well. The analyte lists will continue to be reviewed based on the results obtained during future five-year periods, and proposed revisions will be addressed through a consultative process.

Changes to the exceedance monitoring program will be documented in the FYSR and revisions to the LTMP.

6.2.1.2 Data Evaluation

The criteria in Section 6.2.1.1 were used to choose which monitoring wells in the CSRG exceedance network will be retained or dropped.

1. Wells 37353 and 37428 are retained. They have no CSRG exceedances but are used to define the edge of a CSRG Exceedance area.
2. Monitoring Well 37328 is a replacement well for exceedance well 37318, which was closed after the 2004 sampling event because it was vandalized and could not be sampled.
3. Wells 37150 and 37151 replaced wells 37403 and 37040, respectively; as these were closed because of road construction.
4. Monitoring well 37125 is eliminated from the network as it had no CSRG/PQL exceedances in 2002, 2004, and 2007, and there are no Exceedance areas nearby and no evidence of migration of an upgradient exceedance. Well 37125 is located downgradient of the NWBCS Southwest Extension where dieldrin concentrations have been below the PQL since 2004.
5. Monitoring wells 37062, 37071, 37107, and 37430 are eliminated from the network. Monitoring wells 37062, 37071, and 37107 are located near recharge trenches in the FCS and are influenced by the treated effluent water quality. Other wells near the FCS are also sampled and provide adequate control for mapping the Exceedance areas near the system. Well 37430 had no exceedances in 2004, 2007, and 2009, and was deleted from

the network. Well 37430 is located downgradient of the NWBCS and downgradient of Burlington Ditch.

6. Well 37405 was added to monitor downgradient of the NPS and downgradient of O'Brian Canal.
7. The 58 monitoring wells in the exceedance network are used to construct CSRG Exceedance areas.

6.2.1.3 Monitoring Network

There are 58 RMA water quality monitoring wells in the CSRG Exceedance network. These wells and analytes are listed with the respective analytes in Table 6.2-1 and shown on Figure 6.2-1. Criteria in Section 6.2.1.1 were used in the data evaluation in Section 6.2.1.2 to choose the wells to be included in the network and select the analytes for each well.

6.2.1.4 Off-Post Deletion Evaluation

Deletion is not being proposed at this time. Monitoring required to support deletion will be agreed upon prior to proceeding with the deletion process (EPA 2009).

6.2.2 Off-Post Water Level Monitoring

Off-post water level monitoring serves a different purpose than on-post water level tracking in that it is conducted in conjunction with the exceedance monitoring to confirm water levels and flow paths.

6.2.2.1 Water Level Monitoring Criteria

Objective:

- Conduct water level monitoring in conjunction with the exceedance monitoring to confirm groundwater flow and flow paths for contaminant migration in the Exceedance areas.

Criteria:

- Develop and maintain water level monitoring network that tracks the water levels and flow paths in Exceedance areas.
- Evaluate water level data to assess if water level changes are occurring and could impact flow, flow directions, and contaminant migration pathways.

6.2.2.2 Data Evaluation

Data evaluation for the annual water level monitoring events will entail 1) incorporation of all contemporaneous project-specific monitoring data and contour maps, 2) plotting the current and previous year contours on the same map for comparison to aid the consistency in interpreting the data, and help to identify outliers, 3) an elevation difference map will be generated for the current and previous year maps to identify outliers and areas of potential recharge and discharge 4) significant changes in water elevations will be identified, and 5) significant changes in flow directions that could impact the off-post remedy will also be identified.

The consultation triggers specific to water level tracking are identified in Table 6.1-1 as:

- Missed water level data collection
- Change in flow direction that could affect mass removal or containment objectives

The table identifies the consultative processes that will be triggered by these events.

6.2.2.3 Monitoring Network

The network of wells selected for off-post water level monitoring includes 88 wells located both in and beyond the areas of the systems. This is a net decrease of 9 wells off-post compared to the 1999 LTMP network (23 wells are no longer included and 14 wells have been added). The wells removed from the water level network since the 1999 LTMP are listed in Table 6.2-2. Many of the closed wells were located adjacent to roads and were closed because of road construction or development. Many of these wells were located outside of CSRG exceedance areas where continued water level monitoring was less important or not necessary. The off-post water level monitoring wells are shown along with the on-post water level tracking wells in Figure 6.1-1, and a complete listing of these wells is presented in Table 6.1-2.

Table 6.2-2 Wells Removed From Water Level Network

Well	Reason for Removing Well	Replacement Well
37364	Closed (2004)	
37358	Closed (2004)	
37359	Ownership transferred to SACWSD	
37439	Closed (commercial development)	
37382	Destroyed/cancelled (commercial development)	
37438	Closed (commercial development)	
37345	Destroyed/cancelled	
37433	Closed (2002)	
37443	Closed (2004)	
37355	Destroyed/cancelled (1999)	
37356	Destroyed/cancelled (1999)	
37357	Destroyed/cancelled (1999)	
37109	Destroyed/cancelled	
37434	Destroyed/cancelled	
37104	Closed (O'Brian Canal relocation)	
37432	Destroyed/cancelled	
37408	Closed (housing development)	
37410	Closed (housing development)	
37409	Closed (housing development)	
37040	Closed (104th Ave, construction)	37151
37403	Closed (104th Ave, construction)	37150
37340	Closed (fire department building construction)	
37318	Destroyed/closed	37328

The 14 wells listed below have been added to the off-post water level monitoring network.

- 37150 (Replacement of 37403)
- 37151 (Replacement of 37040)
- 37328 (Replacement of 37318)
- 37343 (FCS)
- 37373 (FCS)
- 37379
- 37397 (NPS)
- 37405 (NPS)
- 37451 (NPS)
- 37452 (NPS)
- 37457 (NPS)
- 37462 (NPS)
- 37463 (NPS)
- 37472 (NPS)

Three wells are replacement wells, eight wells are located near the NPS, and two wells are located near the FCS, where project-specific monitoring will also be conducted. Well 37379 is located southwest of the FCS, along Highway 2.

Off-post water level monitoring is used to support the exceedance monitoring program, as well as to detect changes in water table elevations and groundwater flow directions. Significant changes in water levels or flow directions that could impact plume migration will be summarized in the FYSR, along with water level maps that will show any changes that have occurred during the 5-year period.

6.2.3 On-Post and Off-Post Well Networks Summary

All the LTMP monitoring networks presented in Sections 4, 5, and 6 of this document are summarized in Table 6.3-1. The table includes location and monitoring frequencies for the site-wide monitoring categories and specifies the system the wells are associated with for the system-specific categories. The wells listed are organized by well numbers, starting with the Section 01 wells.

6.3 Surface Water Monitoring

During the multi-year period during which contaminated soil areas were excavated, surface water quality has been monitored as it enters and leaves the RMA site boundary as well as in the off-post area. As noted in Section 2.10, the on-post First Creek surface water sampling sites near the north boundary did not have an organic target analyte detection during excavation of contaminated soil. Further, all contaminated soil with concentrations above site-specific action criteria has either been removed and disposed in landfills or has been covered, thus eliminating the potential for movement of contaminated soil to surface water. The soil remedy is scheduled for completion by the end of 2010. Consequently, long-term monitoring of surface water on post to detect RMA contamination caused by soil contamination no longer is necessary. An MCR for the On-Post ROD-required monitoring will be prepared.

Short-term surface water monitoring needs related to remedy completion and establishing vegetation on soil covers will be addressed separately from the LTMP. Future surface water monitoring related to volume and flow (quantity) will be managed by the USFWS beginning in FY11.

Off-post, DIMP is the only RMA groundwater contaminant detected at concentrations above both the CBSMSW and CSRG at station SW37001 since 2001 (Figure 6.3-1). At station SW24004, located at the north boundary of RMA, there is little groundwater/surface water interaction and DIMP has never been detected. At SW37001, DIMP is detected at elevated levels during low-flow conditions (i.e., approximately 0.5 cubic ft per second or less). With completion of the soil excavation portion of the on-post remedy and termination of on-post surface water monitoring, it no longer is necessary to monitor storm events at SW24004 and SW37001.

In order to continue to evaluate the effect of groundwater treatment on surface water quality in the Off-post OU, which is not monitored during storm events, surface water quality monitoring will continue at SW24004 and off-post site SW37001 (First Creek at Highway 2). Annual surface water quality samples will be collected at off-post site SW37001 when there is low flow in First Creek. Typically, this occurs during the spring or summer and sampling will occur during the third quarter of the fiscal year, i.e., April through June. Guidelines for the sampling conditions include discharge of 0.5 cubic ft per second (cfs) or less at SW37001, and preferably no flow (or less than 1 cfs) at SW24002. If these low-flow conditions do not exist at site SW37001 when annual sampling is scheduled, sampling will be conducted as soon as possible thereafter. If the appropriate low-flow conditions do not occur during the third quarter, sampling could be conducted during the fourth quarter, before the end of the fiscal year. Sampling of SW24004 will also be annual and coincide with sampling of SW37001, if possible. The target analyte list will include DIMP and arsenic.

7.0 WELL MAINTENANCE

The RMA well networks will be maintained to ensure implementation of the remedy. Well maintenance and repairs will be performed on an as-needed basis for on-post and off-post wells in response to observations made during reviews (URS 2010) for damage or deterioration to maintain the integrity of the well. Wells may be modified or adapted to reduce tampering or damage by traffic, construction, grounds maintenance, fire, wildlife, or off-post development.

Monitoring wells will be reviewed each time a well is used during scheduled monitoring events. The wells will be checked to insure they are properly secured, are not damaged, and are able to be used for the intended purpose. When a review indicates that a retained well is damaged, simple repairs will be made, and problems will be identified in the well maintenance log. The following list includes minimum checks on well integrity and follow-up actions based on requirements in the Groundwater Sampling Procedure (URS 2010):

- Is the well stickup height consistent with available information? If not, confirm that the correct well has been located. If the well is correct, is repair or extension of the well needed? If repair or extension is needed, initiate a work order, followed by re-survey of the top-of-casing (TOC) elevation after the repair/extension is completed.
- Is the well stickup damaged? If repair is needed, initiate a work order, followed by re-survey of the TOC elevation after the repair is completed.
- Is the well depth consistent with available information? If not, is there sediment in the bottom of the well or is there an obstruction? If there is more than 5 feet of sediment in the well, initiate a work order to clean out the well. If an obstruction is suspected, initiate a work order to clean out or repair the well.

The Regulatory Agencies will be notified if a well cannot be repaired within a 30 day timeframe.

7.1 Well Protection

Well protection needs and actions will be identified in the Well Networks Updates. Information that will be used for future decisions regarding the need for well protection will be obtained from well condition reviews that will be conducted and documented each time a well is used. The exact well specifications for various wellhead protection will be prepared for specific projects and wells on an as-needed basis.

7.2 Well Security

In order to be able to collect accurate water level and water quality data from monitoring wells, the wells must be secure from damage to well casings and from contamination from foreign substances entering the well casing. The engineering controls used to accomplish this include locking the wells in areas off post where the wells are not inside a locked fence and ensuring that on-post wells have secure well caps. Locking caps will be used in on-post public areas. Additional modifications are needed off post in a highway right-of-way, such as flush mounting the well to avoid damage from highway maintenance activities, yet allowing access for monitoring. All monitoring wells will have caps and concrete well pads in good repair.

8.0 WELL RETENTION

Long-term well network maintenance at RMA is an important component of the remedial actions prescribed by the RODs for both the On-Post and Off-Post OUs (FWENC 1996, HLA 1995). The RMA well networks will be retained to ensure continued remedy and post-remedy monitoring. Well retention is intended to support all groundwater-related aspects of remedy implementation and performance monitoring, including long-term monitoring, other project specific monitoring, and operational monitoring. It is the intent to retain and repair or replace all LTMP wells if they are damaged. In addition, RVO has agreed during LTMP working meetings, to provide a list of identified non-LTMP wells that may be retained as replacement wells, if needed, or for potential future uses. The finalization of the list of retained wells will be documented with a formal transmittal letter to the Regulatory Agencies.

If a well used for long-term monitoring is damaged beyond repair and cannot be sampled, RVO will initiate the consultative process and enter into consultation with the Regulatory Agencies to determine whether the monitoring objectives can be met using an existing substitute well or if a new well is required. Under certain circumstances, it may be decided that further monitoring at this location is not necessary.

Any changes to the LTMP networks, including well replacement or elimination, will be reflected in the Well Networks Updates and in revisions to the LTMP.

9.0 STATISTICAL METHODS

When chemical contaminant trends in groundwater cannot be determined through time-trend evaluations conducted by plotting analyte concentrations for selected wells against time for visual inspection of trends, statistical methods will be applied. The statistical evaluation will be conducted using the Mann-Kendall test. This test is particularly useful because missing values are allowed and the data need not conform to any particular distribution (Gilbert 1987). Non-detectable values can also be included in the evaluation. The Mann-Kendall test is a non-parametric method that uses only relative magnitudes of the data to determine upward or downward trends. The Mann-Kendall test uses the data in temporal order and determines the change from point to point as a positive or negative value. The test statistic is the difference between the number of positive and negative values that indicates whether the overall trend is negative, positive, or if there is no trend. If the data exhibit seasonality, as observed from the graphs, the data will be analyzed using a variation of the Mann-Kendall test known as the Seasonal Kendall test (Gilbert 1987).

10.0 QUALITY ASSURANCE

10.1 Quality Assurance Program Requirements

Groundwater monitoring at RMA is conducted by a number of different organizations. During environmental sampling activities, each of these organizations will comply with the RMA Chemical Quality Assurance Plan (CQAP) (TtEC 2006c) and the Quality Assurance Program (QAP) (RVO 1997d) and any revisions of these documents. Tasks that will or may be required to satisfy the LTMP include the following:

- Water level measurement
- Groundwater sample collection
- Groundwater sample analysis
- Data management
- Data reporting
- Monitoring well installation and development (where new or replacement wells are needed)

For the environmental data collection tasks, the QAP requires preparation of Quality Assurance Project Plans (QAPPs). The QAPPs ensure that the data collected will meet the technical and quality objectives of the LTMP. In most instances, the QAPP is an integral part of the SAP. For example, water level and water quality data collected for comparison to baseline conditions will meet the quality of the previously collected baseline data. With these quality standards in mind, the QAPPs identify appropriate data collection methods, include data quality assessment procedures, and outline the mechanism for identifying, documenting, and reporting any data limitations.

Each QAPP will include sections that address the following four types of quality assurance systems, as appropriate to the task:

- Management systems
- Measurements/data acquisition
- Assessment/oversight
- Data validation and usability

The discussion of management systems describes the task and its objectives and outlines the roles and responsibilities of the participants. In addition, this section of the QAPP defines the data quality requirements of the task, including data quality objectives, and data validation or verification methods that will be used.

The Measurements/Data Acquisition section of the QAPP addresses the following items related to field measurements and sample collection:

- Sampling rationale and strategy
- Sample matrices, locations, and depths
- Analytical parameters and methods
- Sampling equipment and collection methods
- Field equipment and instrument maintenance, testing, and calibration
- Quality control (QC) samples
- Documentation of field sample collection
- Sample identification and labeling
- Sample custody tracking
- Sample handling, packaging, and shipping

In addition, this section outlines the following analytical laboratory requirements:

- Analytical methods and quality performance expectations
- Standard operating procedures for instrument calibrations, measurements, and data acquisition
- QC activities
- Performance and system audits
- Quality assessments and response actions

The Assessment/Oversight section of the QAPP outlines the activities that will be used to assess whether the QAPP is being implemented as required. Assessment activities will be specified according to the level of quality that is required for the task. The following types of assessment activities may be included as appropriate:

- Audits
- Surveillances
- Peer reviews
- Data quality assessments
- Readiness reviews (for field sampling and monitoring activities)
- Inspections and tests

The QAPP will establish performance criteria that will be used to measure attainment. In addition, it will outline how data quality assessments will be reported to the RVO and how corrective action will be taken in response to significant quality assurance problems. Where significant program modifications are required, the Regulatory Agencies will be notified in writing.

The QAPP will include a section on data validation and usability to outline the quality assurance activities that will occur after data collection has been completed. The Post-Laboratory Data Validation procedure may be applied to any outliers identified after the laboratory data validation of the analytical results has been completed (RVO 2007). Data validation requirements are outlined in the CQAP. Data resulting from the monitoring activities will be stored on the RMA Environmental Database. These data will include water level measurements, water quality analytical results, and information on new well construction.

Since data from many sources will be combined for long-term monitoring purposes, the data quality of the combined data collection programs will be evaluated in the Annual Summary Report and the FYSR.

10.2 Establishing Practical Quantitation Limits

In cases where the actual ARARs or to be considered (TBC) values selected as CSRGs for RMA analytes could not be measured with the analytical methods available from a certified commercial laboratory at that time, the RODs identified either Certified Reporting Limits (CRLs) or existing PQLs (CDPHE 1995) as the interim goals. It should be noted that this approach applies only to ARARs or health-based limits with values below then existing PQLs or Army-defined CRLs. In most cases, CRLs were identified in place of the ARARs or other health-based criteria that cannot typically be measured by available methods.

As of 2007, the remaining CSRG analytes with method reporting limits (MRLs) above the CSRGs are aldrin, dieldrin, and NDMA for the NBCS and OGITS and dieldrin and NDMA for the NWBCS.

The 2005 FYRR (PMRMA 2007a) identified the existing process for determining PQLs/MRLs as an issue for compounds for which the PQLs remain above the CSRGs in part because the Army has used an MRL-based approach that differs from industry practice. The ongoing changes to the RMA analytical programs and recent advancements in analytical technology suggest that it would be beneficial to follow a standardized procedure to evaluate the analytical capabilities of several laboratories. Therefore, the RVO has developed the procedure for establishing site-specific PQLs. On October 26, 2006, agreement was reached with the Regulatory Agencies that PQL studies will be conducted in accordance with 40 Code of Federal Regulations 136 Appendix B and Colorado PQL guidance (CDPHE 2008) for compounds for which MRLs exceed CSRGs as outlined in RMA Decision Document DD-RMAPQL-11 (RVO 2006). The site-specific PQLs determined from these studies will be incorporated in the LTMP.

11.0 DATA EVALUATION AND REPORTING

This section describes the reporting mechanisms for the groundwater systems and monitoring programs addressed in the LTMP. Monitoring data will be used to assess the implementation of each groundwater remedy and to evaluate concentration trends and flow paths to meet the requirements of the On-Post and Off-Post RODs. As discussed in Section 2, the ROD requirements include operation of groundwater extraction and treatment systems, attenuation of certain groundwater contaminants that do not require other treatment, monitoring of the CFS, hydraulic control of groundwater levels in the Complex Trenches, Shell Trenches and Lime Basin areas, groundwater monitoring in areas where waste has been left in place, groundwater monitoring to support ICs on off-post groundwater use, and surface water monitoring.

The reporting mechanisms have been revised and formalized in this version of the LTMP. Some important changes are as follows:

- The OARs will be replaced with an Annual Summary Report for Groundwater and Surface Water. The Annual Summary Report will include an evaluation of collected data against the performance criteria and compliance requirements for the operating systems, site-wide water table maps as well as data reports for any site-wide monitoring conducted within the reporting period and any Consultative Process notifications.
- The Quarterly Effluent Reports will be expanded to include reverse hydraulic gradient information where applicable.
- A FYSR for Groundwater and Surface Water will be prepared prior to each FYR. It will be issued prior to the FYRR and used as input to this report.
- On-post plume extent mapping will be performed as part of the FYSR on a 20-year cycle.

Table 11.0-1 summarizes the reporting mechanisms by monitoring category.

Table 11.0-1 Reporting Mechanisms for RMA Monitoring Categories

Monitoring Category	Type of Data	Reporting Mechanism
Effluent Compliance	Water Quality	Quarterly Effluent Report, Annual Summary Report, FYSR, FYRR
Performance Monitoring	Water Level and Water Quality	Annual Summary Report, FYSR, FYRR, hydraulic gradient water level graphs in Quarterly Effluent Report
Operational Monitoring	Water Level and Water Quality, system operations	Annual Summary Report, FYSR, FYRR for data relevant to system evaluation
Pre-Shut-Off Monitoring	Water Quality	Annual Summary Report, Data Summary Report (DSR), Decision Document
Shut-Off Monitoring	Water Quality	Annual Summary Report, FYSR, FYRR, Decision Document, CCR (at completion)
Post-Shut-Off Monitoring	Water Quality	Annual Summary Report, FYSR, FYRR, MCR (at completion)
Water Level Tracking	Water Level	Annual Summary Report, FYSR, FYRR
Water Quality Tracking	Water Quality	Annual Summary Report, FYSR, FYRR
Source Monitoring – as part of Water Quality Tracking	Water Quality	Annual Summary Report, FYSR, FYRR, CCR (at completion)
Confined Flow System Monitoring	Water Quality	Annual Summary Report, FYSR, FYRR, CCR (at completion)
Off-Post Exceedance Monitoring	Water Quality	Annual Summary Report, Exceedance Maps, FYSR, FYRR
Off-Post Water Level Monitoring	Water Level	Annual Summary Report, FYSR, FYRR, Exceedance maps
Surface Water Monitoring	Water Quality	Annual Summary Report, FYSR, FYRR, MCR (at completion)
Complex Trenches Dewatering	Water Level	Annual Summary Report, FYSR, FYRR, Quarterly Effluent Report
Shell Trenches	Water Level	Annual Summary Report, FYSR, FYRR, Quarterly Effluent Report
Lime Basins Dewatering	Water Level	Annual Summary Report, FYSR, FYRR, Quarterly Effluent Report

Table 11.0-2 summarizes the routine reports for groundwater and surface water and their contents.

Table 11.0-2 Reporting for RMA Monitoring Categories

Report	Content	Notes	Preparation Deadline
Quarterly Effluent Report	Effluent compliance monitoring data for all treatment systems	Compliance data presented as running averages for last 4 quarters and annual data.	6 months following the reporting period.
	Reverse hydraulic gradient data and graphs for NWBCS and NBCS performance wells		
	Reverse hydraulic gradient data and graphs for Complex Trenches and Lime Basins; water level data for Shell Trenches		
Annual Summary Report for Groundwater and Surface Water	Complete performance and compliance evaluations for all extraction, treatment, and containment systems	NWBCS, NBCS, RYCS, BANS, BRES, OGITS, Complex Trenches, Shell Trenches, Lime Basins	September 30th, of the year following the reporting period.
	Annual data summaries for all long-term site-wide LTMP monitoring programs during years when monitoring conducted.	Water level tracking, including water level contour map; water quality tracking; CFS monitoring; exceedance monitoring; surface water monitoring; well networks updates	
	Annual data summaries for any on-going shut-off monitoring programs.		
Five-Year Summary Report for Groundwater and Surface Water	Summary and evaluation of all groundwater and surface water monitoring data for all systems and monitoring programs, including project-specific monitoring programs and on-post plume extent maps every 20 years starting in 2015.		December 19th of the last year of the FYR period.
Five-Year Review Report	Summary evaluation of information presented in FYSR.		December 19th of the last year of the FYR period.

11.1 Reporting of Containment and Mass Removal System Performance

11.1.1 System Effluent Compliance Monitoring

Running averages of four quarters of effluent data will be evaluated on a quarterly basis and reported in the Quarterly Effluent Reports. The Regulatory Agencies will be notified of effluent exceedances in accordance with the consultation triggers presented in the Section 4 Consultative

Process tables. The annual compliance evaluations will be included in the Annual Summary Reports, which will be incorporated in the FYSR and FYRR for the applicable FYR periods. Effluent compliance monitoring used to assess attenuation trends for chloride and sulfate will be reported in the Quarterly Effluent Reports, and the Annual Summary Reports and summarized in the FYSR and FYRR. When the FYRR concludes that contaminant attenuation has been achieved and that CSRGs will be met indefinitely, the Regulatory Agencies will be notified and a recommendation to discontinue this monitoring and remove the analytes from the CSRG list will be addressed in the FYRR and other appropriate ROD change documentation.

11.1.2 Performance Monitoring

The performance monitoring results will be presented and evaluated in the Annual Summary Reports, the FYSR, and the FYRR. Additionally, the monitoring results related to reverse hydraulic gradient for systems where such performance criteria apply (Table 11.0-2), will be presented in the Quarterly Effluent Reports. The Regulatory Agencies will be notified of performance issues in accordance with the consultation triggers presented in the Section 4 and 5 Consultative Process tables.

11.1.3 Shut-Off Monitoring

The plans, reports, and decision documents related to shut-off monitoring are addressed in Section 4.9 and summarized in Table 11.0-1.

11.2 Site-Wide Monitoring

11.2.1 On-Post Monitoring

The site-wide on-post monitoring evaluation includes data from water quality tracking, water level tracking, and CFS monitoring.

Water level monitoring for water level tracking is performed annually and a water level contour map is used to present the results. This water level map will be included in the Annual Summary Reports starting with the implementation of this LTMP. The FYSR will include an assessment of the water level contours over the FYR period that will identify any issues and possible recommendations for changes in network or monitoring approach. The water quality monitoring for water quality tracking is performed once or twice in 5 years and CFS monitoring is performed twice in 5 years. The results of these monitoring programs will be reported in the Annual Summary Reports for the applicable monitoring periods and the data will be evaluated in the FYSR which will provide information for the FYRR.

11.2.2 On-Post Plume Extent Mapping

On-post plume extent mapping of selected indicator analytes will be conducted, beginning in 2014, with a 20-year frequency. The indicator analytes are listed below:

On-post Plume Extent Mapping Indicator Analytes:

- DIMP
- Dieldrin
- Chloroform

- Benzene
- NDMA
- Carbon tetrachloride
- Dithiane
- Arsenic

11.2.3 Off-Post Monitoring

The results of exceedance monitoring outlined in Section 6.2.1 will continue to be reported to the State Engineer's office twice in every 5-year period. The State Engineer submittal will be a letter report and CSRG exceedance map. The exceedance monitoring results will support the ICs on groundwater use in the Off-Post OU. The results of the exceedance monitoring will be reported in the Annual Summary Reports for the applicable monitoring periods and the data will be evaluated in the FYSR which will provide information for the FYRR.

The CSRG exceedance map will include data collected from Army and private wells that are part of the exceedance monitoring program. For private wells with a higher than twice in 5 years monitoring frequency, the highest value from each private well for the monitoring period will be used to generate the map and the other data will be included. The plume edge will be drawn half way between wells with exceedances and wells without exceedances. Notification areas used by the State Engineer's office will be identified by the exceedance area to the nearest half-section.

Off-post water level monitoring is conducted in support of the exceedance monitoring program and the results are included in the water level maps presented with the Annual Summary Reports and in the FYSR.

Surface water monitoring results from the two off-post locations included in the program will be included in the Annual Summary Reports, and the FYSR. An MCR will be issued at the time such monitoring is discontinued.

12.0 SCHEDULE

The revised LTMP is to be implemented in FY10. The annual monitoring programs will begin in 2010 and monitoring at a frequency of twice in 5 years will be conducted in 2012. The programs requiring monitoring once in 5 years will begin in 2012 during the next FYR period since sampling has already been conducted once during the 2005–2010 5-year period. The planned monitoring cycles, which will continue until potential revision of the LTMP, are shown in Table 12.0-1 below. The revised monitoring program presented in this document will be implemented in the first quarter of FY10.

Table 12.0-1. LTMP Monitoring Cycles

Five-Year Review Period	Fiscal Year	Monitoring Program by Frequency
2010–2015	2010	• Annual
	2011	• Annual
	2012	• Annual • Once in 5 years • Twice in 5 years
	2013	• Annual
	2014	• Annual • Twice in 5 years
2015–2020	2015	• Annual
	2016	• Annual
	2017	• Annual • Once in 5 years • Twice in 5 years
	2018	• Annual
	2019	• Annual • Twice in 5 years

13.0 REFERENCES

Army (United States Army)

1989 *Basin A Neck Containment System IRA Decision Document.*

Colorado Department of Labor (Colorado Department of Labor, Division of Oil and Public Safety)

1999 (Feb.) Petroleum Storage Tank Owner/Operator Guidance Document

CDPHE (Colorado Department for Public Health and Environment)

2008 Practical Quantitation Limitation Guidance Document.

1995 Water Quality Control Commission State Discharge Permit System, 5 CCR 1002-2, §6.9.2(13), Table 1, by operation of 5 CCR 1002-8 §3.11.5(C) 3, Table A, Footnote 2. (All as amended through 04/30/96).

Ebasco (Ebasco Services Incorporated)

1992 (Jan.) *Final Remedial Investigation Summary Report.* Version 3.2.

1989 (July) *Water Remedial Investigation Report.* Version 3.3.

EPA (U.S. Environmental Protection Agency)

2009 (Nov. 9) *SAPC Resolution for Off-Post Institutional Controls.* DD-LTMP-15.

2008 (Sep. 30) *Section 36 Bedrock Ridge Groundwater Plume Extraction System Construction Completion Report Approval Letter.*

2001 (May) *Monitored Natural Attenuation: USEPA Research Program – An EPA Science Advisory Board Review. EPA-SAB-EEC-01-004.*

1995 (Apr.) *Superfund Guidance on Ground-Water Remedy Performance Monitoring. EPA Region VIII Superfund Technical Guidance.*

FWENC (Foster Wheeler Environmental Corporation)

2003a (Apr.) *Rocky Mountain Arsenal Well Retention and Closure Program.* Final.

2003b (June) *Well Networks Update for Retention and Closure Water Year 2003.* Final.

1999 (Dec.) *Rocky Mountain Arsenal Long-Term Monitoring Plan for Groundwater.* Final.

1997 (May) *South Lakes Groundwater Investigation Final Work Plan.*

1996 (June) *Record of Decision for the On-Post Operable Unit.* Version 3.1, vol. 1–3.

1995a (Oct.) *Detailed Analysis of Alternatives Report.* Final.

1995b (Oct.) *Final South Plants/Basin A Groundwater Flow Model.* Version 4.0.

George Chadwick Consulting

2005 (May) *Intermediate Conceptual Design of Proposed Modifications to the Northern Pathway Portion of the Off-Post Groundwater Intercept and Treatment System.* Prepared for Amber Homes, Inc.

George Chadwick Consulting and Tetra Tech

2005 North Boundary Enhancement for In Situ Biodegradation.

Gilbert, R.O.

1987 *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold, New York.

HLA (Harding Lawson Associates)

1996a (Nov. 19) *n-Nitrosodimethylamine Alternatives Evaluation Report.* Draft Final.

1996b (Sep. 25) *Remediation Scope and Schedule for the Offpost Operable Unit, Rocky Mountain Arsenal, Commerce City, Colorado.*

1995 (Dec. 19) *Rocky Mountain Arsenal Offpost Operable Unit, Final Record of Decision.*

1994 (Mar.) *Final Technical Report for Groundwater Data Evaluation.*

1992 (Nov.) *Offpost Operable Unit, Endangerment Assessment/Feasibility Study.* Final.

1990 (July) *Revised Regional Ground-Water Flow Model at the Rocky Mountain Arsenal, Denver, Colorado. Final Report. RTIC 93032R01.*

1989 (July) *Final Decision Document for the Groundwater Intercept and Treatment System North of Rocky Mountain Arsenal, Interim Response Action.*

Morrison Knudsen Corporation

1999 (Mar.) *Section 36 Bedrock Ridge Groundwater Plume Extraction System, 100 Percent Design Package.*

1998 (June) North Boundary Containment System. System Modifications for *Treatment of NDMA, Construction and Startup Completion Report.*

MK Environmental Services

1994 (Apr.) *White Paper, Evaluation of the Denver Formation at Rocky Mountain Arsenal.*

1993a (Sep.) *White Paper, Groundwater Flows and Recharge on the Rocky Mountain Arsenal.*

1993b *Northwest Boundary Containment System Long-Term Improvements IRA, One-Year Evaluation Report.*

1990a (Mar.) *Final Decision Document for Other Contamination Sources, Interim Response Action, Rail Classification Yard, Rocky Mountain Arsenal.*

1990b (June) *Report of Field Investigations, Assessment, and Final Decision Document, for the Northwest Boundary System Short-Term Improvements Interim Response Action, Rocky Mountain Arsenal.*

1989 *Final Alternatives Assessment for Other Contamination Sources, Interim Response Action, Rail Classification Yard, Rocky Mountain Arsenal.*

1987 *Preliminary Recharge Estimates for the RMA Regional Flow Model, Final Version. WP-122257. Prepared for Holme, Roberts, and Owen, Denver, Colorado.*

MK Environmental Services and FWENC (Foster Wheeler Environmental Corporation)

1996 (Mar.) *Development of Chloride and Sulfate Remediation Goals for the North Boundary Containment System at the Rocky Mountain Arsenal.*

PMRMA (Program Manager Rocky Mountain Arsenal)

2009 *Rocky Mountain Arsenal Containment/Treatment Systems Operational Assessment and Effluent Data Report for All Quarters FY08, All Treatment Systems*

2008a *Annual Well Networks Update for FY06.*

2008b *Annual Well Networks Update Summary for FY07.*

2007a *2005 Five-Year Review Report.* Final.

2006 *Annual Well Networks Update Summary for 04/2004 through 09/2005.*

2005a (Apr.) *Rocky Mountain Arsenal Containment/Treatment Systems Operational Assessment and Effluent Data Report, All Quarters FY02, All Treatment Systems.*

2005b (Nov.) *Rocky Mountain Arsenal Containment/Treatment Systems Operational Assessment and Effluent Data Report, All Quarters FY03, All Treatment Systems.*

2005c (Dec.) *Rocky Mountain Arsenal Containment/Treatment Systems Operational Assessment and Effluent Data Report for All Quarters FY04, All Treatment Systems.*

2003 (May) *Offpost Groundwater Intercept Treatment System Operational Assessment Report, FY01.* Final Report.

2002 (June) *Offpost Groundwater Intercept Treatment System Operational Assessment Report, FY00.* Final Report.

2000 (Oct. 25) *Final Five-Year Review Report for Rocky Mountain Arsenal, Commerce City, Adams County, Colorado.*

1997 (Aug. 13) *Memorandum of Agreement Between Tri-County Health Department and Program Manager for Rocky Mountain Arsenal.*

Public Law 102-402

1992 (Oct.) *Rocky Mountain Arsenal National Wildlife Refuge Act of 1992.*

R.L. Stollar and Associates

1990 (Sep.) *Comprehensive Monitoring Program Draft Final Technical Plan.*

RVO (Remediation Venture Office)

2010 (Mar.) *Rocky Mountain Arsenal Decision Document DD-BasinA-16, Revisions to the Basin A Consolidation and Remediation Project Groundwater Monitoring Plan Requirements Incorporated into the 2010 Long-Term Monitoring Plan for Groundwater and Surface Water.*

2008 *Surface Water Quality Monitoring Report for the Rocky Mountain Arsenal.*

2007 (Jan.) *Post-Laboratory Data Water Quality Data Assessment Procedure (01/24/07).* Rev 0.

2006 (Oct.) *Rocky Mountain Arsenal Decision Document DD-RMAPQL-11, Establishing Site-Specific Practical Quantitation Limits at the Rocky Mountain Arsenal.*

2005 *South Tank Farm and Lime Basins Analytical Models.*

2004a (Sep. 28) *Memorandum for Record. Clarification of BANCS Requirements in ROD.*

2004b *North Boundary Containment System Enhancements to the Well Field and Treatment Systems Summary of New Technology Fact Sheet.*

2001a (Mar. 21) *Letter to EPA, Draft Final Fact Sheet, Documentation of Non- Significant or Minor Off-post ROD Change at RMA of the CFS Well Evaluation Criteria.*

2001b (Mar. 25) *Letter to EPA confirming finalization of the Documentation of Non-Significant or Minor Off-post ROD Change at RMA of the CFS Well Evaluation Criteria.*

1997a (Nov.) *Complex Trenches and Shell Section 36 Trenches Groundwater Barrier Project, 100 Percent Design Package.* Rev. 1.

1997b *Decision Paper to Add UV Treatment Unit to the North Boundary Containment System. 9710603-1/1-D.*

1997c *Basin A Consolidation and Remediation Design Document.*

1997d (June) *Quality Assurance Program.* Rev. 0.

TtEC (Tetra Tech EC, Inc.)

2009a (Sep.) *Basin F Closure Groundwater Monitoring Report (2006 – 2007).* Rev. 1.

2009b (Apr.) *HWL Post-Closure Groundwater Monitoring Plan.* Rev. 1.

2008a (May) *Enhanced Hazardous Waste Landfill (ELF) Closure Groundwater Monitoring Plan.* Draft.

2008b (Oct.) *North Plants Pilot Light Non Aqueous Phase Liquid Removal System Action Plan.* Rev. 0.

2007 (July) *Hazardous Waste Landfill Closure Plan.* Rev. 0.

2006a (Apr.) *Basin F Closure/Post-Closure Groundwater Monitoring Plan.* Rev 1.

2006b (Mar. 31) *Explanation of Significant Differences for Groundwater Remediation and Revegetation Requirements.* Rev. 0.

2006c (Jan. 3) *PMC Chemical Quality Assurance Plan.* Rev. 3.

2005 (Oct. 20) *Amendment to the Record of Decision for the On-Post Operable Unit, Rocky Mountain Arsenal Federal Facility Site, Section 36 Lime Basins Remediation, Basin F Principal Threat Soil Remediation.* Rev. 0.

TtEMI (Tetra Tech EM, Inc.)

2003 *Hydrogen Release compound Barrier Application at the North of Basin F Site, Rocky Mountain Arsenal.* Draft.

TtFW (Tetra Tech FW, Inc.)

2004a (Dec.) *North Plants Soil Remediation Project Petroleum Release Evaluation Report.* Rev. 0.

2004b (Nov.) *Well Networks Update For Retention and Closure, Water Year 2004.*

URS

2010 (Feb.) *Groundwater Sampling Procedure.* Rev. 4.1.

URS Washington Division

2009 (Apr.) *North Boundary Containment Systems Enhancement for In-Situ Biodegradation Termination Report.* Rev. 0.

URS Washington Division and TtEC

2009 (Sep.) *Draft Final Landfill Wastewater Treatment System Closure Plan.* Rev. B.

2008 (Oct.) *North Plants Pilot Light Non-Aqueous Phase Liquid Removal System Action Plan.* Rev. 0.

USACE (U.S. Army Corps of Engineers)

1985 (Dec.) *North Boundary Containment/Treatment System Performance Report.*

USGS (U.S. Geological Survey Water Resources Division Colorado District RMA Project Office)

2004 (Mar.) *Final South Lakes Groundwater Monitoring Report, June 1, 2001 – May 31, 2003.*

2001 (May) *Rocky Mountain Arsenal South Lakes Sampling and Analysis Plan for Groundwater.*

1997 (Apr.) *Ground-Water Monitoring Program Evaluation Report for Water Year 1994, Rocky Mountain Arsenal, Commerce City, Colorado.* Final.

Washington Group International

2008 (Sep.) *Rocky Mountain Arsenal, Section 36 Bedrock Ridge Groundwater Plume Extraction System, Construction Completion Report.*

2005a (Dec.) *Groundwater Mass Removal Project Groundwater Extraction/Recharge System Design Analysis Report Final, Prepared for Rocky Mountain Arsenal Remediation Venture Office.*

2005b (Sep.) *Termination of Operation at the Groundwater Intercept and Treatment System North of Basin F Well, Final Construction Completion Report.*

2003 (May) *Rocky Mountain Arsenal, Irondale Containment System, 5-year Shut-Off Monitoring Program, Final Construction Completion Report.* Rev. 1.

Warner, J.W., Namvargolin, R., and Affifi, S.

1999 *Long Term Management Strategies North Boundary Containment System (NBCS) Rocky Mountain Arsenal (RMA), Denver, Colorado.*

TABLES

Table 2.3-1. Northwest Boundary Containment System (NWBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	PQL[1] (µg/L) 2005 FYRR[2]	CSRG Source
Volatile Halogenated Organics (VHOs)	Trichloroethylene (TCE)	3		ROD health-based value
	Chloroform	6		ROD CBSG[3]
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organochlorine Pesticides (OCPs)	Dieldrin	0.002	0.05	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
	Isodrin	0.06		ROD health-based value
Other Organics	n-Nitrosodimethylamine (NDMA)	0.007	0.033	ROD - EPA Integrated Risk Information System value
Arsenic	Arsenic	2.35		ROD health-based value

Notes:
[1] Practical Quantitation Limit, subject to change pending outcome of 2010 PQL study.
[2] Five-Year Review Report
[3] Colorado Basic Standard for Groundwater

Table 2.3-2. North Boundary Containment System (NBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)[1]	PQL[2] (µg/L) 2005 FYRR[3]	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40		ROD CBSG[4]
	1,2-Dichloroethylene	70		ROD CBSG
	Carbon tetrachloride	0.30		ROD CBSG
	Chloroform	6		ROD CBSG
	Methylene chloride	5.0		ROD CBSG
	Tetrachloroethylene	5		ROD CBSG/MCL[5]
	Trichloroethylene (TCE)	3		ROD health-based value
Volatile Hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		ROD health-based value
Volatile Aromatic Organics (VAOs)	Benzene	3		ROD health-based value
	Xylenes	1,000		ROD health-based value
	Toluene	1,000		ROD CBSG/MCL
Organosulfur Compounds; Mustard Agent Related (OSCMs)	1,4-Oxathiane	160		ROD health-based value
	Dithiane	18		ROD health-based value
Organosulfur Compounds; Herbicide Related (OSCHs)	Chlorophenylmethyl sulfide	30		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfone	36		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfoxide	36		ROD - EPA Region VIII Health Advisory Value
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organophosphorous Compounds; Pesticide Related (OPHPs)	Atrazine	3		ROD CBSG/MCL
	Malathion	100		ROD health-based value
Organochlorine Pesticides (OCPs)	Aldrin	0.002	0.037	ROD CBSG
	Dieldrin	0.002	0.05	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
	Isodrin	0.06		ROD health-based value

Notes:
[1] µg/L unless otherwise noted.
[2] Practical Quantitation Limit, subject to change pending outcome of 2010 PQL study.
[3] Five-Year Review Report
[4] Colorado Basic Standard for Groundwater
[5] Maximum Contaminant Level
[6] ROD change to human health-based CBSG of 4.0 mg/L is under consideration.

Table 2.3-2. North Boundary Containment System (NBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)[1]	PQL[2] (µg/L) 2005 FYRR[3]	CSRG Source
Other Organics	Dibromochloropropane (DBCP)	0.2		ROD CBSG/MCL
	n-Nitrosodimethylamine (NDMA)	0.007	0.033	ROD – EPA Integrated Risk Information System value
Arsenic	Arsenic	2.35		ROD health-based value
Anions	Fluoride	2 mg/L		ROD CBSG; Agricultural standard[6]
	Chloride	250 mg/L		ROD CBSG
	Sulfate	540 mg/L		ROD background value

Notes:
[1] µg/L unless otherwise noted.
[2] Practical Quantitation Limit, subject to change pending outcome of 2010 PQL study.
[3] Five-Year Review Report
[4] Colorado Basic Standard for Groundwater
[5] Maximum Contaminant Level
[6] ROD change to human health-based CBSG of 4.0 mg/L is under consideration.

Table 2.3-3. Railyard (Irondale) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	PQL[1] (µg/L) 2005 FYRR[2]	CSRG Source
Volatile Halogenated Organics (VHOs)	Trichloroethylene (TCE)	5	--	ROD CBSG[3]/MCL[4]
Other Organics	Dibromochloropropane (DBCP)	0.2	--	ROD CBSG/MCL

Notes:
[1] Practical Quantitation Limit, subject to change pending outcome of 2010 PQL study.
[2] Five-Year Review Report
[3] Colorado Basic Standard for Groundwater
[4] Maximum Contaminant Level

Table 2.3-4. Basin A Neck System (BANS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	PQL[1] (µg/L) 2005 FYRR[2]	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40	1.1	ROD CBSG[3]
	1,1,1-Trichloroethane	200		ROD CBSG/MCL[4]
	1,1-Dichloroethylene	7		ROD CBSG/MCL
	Carbon tetrachloride	0.30	1.0	ROD CBSG
	Chlorobenzene	100		ROD CBSG/MCL
	Chloroform	6		ROD CBSG
	Tetrachloroethylene	5		ROD CBSG/MCL
	Trichloroethylene (TCE)	5		ROD CBSG/MCL
Volatile hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		ROD health-based value
Volatile Aromatic Organics (VAOs)	Benzene	5		ROD CBSG/MCL
Organosulfur Compounds; Mustard Agent Related (OSCMs)	1,4-Oxathiane	160		ROD health-based value
	Dithiane	18		ROD health-based value
Organosulfur Compounds; Herbicide Related (OSCHs)	Chlorophenylmethyl sulfide	30		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfone	36		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfoxide	36		ROD - EPA Region VIII Health Advisory Value
Organophosphorous Compounds; Pesticide Related (OPHPs)	Atrazine	3		ROD CBSG/MCL
Semivolatile Halogenated Organics (SHOs)	Hexachlorocyclopentadiene	50		ROD CBSG
Organochlorine Pesticides (OCPs)	Dichlorodiphenyltrichloroethane (DDT)	0.1		ROD CBSG
	Dieldrin	0.002	0.05	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
Arsenic	Arsenic	50		ROD CBSG/MCL
Mercury	Mercury	2		ROD CBSG/MCL

Notes:
[1] Practical Quantitation Limit, subject to change pending outcome of 2010 PQL study.
[2] Five-Year Review Report
[3] Colorado Basic Standard for Groundwater
[4] Maximum Contaminant Level

Table 2.3-5. Off-Post Groundwater Intercept and Treatment System (OGITS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (μg/L)[1]	PQL[2] (μg/L) 2005 FYRR[3]	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40		ROD CBSG[4]
	1,3-Dichlorobenzene	6.5		ROD health-based value
	Chlorobenzene	25		ROD CBSG/MCL[5]
	Carbon tetrachloride	0.30		ROD CBSG
	Chloroform	6		ROD CBSG
	Tetrachloroethylene	5		ROD CBSG/MCL
	Trichloroethylene (TCE)	3		ROD health-based value
Volatile Aromatic Organics (VAOs)	Benzene	3		ROD health-based value
	Ethylbenzene	200		ROD health-based value
	Xylenes	1,000		ROD health-based value
	Toluene	1,000		ROD CBSG/MCL
Volatile Hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		ROD health-based value
Organosulfur Compounds; Mustard Agent Related (OSCMs)	Dithiane	18		ROD health-based value
	1,4-Oxathiane	160		ROD health-based value
Organosulfur Compounds; Herbicide Related (OSCHs)	Chlorophenylmethyl sulfide	30		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfone	36		ROD - EPA Region VIII Health Advisory Value
	Chlorophenylmethyl sulfoxide	36		ROD - EPA Region VIII Health Advisory Value
Organophosphorous Compounds; Isopropylmethyl Phosphonofluoridate (GB) Agent Related	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organophosphorous Compounds; Pesticide Related (OPHPs)	Atrazine	3		ROD CBSG/MCL
	Malathion	100		ROD health-based value
Semivolatile Halogenated Organics (SHOs)	Hexachlorocyclopentadiene	0.23		ROD CBSG
	Chlordane	0.03	0.095	ROD CBSG

Notes:
[1] μg/L unless otherwise noted.
[2] Practical Quantitation Limit, subject to change pending outcome of 2010 PQL study.
[3] Five-Year Review Report
[4] Colorado Basic Standard for Groundwater
[5] Maximum Contaminant Level
[6] ROD change to human health-based CBSG of 4.0 mg/L is under consideration.

Table 2.3-5. Off-Post Groundwater Intercept and Treatment System (OGITS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)[1]	PQL[2] (µg/L) 2005 FYRR[3]	CSRG Source
Organochlorine Pesticides (OCPs)	Aldrin	0.002	0.037	ROD CBSG
	Dieldrin	0.002	0.05	ROD CBSG
	Endrin	2		CBSG (corrected in 2000 FYRR)
	Isodrin	0.06		ROD health-based value
	Dichlorodiphenyltrichloroethane (DDT)	0.1		ROD CBSG
	Dichlorodiphenyldichloroethene (DDE)	0.1		ROD CBSG
Other Organics	Dibromochloropropane (DBCP)	0.2		ROD CBSG/MCL
	n-Nitrosodimethylamine (NDMA)	0.007	0.033	ROD – EPA Integrated Risk Information System value
Arsenic	Arsenic	2.35		ROD health-based value
Anions	Fluoride	2 mg/L		ROD CBSG; Agricultural standard[6]
	Chloride	250 mg/L		ROD CBSG
	Sulfate	540 mg/L		ROD background value

Notes:
[1] µg/L unless otherwise noted.
[2] Practical Quantitation Limit, subject to change pending outcome of 2010 PQL study.
[3] Five-Year Review Report
[4] Colorado Basic Standard for Groundwater
[5] Maximum Contaminant Level
[6] ROD change to human health-based CBSG of 4.0 mg/L is under consideration.

Table 4.3-8. Summary of Wells in Northwest Boundary Containment System (NWBCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
22001	Northeast Extension	X		X
22007	Northeast Extension	X		
22015	Northeast Extension	X	X	
22044	Northeast Extension	X		
22049	Northeast Extension	X		
22060	Northeast Extension	X		
22071	Northeast Extension	X		
22072	Northeast Extension	X		
22504	Northeast Extension	X		
22505	Northeast Extension	X	X	
22506	Northeast Extension	X		
22508	Northeast Extension	X		
22512	Northeast Extension	X	X	
03005	Original			X
22003	Original	X		
22005	Original	X		
22008	Original	X	X	
22009	Original	X		
22010	Original	X		
22016	Original	X		
22017	Original	X		
22018	Original	X		
22019	Original	X		
22021	Original	X		
22035	Original	X		
22042	Original	X		
22043	Original	X	X	
22045	Original	X		
22053	Original		X	
22056	Original	X		
22057	Original	X		
22059	Original	X		
22061	Original	X		
22062	Original	X		
22063	Original	X		
22064	Original	X		
22065	Original	X		
22066	Original	X		
22067	Original	X		

Table 4.3-8. Summary of Wells in Northwest Boundary Containment System (NWBCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
22069	Original	X		
22070	Original	X		
22073	Original	X		
22075	Original	X		
22076	Original	X		
22077	Original	X		
22078	Original	X		
22081	Original		X	
22500	Original	X		
22501	Original	X		
22511	Original	X		
27002	Original			X
27010	Original	X	X	
27025	Original			X
27037	Original			X
27079	Original			X
27082	Original			X
27083	Original			X
27086	Original	X		
27090	Original	X		
27091	Original			X
27500	Original	X	X	
27503	Original	X		
27504	Original	X		
34005	Original			X
34017	Original			X
34020	Original			X
34508	Original			X
35058	Original			X
37330	Original	X	X	
37331	Original	X	X	
37332	Original	X	X	
37333	Original	X	X	
37600	Original	X	X	
03015	Southwest Extension			X
03016	Southwest Extension			X
27003	Southwest Extension	X		
27043	Southwest Extension			X
27092	Southwest Extension	X		

Table 4.3-8. Summary of Wells in Northwest Boundary Containment System (NWBCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
27093	Southwest Extension	X		
27501	Southwest Extension	X		
27505	Southwest Extension	X		
27506	Southwest Extension	X		
27508	Southwest Extension	X		
27509	Southwest Extension	X		
27510	Southwest Extension	X		
27511	Southwest Extension	X		
27516	Southwest Extension	X	X	
27517	Southwest Extension	X	X	
27522	Southwest Extension	X	X	
27524	Southwest Extension	X		
27525	Southwest Extension	X		
27528	Southwest Extension	X		
27529	Southwest Extension	X		
27530	Southwest Extension	X		
27531	Southwest Extension	X		
27532	Southwest Extension	X		
27533	Southwest Extension	X		
28002	Southwest Extension	X		
28003	Southwest Extension	X		
28004	Southwest Extension	X		
28005	Southwest Extension	X		
28031	Southwest Extension	X		
28519	Southwest Extension	X		
28521	Southwest Extension	X	X	
28522	Southwest Extension	X		
34008	Southwest Extension			X
34015	Southwest Extension			X

Table 4.3-9. Northwest Boundary Containment System (NWBCS) CSRG Analyte Screening Summary

ROD CSRG Analyte	Influent Review	Extraction Well Review	Upgradient Well Review	Conclusion
Trichloroethylene (TCE)	Removed	Removed	Removed	Removed
Chloroform	Removed	Retained	Retained	Retained
Diisopropylmethyl phosphonate (DIMP)	Removed	Removed	Removed	Removed
Dieldrin	Removed	Retained	Retained	Retained
Endrin	Removed	Removed	Removed	Removed
Isodrin	Removed	Retained	Retained	Retained
n-Nitrosodimethylamine (NDMA)	Removed	Retained (not analyzed)	Retained (limited analyses)	Retained due to lack of data; further evaluation as new data become available
Arsenic	Removed	Retained (limited analyses)	Retained (not analyzed)	Retained due to lack of data; further evaluation as new data become available

Table 4.3-10. Northwest Boundary Containment System (NWBCS) Routine CSRG Analyte List

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)	PQL[1] (µg/L) 2005 FYRR[2]	CSRG Source
Volatile Halogenated Organics (VHOs)	Chloroform	6.0		ROD CBSG[3]
Organochlorine Pesticides (OCPs)	Dieldrin	0.002	0.05	ROD CBSG
	Isodrin	0.06		ROD health-based value
Other Organics	n-Nitrosodimethylamine (NDMA)	0.007	0.033	ROD - EPA Integrated Risk Information System value
Arsenic	Arsenic	2.35		ROD health-based value

Notes:
[1] Practical Quantitation Limit
[2] Five-Year Review Report
[3] Colorado Basic Standard for Groundwater

Table 4.4-6. Summary of Wells in North Boundary Containment System (NBCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
23095	Upgradient			X
23096	Upgradient			X
23119	Upgradient		X	
23142	Upgradient			X
23160	Upgradient		X	
23161	CFS[1], downgradient		X	
23194	UFS[2], downgradient		X	
23195	UFS[2], upgradient		X	
23200	CFS[1], downgradient		X	
23207	Upgradient	X		
23208	Upgradient	X		
23211	Upgradient		X	
23212	Upgradient	X		
23214	Upgradient	X		
23217	Downgradient	X		
23235	UFS[2], downgradient		X	
23405	Downgradient		X	
23434	Downgradient		X	
23436	Downgradient		X	
23438	Downgradient		X	
23510	Downgradient	X		
23513	Downgradient	X		
23516	Downgradient	X		
23519	Downgradient	X		
23522	Downgradient	X		
23528	Downgradient	X		
23529	Downgradient	X		
23533	Upgradient	X		
23534	Upgradient	X		

Notes:
[1] Confined Flow System (Denver). Sampled once in 5 years.
[2] Unconfined Flow System (Denver). Sampled once in 5 years.

Table 4.4-6. Summary of Wells in North Boundary Containment System (NBCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
23535	Upgradient	X		
23540	UFS[2], downgradient		X	
23541	UFS[2], upgradient		X	
23542	UFS[2], downgradient		X	
23543	UFS[2], upgradient		X	
23544	Upgradient	X		
23548	UFS[2], upgradient			X
24004	Downgradient		X	
24006	Downgradient		X	
24081	Upgradient, North Plants			X
24092	Upgradient			X
24094	Upgradient			X
24101	Upgradient		X	
24105	Upgradient		X	
24106	Upgradient		X	
24114	Upgradient		X	
24117	Upgradient		X	
24171	CFS[1], downgradient		X	
24179	Upgradient	X		
24180	Upgradient	X		
24185	Upgradient		X	
24191	UFS[2], downgradient		X	
24199	Upgradient		X	
24201	Upgradient		X	
24415	Downgradient		X	
24418	Downgradient		X	
24421	Downgradient		X	
24424	Downgradient		X	
24503	Downgradient	X		

Notes:
[1] Confined Flow System (Denver). Sampled once in 5 years.
[2] Unconfined Flow System (Denver). Sampled once in 5 years.

Table 4.4-6. Summary of Wells in North Boundary Containment System (NBCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
24506	Downgradient	X		
24509	Downgradient	X		
24512	Downgradient	X		
24515	Downgradient	X		
24518	Downgradient	X		
24521	Downgradient	X		
24522	Upgradient	X		
24523	Upgradient	X		
24526	Downgradient	X		
24527	Upgradient	X		
24528	Upgradient	X		
24529	Upgradient	X		
24530	Upgradient	X		
25059	Upgradient, North Plants			X
37362	Downgradient		X	

Notes:
[1] Confined Flow System (Denver). Sampled once in 5 years.
[2] Unconfined Flow System (Denver). Sampled once in 5 years.

Table 4.4-7. North Boundary Containment System (NBCS) CSRG Analyte Screening Summary

ROD CSRG Analyte	Influent Review	Extraction Well Review	Upgradient Well Review	Conclusion
1,2-Dichloroethane	Removed	Retained	Removed	Retained
1,2-Dichloroethylene	Removed	Removed	Removed	Removed
Carbon tetrachloride	Retained	Retained	Removed	Retained
Chloroform	Retained	Retained	Removed	Retained
Methylene chloride	Removed	Removed	Removed	Removed
Tetrachloroethylene	Removed	Retained	Removed	Retained
Trichloroethylene (TCE)	Removed	Retained	Removed	Retained
Dicyclopentadiene (DCPD)	Removed	Retained	Removed	Retained
Benzene	Removed	Removed	Removed	Removed
Xylenes	Removed	Removed	Removed	Removed
Toluene	Removed	Removed	Removed	Removed
1,4-Oxathiane	Removed	Removed	Removed	Removed
Dithiane	Removed	Removed	Removed	Removed
Chlorophenylmethyl sulfide	Removed	Removed	Removed	Removed
Chlorophenylmethyl sulfone	Removed	Removed	Removed	Removed
Chlorophenylmethyl sulfoxide	Removed	Removed	Removed	Removed
Diisopropylmethyl phosphonate (DIMP)	Retained	Retained	Removed	Retained
Atrazine	Removed	Removed	Removed	Removed
Malathion	Removed	Removed	Removed	Removed
Aldrin	Retained	Retained	Removed	Retained
Dieldrin	Retained	Retained	Retained	Retained
Endrin	Removed	Removed	Removed	Removed
Isodrin	Removed	Retained	Removed	Retained
Dibromochloropropane (DBCP)	Removed	Removed	Removed	Removed
n-Nitrosodimethylamine (NDMA)	Retained	Retained	Removed	Retained
Arsenic	Removed	Removed	Removed	Retained due to lack of data; further evaluation as new data become available
Fluoride	Retained	Retained	Retained	Retained
Chloride	Retained	Retained	Retained	Retained
Sulfate	Removed	Retained	Retained	Retained

Table 4.4-8. North Boundary Containment System (NBCS) Routine CSRG Analyte List

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)[1]	PQL[2] (µg/L) 2005 FYRR[3]	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40		ROD CBSG[4]
	Carbon tetrachloride	0.30		ROD CBSG
	Chloroform	6		ROD CBSG
	Tetrachloroethylene	5		ROD CBSG/MCL[5]
	Trichloroethylene (TCE)	3		ROD health-based value
Volatile Hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		ROD health-based value
Organophosphorous Compounds Isopropylmethyl Phosphonofluoridate (GB) Agent Related	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organochlorine Pesticides (OCPs)	Aldrin	0.002	0.037	ROD CBSG
	Dieldrin	0.002	0.05	ROD CBSG
	Isodrin	0.06		ROD health-based value
	n-Nitrosodimethylamine (NDMA)	0.007	0.033	ROD – EPA Integrated Risk Information System value
Anions	Fluoride	2 mg/L		ROD CBSG; Agricultural Standard[6]
	Chloride	250 mg/L		ROD CBSG
	Sulfate	540 mg/L		ROD background value
Arsenic	Arsenic	2.35		ROD health-based value[7]

Notes:
[1] µg/L unless otherwise noted.
[2] Practical Quantitation Limit
[3] Five-Year Review Report
[4] Colorado Basic Standard for Groundwater
[5] Maximum Contaminant Level
[6] ROD change to human health-based CBSG of 4.0 mg/L is under consideration.
[7] Retained due to limited analytical data.

Table 4.5-4. Summary of Wells in Railyard Containment System (RYCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
03001	Cross-gradient	X	X[1]	
03010	Upgradient	X		
03017	Downgradient	X		
03301	Upgradient	X		
03302	Upgradient	X		
03303	Upgradient	X		
03304	Upgradient	X		
03305	Upgradient	X		
03501	Upgradient	X	X	
03502	Upgradient	X		
03503	Upgradient	X	X	
03505	Upgradient	X		
03506	Upgradient	X		
03507	Downgradient	X	X[1]	
03508	Downgradient	X	X[2]	
03509	Downgradient	X	X[1]	
03510	Upgradient	X		
03511	Upgradient	X		
03512	Downgradient	X		
03513	Downgradient	X		
03522	Downgradient	X		
03523	Upgradient			X
03527	Cross-gradient	X	X[1]	
03528	Downgradient	X		
03529	Downgradient	X	X	
03530	Downgradient	X	X	
03531	Downgradient	X		
03532	Downgradient	X		
03533	Downgradient	X		

Notes:
[1] Sample even years.
[2] Sample odd years.

Table 4.5-4. Summary of Wells in Railyard Containment System (RYCS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
03534	Upgradient	X		
03535	Downgradient	X		
03536	Upgradient	X		
03537	Upgradient	X		
03538	Upgradient	X	X	
04506	Downgradient	X	X[2]	

Notes:
[1] Sample even years.
[2] Sample odd years.

Table 4.6-4. Summary of Wells in Basin A Neck System (BANS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
26096	Downgradient	X		
26501	Downgradient	X	X	
26502	Downgradient	X		
26503	Downgradient	X		
26504	Downgradient	X		
26505	Downgradient	X	X	
26506	Upgradient	X		
26507	Upgradient	X	X	
26509	Downgradient	X		
26510	Upgradient	X		
26511	Downgradient	X		
26512	Upgradient	X		
35012	Downgradient	X		
35018	Downgradient	X		
35065	Upgradient			X
35079	Upgradient	X		
35304	Upgradient	X		
35305	Upgradient	X		
35306	Upgradient	X		
35505	Downgradient	X	X	
35509	Downgradient	X		
35510	Downgradient	X		
35511	Upgradient	X		
35512	Upgradient	X	X	
35513	Upgradient	X		
35514	Upgradient	X	X	
35515	Upgradient	X		
35516	Upgradient	X	X	
35518	Downgradient	X		
35519	Upgradient	X		
35520	Downgradient	X		

Table 4.6-4. Summary of Wells in Basin A Neck System (BANS) Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
35521	Upgradient	X		
35522	Downgradient	X		
35523	Upgradient	X		
35525	Downgradient	X	X	
35526	Upgradient	X		
35544	Upgradient	X		
35549	Upgradient	X		
36627	Upgradient			X
36629	Upgradient			X
36630	Upgradient			X
36631	Upgradient			X
36632	Upgradient			X
36633	Upgradient			X
26006	Downgradient			X
27025	Downgradient			X
27082	Downgradient			X

Table 4.7-4. Summary of Wells in Bedrock Ridge Extraction System Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
25502	Downgradient			X
25503	Downgradient	X		
25504	Downgradient	X		
25505	Downgradient	X		
25506	Downgradient	X		
36302	Upgradient	X		
36303	Upgradient	X		
36304	Upgradient	X		
36306	Upgradient	X		
36502	Upgradient	X		
36552	Upgradient			X
36555	Downgradient	X	X	
36556	Downgradient	X		
36557	Upgradient	X		
36558	Upgradient	X		
36559	Downgradient	X		
36561	Downgradient	X		
36562	Downgradient	X		
36563	Upgradient	X		
36564	Upgradient	X		
36565	Upgradient	X	X	
36566	Downgradient	X	X	
36567	Upgradient	X	X	
36568	Upgradient	X		
36569	Downgradient	X		
36570	Downgradient	X		
36571	Downgradient	X	X	
36572	Downgradient	X	X	
36573	Upgradient	X		
36574	Upgradient	X		
36575	Upgradient	X	X	
36576	Upgradient	X		

Table 4.7-4. Summary of Wells in Bedrock Ridge Extraction System Monitoring Networks

Well	Location	Performance		Water Quality Tracking
		Water Level	Water Quality	
36577	Upgradient	X		
36578	Upgradient	X	X	
36579	Upgradient	X		
36580	Upgradient	X		
36594	Upgradient			X

Table 4.8-4. Summary of Wells in the Off-Post Groundwater Intercept and Treatment System (OGITS) Monitoring Networks

Well	Location	Performance	
		Water Level	Water Quality
37008	Northern Pathway, Downgradient	X	X
37009	Northern Pathway, Downgradient	X	X
37010	Northern Pathway, Downgradient	X	X
37011	Northern Pathway, Downgradient	X	X
37012	Northern Pathway, Downgradient	X	X
37013	Northern Pathway, Downgradient	X	X
37014	Northern Pathway, Downgradient	X	
37015	Northern Pathway, Downgradient	X	
37016	Northern Pathway, Downgradient	X	
37017	Northern Pathway, Downgradient	X	
37018	Northern Pathway, Downgradient	X	
37019	Northern Pathway, Downgradient	X	
37020	Northern Pathway, Downgradient	X	
37021	Northern Pathway, Downgradient	X	
37022	Northern Pathway, Downgradient	X	
37023	Northern Pathway, Downgradient	X	
37024	Northern Pathway, Downgradient	X	
37025	Northern Pathway, Downgradient	X	
37026	Northern Pathway, Downgradient	X	
37027	Northern Pathway, Cross-gradient	X	X
37028	Northern Pathway, Upgradient	X	
37029	Northern Pathway, Upgradient	X	
37030	Northern Pathway, Upgradient	X	
37031	Northern Pathway, Upgradient	X	
37032	Northern Pathway, Upgradient	X	
37033	Northern Pathway, Upgradient	X	
37034	Northern Pathway, Upgradient	X	
37035	Northern Pathway, Upgradient	X	
37037	Northern Pathway, Upgradient	X	
37038	Northern Pathway, Upgradient	X	
37039	Northern Pathway, Cross-gradient	X	X
37045	First Creek Pathway, Upgradient	X	

Table 4.8-4. Summary of Wells in the Off-Post Groundwater Intercept and Treatment System (OGITS) Monitoring Networks

Well	Location	Performance	
		Water Level	Water Quality
37048	First Creek Pathway, Upgradient	X	
37050	First Creek Pathway, Upgradient	X	
37054	First Creek Pathway, Upgradient	X	
37058	First Creek Pathway, Downgradient	X	
37059	First Creek Pathway, Downgradient	X	
37060	First Creek Pathway, Upgradient	X	
37061	First Creek Pathway, Upgradient	X	
37062	First Creek Pathway, Upgradient	X	
37063	First Creek Pathway, Upgradient	X	
37064	First Creek Pathway, Upgradient	X	
37065	First Creek Pathway, Upgradient	X	
37066	First Creek Pathway, Upgradient	X	
37067	First Creek Pathway, Upgradient	X	
37068	First Creek Pathway, Upgradient	X	
37069	First Creek Pathway, Upgradient	X	
37071	First Creek Pathway, Upgradient	X	
37072	First Creek Pathway, Upgradient	X	
37073	First Creek Pathway, Upgradient	X	
37074	First Creek Pathway, Upgradient	X	X
37075	First Creek Pathway, Upgradient	X	X
37076	First Creek Pathway, Upgradient	X	X
37080	Northern Pathway, Upgradient	X	
37083	First Creek Pathway, Upgradient	X	X
37084	First Creek Pathway, Downgradient	X	X
37090	First Creek Pathway, Upgradient	X	
37094	Northern Pathway, Upgradient	X	X
37095	Northern Pathway, Upgradient	X	X
37098	Northern Pathway, Downgradient	X	
37099	Northern Pathway, Downgradient	X	
37100	Northern Pathway, Downgradient	X	
37101	Northern Pathway, Downgradient	X	
37102	Northern Pathway, Upgradient	X	

Table 4.8-4. Summary of Wells in the Off-Post Groundwater Intercept and Treatment System (OGITS) Monitoring Networks

Well	Location	Performance	
		Water Level	Water Quality
37103	Northern Pathway, Upgradient	X	
37105	First Creek Pathway, Cross-gradient	X	
37106	First Creek Pathway, Cross-gradient	X	
37107	First Creek Pathway, Upgradient	X	
37110	First Creek Pathway, Downgradient	X	X
37111	Northern Pathway, Downgradient	X	
37112	Northern Pathway, Downgradient	X	
37113	Northern Pathway, Downgradient	X	
37114	Northern Pathway, Downgradient	X	
37115	Northern Pathway, Downgradient	X	
37116	First Creek Pathway, Cross-gradient	X	
37117	First Creek Pathway, Cross-gradient	X	
37118	First Creek Pathway, Upgradient	X	
37127	First Creek Pathway, Upgradient	X	
37128	First Creek Pathway, Upgradient	X	
37130	First Creek Pathway, Upgradient	X	
37131	First Creek Pathway, Downgradient	X	
37132	First Creek Pathway, Downgradient	X	
37133	First Creek Pathway, Cross-gradient	X	
37135	First Creek Pathway, Upgradient	X	
37136	First Creek Pathway, Cross-gradient	X	
37137	First Creek Pathway, Cross-gradient	X	
37138	First Creek Pathway, Downgradient	X	
37139	First Creek Pathway, Upgradient	X	
37140	First Creek Pathway, Upgradient	X	
37141	First Creek Pathway, Downgradient	X	
37142	First Creek Pathway, Cross-gradient	X	
37313	First Creek Pathway, Downgradient	X	
37343	First Creek Pathway, Downgradient	X	X
37368	Northern Pathway, Upgradient	X	
37370	First Creek Pathway, Upgradient	X	X
37373	First Creek Pathway, Upgradient	X	X

Table 4.8-4. Summary of Wells in the Off-Post Groundwater Intercept and Treatment System (OGITS) Monitoring Networks

Well	Location	Performance	
		Water Level	Water Quality
37395	Northern Pathway, Upgradient	X	X
37396	First Creek Pathway, Downgradient	X	
37397	Northern Pathway, Cross-gradient	X	
37404	Northern Pathway, Upgradient	X	X
37405	Northern Pathway, Downgradient	X	
37407	First Creek Pathway, Downgradient	X	
37419	First Creek Pathway, Upgradient	X	
37422	First Creek Pathway, Upgradient	X	
37426	First Creek Pathway, Upgradient	X	
37427	First Creek Pathway, Upgradient	X	
37451	Northern Pathway, Cross-gradient	X	
37452	Northern Pathway, Cross-gradient	X	X
37453	Northern Pathway, Upgradient	X	
37454	Northern Pathway, Upgradient	X	
37455	Northern Pathway, Upgradient	X	
37456	Northern Pathway, Upgradient	X	
37457	Northern Pathway, Upgradient	X	X
37458	Northern Pathway, Upgradient	X	X
37459	Northern Pathway, Upgradient	X	
37460	Northern Pathway, Cross-gradient	X	
37461	Northern Pathway, Cross-gradient	X	
37462	Northern Pathway, Cross-gradient	X	
37463	Northern Pathway, Upgradient	X	
37464	Northern Pathway, Upgradient	X	
37465	Northern Pathway, Upgradient	X	
37469	Northern Pathway, Upgradient	X	X
37470	Northern Pathway, Upgradient	X	
37471	Northern Pathway, Upgradient	X	X
37472	Northern Pathway, Cross-gradient	X	
37473	Northern Pathway, Upgradient	X	X
37474	Northern Pathway, Upgradient	X	X
37475	Northern Pathway, Recharge trench piezometer	X	

Table 4.8-4. Summary of Wells in the Off-Post Groundwater Intercept and Treatment System (OGITS) Monitoring Networks

Well	Location	Performance	
		Water Level	Water Quality
37476	Northern Pathway, Recharge trench piezometer	X	
37477	Northern Pathway, Recharge trench piezometer	X	
37478	Northern Pathway, Recharge trench piezometer	X	
37479	Northern Pathway, Recharge trench piezometer	X	
37480	Northern Pathway, Recharge trench piezometer	X	
37481	Northern Pathway, Recharge trench piezometer	X	
37482	Northern Pathway, Recharge trench piezometer	X	
37484	Northern Pathway, Recharge trench piezometer	X	
37485	Northern Pathway, Recharge trench piezometer	X	
37487	Northern Pathway, Recharge trench piezometer	X	
37488	Northern Pathway, Recharge trench piezometer	X	
37494	Northern Pathway, Upgradient	X	
37495	Northern Pathway, Upgradient	X	
37496	Northern Pathway, Upgradient	X	
37800	First Creek Pathway, Upgradient	X	
37803	First Creek Pathway, Upgradient	X	
37804	First Creek Pathway, Upgradient	X	
37811	Northern Pathway, Upgradient	X	
37817	Northern Pathway, Upgradient	X	
37818	Northern Pathway, Upgradient	X	
37819	Northern Pathway, Upgradient	X	
37820	Northern Pathway, Upgradient	X	
37821	Northern Pathway, Upgradient	X	
37822	Northern Pathway, Upgradient	X	
EPA-4	Northern Pathway, Upgradient (replaces 37470 for Performance Water Quality)	X	X

Table 4.8-5. Off-Post Groundwater Intercept and Treatment System (OGITS) CSRG Analyte Screening Summary

ROD CSRG Analyte	Influent Review	Extraction Well Review	Upgradient Well Review	Conclusion
1,2-Dichloroethane	Removed	Removed	Retained	Retained
1,3-Dichlorobenzene	Removed	Removed	Removed	Removed
Chlorobenzene	Removed	Removed	Removed	Removed
Carbon tetrachloride	Removed	Removed	Retained	Retained
Chloroform	Removed	Retained	Retained	Retained
Tetrachloroethylene	Removed	Retained	Retained	Retained
Trichloroethylene (TCE)	Removed	Removed	Removed	Removed
Benzene	Removed	Removed	Removed	Removed
Ethylbenzene	Removed	Removed	Removed	Removed
Xylenes	Removed	Removed	Removed	Removed
Toluene	Removed	Removed	Removed	Removed
Dicyclopentadiene (DCPD)	Removed	Removed	Retained	Retained
Dithiane	Removed	Removed	Removed	Removed
1,4-Oxathiane	Removed	Removed	Removed	Removed
Chlorophenylmethyl sulfide	Removed	Removed	Removed	Removed
Chlorophenylmethyl sulfone	Removed	Removed	Removed	Removed
Chlorophenylmethyl sulfoxide	Removed	Removed	Removed	Removed
Diisopropylmethyl phosphonate (DIMP)	Retained	Retained	Retained	Retained
Atrazine	Removed	Removed	Removed	Removed
Malathion	Removed	Removed	Removed	Removed
Hexachlorocyclopentadiene	Removed	Removed	Removed	Removed
Chlordane	Removed	Removed	Removed	Removed
Aldrin	Removed	Removed	Removed	Removed
Dieldrin	Removed	Retained	Retained	Retained
Endrin	Removed	Removed	Removed	Removed
Isodrin	Removed	Removed	Removed	Removed
Dichlorodiphenyltrichloroethane (DDT)	Removed	Removed	Removed	Removed
DDE	Removed	Removed	Removed	Removed
Dibromochloropropane (DBCP)	Removed	Retained	Removed	Retained
n-Nitrosodimethylamine (NDMA)	Removed	Removed	Retained	Retained
Arsenic	Removed	Retained	Removed	Retained
Fluoride	Removed	Retained	Retained	Retained
Chloride	Retained	Retained	Retained	Retained
Sulfate	Retained	Retained	Retained	Retained

Table 4.8-6. Off-Post Groundwater Intercept and Treatment System (OGITS) Routine CSRG Analyte List

Chemical Group	ROD CSRG Analyte	CSRG (µg/L)[1]	PQL[2] (µg/L) 2005 FYRR[3]	CSRG Source
Volatile Halogenated Organics (VHOs)	1,2-Dichloroethane	0.40		ROD CBSG[4]
	Carbon tetrachloride	0.30		ROD CBSG
	Chloroform	6		ROD CBSG
	Tetrachloroethylene	5		ROD CBSG/MCL[5]
Volatile Hydrocarbon Compounds (VHCs)	Dicyclopentadiene (DCPD)	46		ROD health-based value
Organophosphorous Compounds Isopropylmethyl Phosphonofluoridate (GB) Agent Related)	Diisopropylmethyl phosphonate (DIMP)	8		ROD CBSG
Organochlorine Pesticides (OCPs)	Dieldrin	0.002	0.05	ROD CBSG
Other Organics	Dibromochloropropane (DBCP)	0.2		ROD CBSG/MCL
	n-Nitrosodimethylamine (NDMA)	0.007	0.033	ROD - EPA Integrated Risk Information System value
Anions	Fluoride	2 mg/L		ROD CBSG; Agricultural Standard[6]
	Chloride	250 mg/L		ROD CBSG
	Sulfate	540 mg/L		ROD background value
Arsenic	Arsenic	2.35		ROD health-based value

Notes:
[1] µg/L unless otherwise noted.
[2] Practical Quantitation Limit
[3] Five-Year Review Report
[4] Colorado Basic Standard for Groundwater
[5] Maximum Contaminant Level
[6] ROD change to human health based CBSG of 4.0 mg/L is under consideration.

Table 6.1-2. Water Level Tracking Wells

01001	01021	01024	01033	01041	01044	01047	01049
01063	01068	01069	01078	01101	01407	01408	01517
01525	01534	01582	01583	01600	01605	01656	01669
01670	01681	01685	01686	01687	01702	02011	02014
02023	02026	02034	02041	02043	02052	02056	02058
02065	02505	02512	02515	02520	02522	02523	02524
02525	02576	02580	02683	02597	03002	03005	03008
03012	03013	03014	03015	03016	03503	03523	04014
04020	04021	04024	04029	04038	04040	04076	04080
04082	04525	04528	04535	05001	05005	06002	06003
07001	07032	07033	07139	08003	08026	08027	11002
11023	12001	12002	12005	19001	19004	19007	19015
19017	20002	22001	22006	22007	22052	22053	22054
22081	22505	23002	23004	23008	23029	23040	23053
23095	23096	23135	23140	23142	23160	23182	23185
23196	23198	23199	23211	23227	23253	23548	24003
24006	24080	24081	24092	24094	24096	24098	24106
24107	24108	24109	24112	24124	24126	24135	24158
24162	24163	24164	24166	24187	24201	25001	25011
25015	25022	25041	25048	25054	25059	25091	25126
25129	25133	25500	25502	26006	26015	26016	26017
26020	26040	26049	26061	26071	26083	26094	26097
26154	26157	26158	26160	26163	26170	26500	27002
27003	27018	27025	27035	27037	27043	27049	27051
27053	27060	27063	27066	27072	27077	27078	27079
27082	27083	27084	27091	27500	27522	28004	28012
28022	28024	28027	28520	28522	29002	30004	30006
30009	30020	31005	31012	31014	31016	31537	32001
32004	32005	33001	33025	33043	33061	33081	33341
33510	33514	33533	34005	34008	34014	34015	34017
34018	34019	34020	34503	34508	35013	35023	35037
35058	35061	35065	35069	35087	35093	35504	35512
36052	36054	36069	36077	36087	36089	36092	36094
36112	36120	36123	36142	36157	36158	36168	36169
36181	36186	36200	36201	36210	36212	36216	36217
36502	36521	36538	36541	36552	36575	36594	36595
36627	36628	36629	36630	36631	36632	36633	37008
37009	37010	37011	37012	37013	37027	37039	37041
37062	37063	37065	37070	37071	37073	37074	37075
37076	37080	37081	37083	37084	37094	37095	37097
37103	37107	37108	37110	37125	37126	37150	37151
37320	37323	37327	37328	37334	37335	37336	37337
37338	37339	37341	37342	37343	37346	37347	37348

Table 6.1-2. Water Level Tracking Wells

37349	37350	37351	37353	37361	37362	37363	37367
37368	37369	37370	37373	37374	37377	37378	37379
37385	37387	37389	37391	37392	37395	37396	37397
37404	37405	37407	37428	37429	37430	37440	37441
37442	37451	37452	37457	37462	37463	37472	

Table 6.1-6. Site-Wide Water-Quality Tracking

Location	Site ID	Frequency	Indicator Analytes	Justification
NWBCS	03005	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants source.
NWBCS	03015	Twice in 5 Years	Dieldrin	Upgradient of Southwest Extension (SWE), downgradient from Lake Mary, South Plants source.
NWBCS	03016	Twice in 5 Years	Dieldrin	Upgradient of SWE, downgradient from Lake Mary, South Plants source.
NWBCS	22001	Twice in 5 Years	DIMP, OCPs	Upgradient of Northeast Extension (NEE) slurry wall, downgradient from Basin F source. Travel time to NEE is 4–7 years.
NWBCS	27002	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants source.
NWBCS/BANS	27025	Twice in 5 Years	Arsenic, chloroform, dieldrin, DIMP, NDMA	Upgradient of Original System, downgradient from BANS.
NWBCS	27037	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants source.
NWBCS	27043	Twice in 5 Years	Dieldrin	Upgradient of SWE, downgradient from South Plants source.
NWBCS	27079	Twice in 5 Years	Arsenic, chloroform, dieldrin, DIMP	Upgradient of Original System, downgradient from Basin F source.
NWBCS/BANS	27082	Twice in 5 Years	Arsenic, chloroform, dieldrin, DIMP, NDMA	Upgradient of Original System, downgradient from BANS.
NWBCS	27083	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants/Sand Creek Lateral source.
NWBCS	27091	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants source.
NWBCS	34005	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants source.
NWBCS	34008	Twice in 5 Years	Dieldrin	Upgradient of SWE, downgradient from South Plants source.
NWBCS	34015	Twice in 5 Years	Dieldrin	Upgradient of SWE, downgradient from South Plants source.
NWBCS	34017	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants source.
NWBCS	34020	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from South Plants source.

Table 6.1-6. Site-Wide Water-Quality Tracking

Location	Site ID	Frequency	Indicator Analytes	Justification
NWBCS	34508	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from Sand Creek Lateral source.
NWBCS	35058	Twice in 5 Years	Chloroform, dieldrin	Upgradient of Original System, downgradient from Sand Creek Lateral source.
NBCS	23095	Twice in 5 Years	Arsenic, chloride, chloroform, dieldrin, DIMP, fluoride, NDMA, sulfate	Upgradient of NBCS, downgradient from Basins C/F source.
NBCS	23096	Twice in 5 Years	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA, sulfate	Upgradient of NBCS, downgradient from Basins C/F source.
NBCS	23142	Twice in 5 Years	Chloride, chloroform, dieldrin, DIMP, fluoride, sulfate	Upgradient of NBCS, downgradient from Basins C/F source.
NBCS/NBE	23548	Once in 5 Years	Chloride, chloroform, DBCP, dieldrin, DIMP, fluoride, NDMA	Upgradient of NBCS, downgradient from NBE/HRC treatment.
NBCS	24092	Twice in 5 Years	Chloride, chloroform, DIMP, fluoride, sulfate	Upgradient of NBCS, downgradient from North Plants source.
NBCS	24094	Twice in 5 Years	Chloride, carbon tetrachloride, chloroform, DIMP, fluoride, sulfate	Upgradient of NBCS.
North Plants	24081	Twice in 5 Years	Chloride, carbon tetrachloride, chloroform, DIMP, fluoride, tetrachloroethylene	Upgradient of NBCS, downgradient from North Plants source.
North Plants	25059	Twice in 5 Years	Chloride, chloroform, DIMP, fluoride, tetrachloroethylene	Upgradient of NBCS, downgradient from North Plants source, Travel time to NBCS is 6 years.
Railyard System	03523	Twice in 5 Years	DBCP	Upgradient of RY system, near RY source.
Motor Pool	04535	Twice in 5 years (until MCR approved)	TCE	Upgradient of Motor Pool extraction wells, downgradient of Motor Pool source.
BANS/Basin A Neck	26006	Twice in 5 Years	Arsenic, DIMP, dieldrin, dithiane, NDMA, DDT	Downgradient from BANS.
BANS/Basin A Neck	35065	Twice in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE	Upgradient of BANS, downgradient of Basin A source.
Lime Basins/Basin A	36210	Twice in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE	Downgradient from Lime Basins/South Plants source. Monitors flow around west side of Lime Basins slurry-wall enclosure.

Table 6.1-6. Site-Wide Water-Quality Tracking

Location	Site ID	Frequency	Indicator Analytes	Justification
Basin A Source	36627	Once in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE	Downgradient from Lime Basins/South Plants source. Replacement for well 36056.
Basin A Source	36629	Once in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE	Basin A source. Replacement for well 36093.
Basin A Source	36630	Once in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE	Downgradient from Basin A source. Replacement for well 36108.
Basin A Source	36631	Once in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE	Downgradient from South Plants source. Replacement for well 36109.
Basin A Source	36632	Once in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, NDMA, TCE	Downgradient from Basin A source. Replacement for well 36177.
Basin A Source	36633	Once in 5 Years	Arsenic, benzene, chloroform, chloride, DBCP, dieldrin, DIMP, dithiane, TCE	Basin A source. Replacement for well 36599.
Bedrock Ridge	25502	Twice in 5 Years	Carbon tetrachloride, chloroform, DIMP, tetrachloroethylene	Downgradient from Bedrock Ridge system, upgradient of North Plants.
Bedrock Ridge	36552	Twice in 5 Years	Benzene, chloroform, TCE	Upgradient of Bedrock Ridge system, downgradient from Basin A/Complex Disposal Trenches source.
Bedrock Ridge	36594	Twice in 5 Years	Carbon tetrachloride, chloroform, dieldrin, DIMP, tetrachloroethylene, TCE	Upgradient of Bedrock Ridge system, downgradient of Basin A/Complex Disposal Trenches source.
South Plants SPSA-2d Ditch Source	01044	Once in 5 Years	Aldrin, dieldrin	Downgradient from South Plants SPSA-2d Ditch source.
South Plants SPSA-2d Ditch Source	01047	Once in 5 Years	Aldrin, dieldrin	Downgradient from South Plants SPSA-2d Ditch source.
South Plants Central Processing Area Source	01078	Once in 5 Years	Arsenic, benzene, chloride, chloroform, dieldrin	South Plants source.
South Plants SPSA-2d Ditch Source	01101	Once in 5 Years	Aldrin, dieldrin, chloride	Upgradient of South Plants SPSA-2d Ditch source.
South Plants Central Processing Area Source	01525	Once in 5 Years	Arsenic, benzene, chloroform, dieldrin	South Plants source.
South Tank Farm	01534	Twice in 5 Years	Benzene, chloride, chloroform	STF benzene plume.
South Plants SPSA-2d Ditch Source	01582	Once in 5 Years	Aldrin, dieldrin	Downgradient from South Plants SPSA-2d Ditch source.

Table 6.1-6. Site-Wide Water-Quality Tracking

Location	Site ID	Frequency	Indicator Analytes	Justification
South Plants SPSA-2d Ditch Source	01669	Once in 5 Years	Aldrin, dieldrin	Upgradient of South Plants SPSA-2d Ditch source.
South Plants SPSA-2d Ditch Source	01670	Once in 5 Years	Aldrin, dieldrin	Upgradient of South Plants SPSA-2d Ditch source.
South Plants	02065	Once in 5 Years	Benzene, chloroform, dieldrin	South Plants area.
South Plants	36181	Once in 5 Years	Arsenic, benzene, chloride, chloroform, DBCP, dieldrin	South Plants area, upgradient of Lime Basins.
South Lakes	02034	Twice in 5 Years	Benzene, chloroform, dieldrin	Downgradient from South Plants source.
South Lakes/South Tank Farm (STF)	02505	Twice in 5 Years	Benzene, chloroform	Downgradient from STF plume.
South Lakes/STF	02512	Twice in 5 Years	Benzene, dieldrin	Downgradient from STF plume.
South Lakes	02523	Twice in 5 Years	Benzene, chloroform, dieldrin, TCE	Downgradient from South Plants/Sand Creek Lateral.
South Lakes	02524	Twice in 5 Years	Benzene, chloroform, dieldrin	Downgradient from South Plants/Sand Creek Lateral.
South Lakes	02525	Twice in 5 Years	Benzene, chloroform, dieldrin	Downgradient from South Plants/Sand Creek Lateral.
South Lakes	02597	Twice in 5 Years	Benzene, chloroform, dieldrin	Downgradient from South Plants/Sand Creek Lateral.

Table 6.1-7. Water Level Data and Hydraulic Gradients for Confined Flow System (CFS) and Unconfined Flow System (UFS)

Well ID	Flow System	Sample Date	TOC[1] Elevation (ft)	Depth TOC (ft)	Water Elevation (ft)	Hydraulic Gradient
01068	Denver Unconfined	7/19/2006	5277.78	32.65	5245.13	
01068	Denver Unconfined	11/14/2006	5277.78	32.7	5245.08	
01068	Denver Unconfined	1/31/2007	5277.78	32.84	5244.94	
01067	Denver Confined	7/19/2006	5276.8	38.72	5238.08	Downward
01078	Denver Unconfined	7/19/2006	5285.88	39.93	5245.95	
01300	Denver Confined	7/19/2006	5285.5	44.69	5240.81	Downward
01101	Denver Unconfined	7/19/2006	5274.42	29.76	5244.66	
01101	Denver Unconfined	11/14/2006	5274.42	30.02	5244.40	
01101	Denver Unconfined	1/31/2007	5274.42	30.39	5244.03	
01109	Denver Confined	7/19/2006	5274.76	68.69	5206.07	Downward
01534	Denver Unconfined	7/19/2006	5266.18	19.69	5246.49	
01534	Denver Unconfined	11/14/2006	5266.18	19.65	5246.53	
01534	Denver Unconfined	1/31/2007	5266.18	20.4	5245.78	
01102	Denver Confined	7/19/2006	5269.36	30.81	5238.55	Downward
02058	Alluvium/Denver Unconfined	7/19/2006	5253.13	15.27	5237.86	
02058	Alluvium/Denver Unconfined	11/14/2006	5253.13	16.17	5236.96	
02057	Denver Confined	7/19/2006	5253.11	14.93	5238.18	**Upward**
23185	Denver Unconfined	7/18/2006	5181.86	46.09	5135.77	
23187	Denver Confined	7/18/2006	5183.3	66.13	5117.17	Downward
Map	Unconfined Flow System	7/2006			5138	

Notes:
[1] Top of Casing

Table 6.1-7. Water Level Data and Hydraulic Gradients for Confined Flow System (CFS) and Unconfined Flow System (UFS)

Well ID	Flow System	Sample Date	TOC[1] Elevation (ft)	Depth TOC (ft)	Water Elevation (ft)	Hydraulic Gradient
23191	Alluvial/Denver Unconfined	7/10/2007	5193.98	57.87	5136.11	
23193	Denver Confined	7/10/2007	5194.06	63.78	5130.28	Downward
26146	Denver Unconfined	7/19/2006	5180.17	35.91	5144.26	Downward
26147	Denver Confined	7/19/2006	5180.17	38.64	5141.53	Downward
Map	Unconfined Flow System				5182	
26150	Denver Confined	4/19/2006	5220.96	50.12	5170.84	
26150	Denver Confined	7/19/2006	5220.96	50.14	5170.82	
26150	Denver Confined	11/7/2006	5220.96	50.02	5170.94	
26150	Denver Confined	1/17/2007	5220.96	50.05	5170.91	Downward
26154	Alluvium/Denver Unconfined	7/19/2006	5198.30	29.32	5168.98	
26152	Denver Confined	7/19/2006	5196.73	46.41	5150.32	Downward
Map	Unconfined Flow System				5143	
26153	Denver Confined	7/19/2006	5190.7	52.65	5138.05	Downward
35061	Alluvium/Denver Unconfined	7/18/2006	5248.93	30.72	5218.21	
35063	Denver Confined	7/18/2006	5249.99	56.62	5193.37	Downward
35065	Alluvium/Denver Unconfined	7/18/2006	5235.77	17.72	5218.05	
35067	Denver Confined	7/18/2006	5236.54	35.92	5200.62	Downward
35065	Alluvium/Denver Unconfined	7/18/2006	5235.77	17.72	5218.05	
35067	Denver Confined	7/18/2006	5236.54	35.92	5200.62	
35068	Denver Confined	7/18/2006	5236.88	44.41	5192.47	Downward

Notes:
[1] Top of Casing

Table 6.1-7. Water Level Data and Hydraulic Gradients for Confined Flow System (CFS) and Unconfined Flow System (UFS)

Well ID	Flow System	Sample Date	TOC[1] Elevation (ft)	Depth TOC (ft)	Water Elevation (ft)	Hydraulic Gradient
Map	Unconfined Flow System				5242	
35083	Denver Confined	7/18/2006	5265.26	68.35	5196.91	Downward
36112	Denver Unconfined	7/18/2006	5249.08	29.25	5219.83	
36113	Denver Confined	7/18/2006	5250.12	35.67	5214.45	Downward
36114	Denver Confined	7/18/2006	5249.94	57.8	5192.14	Downward
36159	Denver Confined	7/18/2006	5254.5	51.54	5202.96	Downward
36171	Denver Confined	7/18/2006	5244.39	47.95	5196.44	Downward
36183	Denver Confined	7/18/2006	5264.83	31.22	5233.61	Downward

Notes:
[1] Top of Casing

Table 6.1-8. Confined Flow System Well Network Evaluation

Area	Retain Wells	Rationale
South Plants	01067	Chloride concentration trend is slightly upward. No other indicator analytes were detected in past 10 years.
	01102	Chloride concentration trend is slightly upward. Benzene was detected near the detection limit in 2002.
	01109	Chloride concentrations show decreasing trend since 1999; however, concentrations are near historic levels. Also higher chloride concentrations than in other CFS South Plants wells. No other indicator analytes were detected in past 10 years.
	01300	Chloride concentrations lower in 2002 and 2004 than historic levels. No other indicator analytes were detected in past 10 years. Remove from CFS network if decreasing chloride trend continues.
	02057	Chloride concentration trend slightly upward since 1989, but below historic levels. Chlorobenzene and 1,1-dichloroethylene decreasing, but still present. Upward gradient between this well and unconfined well 02058. Consider removing from network if upward gradient persists.
	35083	Chloride concentrations show steady increasing trend. No other indicator analytes were detected in past 10 years. Higher chloride concentrations in 2002 and 2004 were anomalous and were much lower in 2007.
	36183	Although 36183 shows small decreasing chloride trend, adjacent twinned well 36182 was highly contaminated and was closed in 2000. No other indicator analytes were detected in past 10 years.
Basin F	23187	Chloride concentrations are stable or slightly increasing over past 20 years; high concentrations are present. No other indicator analytes were detected in past 10 years.
	23193	Chloride stable, but at very high concentrations. No other indicator analytes were detected in past 10 years.
	26147	Chloride stable, but high concentrations are present. No other indicator analytes were detected in past 10 years.
	26150	Chloride on short downward trend since 1998; high concentrations are still present. No other indicator analytes were detected in past 10 years.
	26152	Chloride on downward trend since 1998, but some historic levels were lower. No other indicator analytes were detected in past 10 years. Retain to confirm downward trend.
	26153	Chloride concentrations are highly variable and generally below 1980s levels. Dieldrin was detected below its CSRG once in 1997, but not confirmed by 4 more recent samples. Retain to establish chloride trend.
Basin A	35063	Chloride concentrations show a decreasing trend. No other indicator analytes were detected in past 10 years.
	35067	Chloride concentrations on upward trend since 1989. No other indicator analytes were detected in past 10 years. Aquitard is questionable and well may be semi-confined.
	35068	Chloride concentrations stable or decreasing, but levels in adjacent well 35067 are increasing. No other indicator analytes were detected in past 10 years. Retain to better evaluate potential migration in this area.
	36113	Chloride concentrations are stable or decreasing. No other indicator analytes were detected in past 10 years. Remove from network in 5 years if decreasing chloride trend continues. Increasing pH suggests decreasing well seal integrity.

Table 6.1-8. Confined Flow System Well Network Evaluation

Area	Retain Wells	Rationale
	36114	Chloride concentrations indicate a possible decreasing trend since 1999, but higher than some historic levels. No other indicator analytes were detected in past 10 years.
	36159	Chloride concentrations variable and generally stable, but high concentrations. No other indicator analytes were detected in past 10 years. Retain because chloride concentrations are very high.
	36171	Chloride concentrations show a very small increasing trend beginning in 1989. No other indicator analytes were detected in past 10 years. Remove from network in 5 years if decreasing chloride trend is observed. High pH suggests poor well construction or compromised well seal.
	Remove Well	
Basin F	23193	Chloride stable, but at very high concentrations. No other indicator analytes were detected in past 10 years. Well 23193 is damaged and cannot be sampled, but water level measurements are still possible. Retain for water levels.

Table 6.1-9. Confined Flow System Monitoring

Area	CFS Well	UFS Paired Well	Frequency	CFS Indicator Analytes
Basin A			Twice in 5 years	Chloride
	35063	35061		
	35067	35065[1]		
	35068	35065[1]		
	36113	36112		
	36114	36112		
	36159	36158		
	36171	36169		
Basin F			Twice in 5 years	Chloride, dieldrin
	23187	23185		
	23193[2]	23191, 23142[1,3]		
	26147	26146, 26017[1,3]		
	26150	26158		
	26152	26154		
	26153	26015[1]		
South Plants			Twice in 5 years	Chloride, benzene, chlorobenzene, 1,1-dichloroethane
	01067	01068		
	01072			
	01102	01534[1]		
	01109	01101[1]		
	01300[4]	01078[1]		
	02047			
	02048			
	02057	02058		
	35083[4]	35013		
	36183[4]	36181[1]		

Notes:
*Denotes alternate South Plants well to be monitored if primary well cannot be sampled.
[1]Only UFS paired wells in a current long-term water quality monitoring program are sampled. UFS paired wells for other CFS wells may be sampled if warranted.
[2]CFS well 23193 is damaged and cannot be sampled. Water levels will be measured, however.
[3]UFS wells 23142 and 26017 are alternate UFS wells for water quality comparisons. Additionally, UFS well 23142 is an alternate water level well because UFS well 23191 is dry periodically.
[4]Primary South Plants well. Well 01072 is the alternate for well 01300. Wells 02047 and 02048 are alternates for wells 35083 and 36183.

Table 6.2-1. Monitoring Wells in the CSRG Exceedance Network

Well ID	Location	Analytes
23198	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate
24162	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate
24166	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate
37008	Northern Pathway	OGITS CSRG analyte list
37009	Northern Pathway	OGITS CSRG analyte list
37010	Northern Pathway	OGITS CSRG analyte list
37011	Northern Pathway	OGITS CSRG analyte list
37012	Northern Pathway	OGITS CSRG analyte list
37013	Northern Pathway	OGITS CSRG analyte list
37027	Northern Pathway	Chloroform, tetrachloroethylene, DIMP, fluoride, chloride, sulfate
37039	Northern Pathway	Carbon tetrachloride, DIMP
37041	First Creek Pathway	DIMP, chloride
37065	First Creek Pathway	OGITS CSRG analyte list
37070	First Creek Pathway	DIMP, fluoride
37074	First Creek Pathway	DIMP, fluoride, chloride, sulfate

Notes:
DIMP – diisopropylmethyl phosphonate
DCPD – dicyclopentadiene

Table 6.2-1. Monitoring Wells in the CSRG Exceedance Network

Well ID	Location	Analytes
37076	First Creek Pathway	DIMP, 1,2-dichloroethane, fluoride, chloride, sulfate
37080	Northern Pathway	DIMP, chloride
37081	First Creek Pathway	Fluoride, chloride, sulfate, dieldrin, DIMP, VOCs
37083	First Creek Pathway	DCPD, DIMP, 1,2-dichloroethane, fluoride, chloride, sulfate
37084	First Creek Pathway	OGITS CSRG analyte list
37094	Northern Pathway	OGITS CSRG analyte list
37095	Northern Pathway	OGITS CSRG analyte list
37097	Off-Post Plume	DIMP
37108	Off-Post Plume	DIMP
37110	First Creek Pathway	OGITS CSRG analyte list
37126	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride
37150	Off-Post Plume	Carbon tetrachloride, DIMP, chloride
37151	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride
37320	Off-Post Plume	DIMP, dieldrin, chloride
37328	Off-Post Plume	DIMP, dieldrin, fluoride, chloride, sulfate , VOCs

Notes:
DIMP – diisopropylmethyl phosphonate
DCPD – dicyclopentadiene

Table 6.2-1. Monitoring Wells in the CSRG Exceedance Network

Well ID	Location	Analytes
37338	North Boundary	DIMP, dieldrin, fluoride, chloride
37339	North Boundary	DIMP, fluoride, chloride, sulfate
37342	First Creek Pathway	Chloride, sulfate, DIMP, VOCs
37343	First Creek Pathway	OGITS CSRG analyte list
37347	Off-Post Plume	DIMP
37349	Off-Post Plume	DIMP
37351	Off-Post Plume	DIMP
37353	Off-Post Plume	DIMP
37367	Off-Post Plume	DIMP, chloroform, tetrachloroethylene, fluoride, chloride
37368	Northern Pathway	DIMP, chloroform, tetrachloroethylene, chloride, sulfate
37369	First Creek Pathway	DIMP, dieldrin, fluoride, chloride, VOCs
37370	First Creek Pathway	OGITS CSRG analyte list
37374	Off-Post Plume	Fluoride, chloride, sulfate, DIMP, dieldrin
37377	Off-Post Plume	DIMP, fluoride, chloride, sulfate, VOCs
37378	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride

Notes:
DIMP – diisopropylmethyl phosphonate
DCPD – dicyclopentadiene

Table 6.2-1. Monitoring Wells in the CSRG Exceedance Network

Well ID	Location	Analytes
37379	Off-Post Plume	DIMP, chloride, sulfate
37389	Off-Post Plume	DIMP, dieldrin, tetrachloroethylene, chloride
37391	Off-Post Plume	DIMP, dieldrin, tetrachloroethylene, chloride, sulfate
37392	Off-Post Plume	DIMP, dieldrin, chloride
37395	First Creek Pathway	OGITS CSRG analyte list
37396	First Creek Pathway	DIMP, chloride, sulfate
37397	Off-Post Plume	DIMP, chloroform, fluoride, chloride, sulfate
37404	Northern Pathway	OGITS CSRG analyte list
37405	Off-Post Plume	VOCs
37407	First Creek Pathway	DIMP, fluoride, sulfate
37428	Off-Post Plume	DIMP
37429	Off-Post Plume	DIMP
37452	Northern Pathway	DIMP, carbon tetrachloride, chloride

Notes:
DIMP – diisopropylmethyl phosphonate
DCPD – dicyclopentadiene

Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
01001	South Lakes			X							
01021	South Lakes			X							
01024	South Lakes			X							
01033	South Plants			X							
01041	South Plants			X							
01044	South Plants SPSA-2 Ditch Source			X	X	Once in 5 yrs					
01047	South Plants SPSA-2 Ditch Source			X	X	Once in 5 yrs					
01049	South Lakes			X							
01063	South Plants			X							
01067	South Plants/CFS						X	X	Twice in 5 yrs		
01068	South Plants			X							
01069	South Lakes			X							
01072	South Plants/CFS[1]							Alternate well			
01078	South Plants Source			X	X	Once in 5 yrs					
01101	South Plants SPSA-2 Ditch Source			X	X	Once in 5 yrs					
01102	South Plants/CFS						X	X	Twice in 5 yrs		
01109	South Plants/CFS						X	X	Twice in 5 yrs		
01300	South Plants/CFS						X	X	Twice in 5 yrs		
01407	South Tank Farm (STF)			X							
01408	STF			X							
01517	South Plants			X							
01525	South Plants Source			X	X	Once in 5 yrs					
01534	STF			X	X	Twice in 5 yrs					

[1] Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
[2] Well 24126 replaced 24063.
[3] Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
[4] Well 37150 replaced 37403.
[5] Well 37151 replaced 37040.
[6] Sampling frequency is biannual, during even years.
[7] Sampling frequency is biannual, during odd years.
[8] NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
* BANS and OGITS Performance Water Level Monitoring frequency is annual.

Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance: Water Level (Quarterly)	Performance: Water Quality (Annual)	Water Level Tracking (Annual)	Water Quality Tracking: Monitored	Water Quality Tracking: Frequency	Denver UFS/CFS: Water Level (Annual)	Confined Flow System (CFS): Water Quality Monitored	Confined Flow System (CFS): Water Quality Frequency	Off-Post CSRG Exceedance: Monitored	Off-Post CSRG Exceedance: Frequency
01582	South Plants SPSA-2 Ditch Source			X	X	Once in 5 yrs					
01583	South Lakes			X							
01600	South Lakes/STF			X							
01605	South Lakes/STF			X							
01656	South Plants			X							
01669	South Plants SPSA-2 Ditch Source			X	X	Once in 5 yrs					
01670	South Plants SPSA-2 Ditch Source			X	X	Once in 5 yrs					
01681	STF			X							
01685	STF			X							
01686	STF			X							
01687	STF			X							
01702	South Plants			X							
02011	Southern Tier			X							
02014	South Plants			X							
02023	South Lakes			X							
02026	South Lakes			X							
02034	South Lakes			X	X	Twice in 5 yrs					
02041	South Plants			X							
02043	South Plants			X							
02047	South Plants/CFS[1]							Alternate well			
02048	South Plants/CFS[1]							Alternate well			
02052	South Lakes			X							
02056	South Lakes/Lake Mary			X							

[1] Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
[2] Well 24126 replaced 24063.
[3] Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
[4] Well 37150 replaced 37403.
[5] Well 37151 replaced 37040.
[6] Sampling frequency is biannual, during even years.
[7] Sampling frequency is biannual, during odd years.
[8] NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
* BANS and OGITS Performance Water Level Monitoring frequency is annual.

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
02057	South Plants/CFS						X	X	Twice in 5 yrs		
02058	South Plants/STF			X							
02065	South Plants			X	X	Once in 5 yrs					
02505	South Lakes/STF			X	X	Twice in 5 yrs					
02512	South Lakes/STF			X	X	Twice in 5 yrs					
02515	South Lakes			X							
02520	South Plants			X							
02522	South Plants			X							
02523	South Lakes			X	X	Twice in 5 yrs					
02524	South Lakes			X	X	Twice in 5 yrs					
02525	South Lakes/STF			X	X	Twice in 5 yrs					
02576	South Lakes/STF			X							
02580	South Plants			X							
02683	STF			X							
02597	South Lakes			X	X	Twice in 5 yrs					
03001	RYCS	X	X[6]								
03002	Western Tier			X							
03005	Western Tier/NWBCS Original System (OS)			X	X	Twice in 5 yrs					
03008	Western Tier			X							
03010	RYCS	X									
03012	Western Tier			X							
03013	Western Tier			X							
03014	Western Tier			X							
03015	Western Tier/NWBCS Southwest Extension			X	X	Twice in 5 yrs					

[1] Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
[2] Well 24126 replaced 24063.
[3] Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
[4] Well 37150 replaced 37403.
[5] Well 37151 replaced 37040.
[6] Sampling frequency is biannual, during even years.
[7] Sampling frequency is biannual, during odd years.
[8] NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
* BANS and OGITS Performance Water Level Monitoring frequency is annual.

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
	(SWE)										
03016	Western Tier/NWBCS SWE			X	X	Twice in 5 yrs					
03017	RYCS	X									
03301	RYCS	X									
03302	RYCS	X									
03303	RYCS	X									
03304	RYCS	X									
03305	RYCS	X									
03501	RYCS	X	X								
03502	RYCS	X									
03503	RYCS	X	X	X							
03505	RYCS	X									
03506	RYCS	X									
03507	RYCS	X	X[6]								
03508	RYCS	X	X[7]								
03509	RYCS	X	X[6]								
03510	RYCS	X									
03511	RYCS	X									
03512	RYCS	X									
03513	RYCS	X									
03522	RYCS	X									
03523	RYCS			X	X	Twice in 5 yrs					
03527	RYCS	X	X[6]								
03528	RYCS	X									

[1] Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
[2] Well 24126 replaced 24063.
[3] Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
[4] Well 37150 replaced 37403.
[5] Well 37151 replaced 37040.
[6] Sampling frequency is biannual, during even years.
[7] Sampling frequency is biannual, during odd years.
[8] NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
* BANS and OGITS Performance Water Level Monitoring frequency is annual.

Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
03529	RYCS	X	X								
03530	RYCS	X	X								
03531	RYCS	X									
03532	RYCS	X									
03533	RYCS	X									
03534	RYCS	X									
03535	RYCS	X									
03536	RYCS	X									
03537	RYCS	X									
03538	RYCS	X	X								
04014	Western Tier			X							
04020	Western Tier			X							
04021	Western Tier			X							
04024	Western Tier			X							
04029	Western Tier			X							
04038	Western Tier			X							
04040	Western Tier			X							
04076	Western Tier			X							
04080	Western Tier			X							
04082	Western Tier			X							
04506	RYCS	X	X[7]								
04525	Western Tier			X							
04528	Western Tier			X							
04535	Motor Pool			X	X	Twice in 5 yrs (until Motor Pool MCR					

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Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
						completed)					
05001	Eastern Tier			X							
05005	Eastern Tier			X							
06002	Eastern Tier			X							
06003	Eastern Tier			X							
07001	Southern Tier			X							
07032	Southern Tier			X							
07033	Southern Tier			X							
07139	Southern Tier			X							
08003	Southern Tier			X							
08026	Southern Tier			X							
08027	Southern Tier			X							
11002	Southern Tier			X							
11023	Southern Tier			X							
12001	Southern Tier			X							
12002	Southern Tier			X							
12005	Southern Tier			X							
19001	Eastern Tier			X							
19004	Eastern Tier			X							
19007	Eastern Tier			X							
19015	Eastern Tier			X							
19017	Eastern Tier			X							
20002	Eastern Tier			X							
22001	NWBCS Northeast Extension (NEE)	X		X	X	Twice in 5 yrs					

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
22003	NWBCS OS	X									
22005	NWBCS OS	X									
22006	Northern Tier			X							
22007	NWBCS NEE	X		X							
22008	NWBCS OS	X	X								
22009	NWBCS OS	X									
22010	NWBCS OS	X									
22015	NWBCS NEE	X	X								
22016	NWBCS OS	X									
22017	NWBCS OS	X									
22018	NWBCS OS	X									
22019	NWBCS OS	X									
22021	NWBCS OS	X									
22035	NWBCS OS	X									
22042	NWBCS OS	X									
22043	NWBCS OS	X	X								
22044	NWBCS NEE	X									
22045	NWBCS OS	X									
22049	NWBCS NEE	X									
22052	NWBCS			X							
22053	NWBCS		X	X							
22054	NWBCS			X							
22056	NWBCS OS	X									
22057	NWBCS OS	X									
22059	NWBCS OS	X									

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
22060	NWBCS NEE	X									
22061	NWBCS OS	X									
22062	NWBCS OS	X									
22063	NWBCS OS	X									
22064	NWBCS OS	X									
22065	NWBCS OS	X									
22066	NWBCS OS	X									
22067	NWBCS OS	X									
22069	NWBCS OS	X									
22070	NWBCS OS	X									
22071	NWBCS NEE	X									
22072	NWBCS NEE	X									
22073	NWBCS OS	X									
22075	NWBCS OS	X									
22076	NWBCS OS	X									
22077	NWBCS OS	X									
22078	NWBCS OS	X									
22081	NWBCS OS		X	X							
22500	NWBCS OS	X									
22501	NWBCS OS	X									
22504	NWBCS NEE	X									
22505	NWBCS NEE	X	X	X							
22506	NWBCS NEE	X									
22508	NWBCS NEE	X									
22511	NWBCS OS	X									

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
22512	NWBCS NEE	X	X								
23002	Basin F/NBCS			X							
23004	Basin F/NBCS			X							
23008	Basin F/NBCS			X							
23029	NBCS			X							
23040	NBCS			X							
23053	Basin F/NBCS			X							
23095	Basin F/NBCS			X	X	Twice in 5 yrs					
23096	Basin F/NBCS			X	X	Twice in 5 yrs					
23119	NBCS		X								
23135	Basin F/NBCS			X							
23140	Basin F/NBCS			X							
23142	Basin F/NBCS			X	X	Twice in 5 yrs					
23160	NBCS		X	X							
23161	NBCS/Denver CFS		X[8]				X				
23182	Northern Tier			X							
23185	Northern Tier			X							
23187	Basin F/CFS						X	X	Twice in 5 yrs		
23193	Basin F/CFS						X	Damaged			
23194	NBCS/Denver UFS		X[8]				X				
23195	NBCS/Denver UFS		X[8]				X				
23196	NBCS			X							
23198	NBCS			X						X	Twice in 5 yrs
23199	NBCS			X							
23200	NBCS/Denver CFS		X[8]				X				

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Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
23207	NBCS	X									
23208	NBCS	X									
23211	NBCS		X	X							
23212	NBCS	X									
23214	NBCS	X									
23217	NBCS	X									
23227	NBCS			X							
23235	NBCS/Denver UFS		X[8]				X				
23253	NBCS			X							
23405	NBCS		X								
23434	NBCS		X								
23436	NBCS		X								
23438	NBCS		X								
23510	NBCS	X									
23513	NBCS	X									
23516	NBCS	X									
23519	NBCS	X									
23522	NBCS	X									
23528	NBCS	X									
23529	NBCS	X									
23533	NBCS	X									
23534	NBCS	X									
23535	NBCS	X									
23540	NBCS/Denver UFS		X[8]				X				
23541	NBCS/Denver UFS		X[8]				X				

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		Performance			Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
Well	Location/Network	Water Level (Quarterly)	Water Quality (Annual)	Water Level Tracking (Annual)	Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
23542	NBCS/Denver UFS		X[8]				X				
23543	NBCS/Denver UFS		X[8]				X				
23544	NBCS	X									
23548	NBCS/NBE			X	X	Once in 5 yrs					
24003	NBCS			X							
24004	NBCS		X								
24006	NBCS		X	X							
24080	North Plants Plume			X							
24081	North Plants Plume/NBCS			X	X	Twice in 5 yrs					
24092	North Plants Plume/NBCS			X	X	Twice in 5 yrs					
24094	NBCS			X	X	Twice in 5 yrs					
24096	NBCS			X							
24098	NBCS			X							
24101	NBCS		X								
24105	NBCS		X								
24106	NBCS			X							
24107	NBCS			X							
24108	NBCS			X							
24109	NBCS			X							
24112	North Plants/NBCS			X							
24114	NBCS		X								
24117	NBCS		X								
24124	North Plants/NBCS			X							
24126[2]	North Plants/NBCS			X							
24135	NBCS			X							

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Well	Location/Network	Performance: Water Level (Quarterly)	Performance: Water Quality (Annual)	Water Level Tracking (Annual)	Water Quality Tracking: Monitored	Water Quality Tracking: Frequency	Denver UFS/CFS: Water Level (Annual)	Confined Flow System (CFS): Water Quality Monitored	Confined Flow System (CFS): Water Quality Frequency	Off-Post CSRG Exceedance: Monitored	Off-Post CSRG Exceedance: Frequency
24158	NBCS			X							
24162	NBCS			X						X	Twice in 5 yrs
24163	NBCS			X							
24164	NBCS			X							
24166	NBCS			X						X	Twice in 5 yrs
24171	NBCS/Denver CFS		X[8]				X				
24179	NBCS	X									
24180	NBCS	X									
24185	NBCS		X								
24187	NBCS			X							
24191	NBCS/Denver UFS		X[8]				X				
24199	NBCS		X								
24201	NBCS		X	X							
24415	NBCS		X								
24418	NBCS		X								
24421	NBCS		X								
24424	NBCS		X								
24503	NBCS	X									
24506	NBCS	X									
24509	NBCS	X									
24512	NBCS	X									
24515	NBCS	X									
24518	NBCS	X									
24521	NBCS	X									
24522	NBCS	X									

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
24523	NBCS	X									
24526	NBCS	X									
24527	NBCS	X									
24528	NBCS	X									
24529	NBCS	X									
24530	NBCS	X									
25001	Eastern Tier			X							
25011	Eastern Tier			X							
25015	HWL			X							
25022	HWL			X							
25041	North Plants			X							
25048	North Plants			X							
25054	North Plants			X							
25059	North Plants			X	X	Twice in 5 yrs					
25091	Corrective Action Management Unit (CAMU)/HWL			X							
25126	North Plants LNAPL			X							
25129	North Plants LNAPL			X							
25133	North Plants LNAPL			X							
25500	Basin A			X							
25502	BRES/North Plants			X	X	Twice in 5 yrs					
25503	BRES	X									
25504	BRES	X									
25505	BRES	X									
25506	BRES	X									

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
26006	Basin A Neck/BANS			X	X	Twice in 5 yrs					
26015	Basin F			X							
26016	Basin F			X							
26017	Basin F			X							
26020	Basin F			X							
26040	Basin F			X							
26049	Basin F			X							
26061	Basins D/E			X							
26071	Basin F			X							
26083	Basin F			X							
26094	Section 26			X							
26096	BANS	X*									
26097	CAMU			X							
26147	Basin F/CFS						X	X	Twice in 5 yrs		
26150	Basin F/CFS						X	X	Twice in 5 yrs		
26152	Basin F/CFS						X	X	Twice in 5 yrs		
26153	Basin F/CFS						X	X	Twice in 5 yrs		
26154	Basin A Neck			X							
26157	Basin F			X							
26158	Basin C			X							
26160	Basin F			X							
26163	Basin F			X							
26170	Basin F			X							
26500	Basin A			X							
26501	BANS	X*	X								

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
26502	BANS	X*									
26503	BANS	X*									
26504	BANS	X*									
26505	BANS	X*	X								
26506	BANS	X*									
26507	BANS	X*	X								
26509	BANS	X*									
26510	BANS	X*									
26511	BANS	X*									
26512	BANS	X*									
27002	NWBCS OS			X	X	Twice in 5 yrs					
27003	NWBCS SWE	X		X							
27010	NWBCS OS	X	X								
27018	NWBCS			X							
27025	Basin A Neck/NWBCS			X	X	Twice in 5 yrs					
27035	NWBCS			X							
27037	NWBCS OS			X	X	Twice in 5 yrs					
27043	NWBCS SWE			X	X	Twice in 5 yrs					
27049	NWBCS			X							
27051	NWBCS			X							
27053	NWBCS			X							
27060	NWBCS			X							
27063	NWBCS OS			X							
27066	NWBCS OS			X							
27072	NWBCS OS			X							

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Well	Location/Network	Water Level (Quarterly)	Water Quality (Annual)	Water Level Tracking (Annual)	Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
27077	NWBCS OS			X							
27078	NWBCS OS			X							
27079	NWBCS OS			X	X	Twice in 5 yrs					
27082	Basin A Neck/NWBCS			X	X	Twice in 5 yrs					
27083	NWBCS OS			X	X	Twice in 5 yrs					
27084	NWBCS			X							
27086	NWBCS OS	X									
27090	NWBCS OS	X									
27091	NWBCS OS			X	X	Twice in 5 yrs					
27092	NWBCS SWE	X									
27093	NWBCS SWE	X									
27500	NWBCS OS	X	X	X							
27501	NWBCS SWE	X									
27503	NWBCS OS	X									
27504	NWBCS OS	X									
27505	NWBCS SWE	X									
27506	NWBCS SWE	X									
27508	NWBCS SWE	X									
27509	NWBCS SWE	X									
27510	NWBCS SWE	X									
27511	NWBCS SWE	X									
27516	NWBCS SWE	X	X								
27517	NWBCS SWE	X	X								
27522	NWBCS SWE	X	X	X							
27524	NWBCS SWE	X									

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Well	Location/Network	Water Level (Quarterly)	Water Quality (Annual)	Water Level Tracking (Annual)	Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
27525	NWBCS SWE	X									
27528	NWBCS SWE	X									
27529	NWBCS SWE	X									
27530	NWBCS SWE	X									
27531	NWBCS SWE	X									
27532	NWBCS SWE	X									
27533	NWBCS SWE	X									
28002	NWBCS SWE	X									
28003	NWBCS SWE	X									
28004	NWBCS SWE	X		X							
28005	NWBCS SWE	X									
28012	Western Tier			X							
28022	Western Tier			X							
28024	Western Tier			X							
28027	Western Tier			X							
28031	NWBCS SWE	X									
28519	NWBCS SWE	X									
28520	NWBCS SWE			X							
28521	NWBCS SWE	X	X								
28522	NWBCS SWE	X		X							
29002	Eastern Tier			X							
30004	Eastern Tier			X							
30006	Eastern Tier			X							
30009	Eastern Tier			X							
30020	Eastern Tier			X							

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
31005	Eastern Tier			X							
31012	Eastern Tier			X							
31014	Eastern Tier			X							
31016	Eastern Tier			X							
31537	Eastern Tier			X							
32001	Eastern Tier			X							
32004	Eastern Tier			X							
32005	Eastern Tier			X							
33001	Western Tier			X							
33025	Western Tier			X							
33043	Western Tier			X							
33061	Western Tier			X							
33081	Western Tier			X							
33341	Western Tier			X							
33510	Western Tier			X							
33514	Western Tier			X							
33533	Western Tier			X							
34005	Western Tier/NWBCS OS			X	X	Twice in 5 yrs					
34008	Western Tier/NWBCS SWE			X	X	Twice in 5 yrs					
34014	Western Tier			X							
34015	Western Tier/NWBCS SWE			X	X	Twice in 5 yrs					
34017	Wester Tier/NWBCS OS			X	X	Twice in 5 yrs					
34018	Western Tier			X							
34019	Western Tier			X							

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Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
34020	Western Tier/NWBCS OS			X	X	Twice in 5 yrs					
34503	NWBCS			X							
34508	Sand Creek Lateral (SCL)/NWBCS OS			X	X	Twice in 5 yrs					
35012	BANS	X*									
35013	South Plants			X							
35018	BANS	X*									
35023	Basin A			X							
35037	Section 35			X							
35058	SCL/NWBCS OS			X	X	Twice in 5 yrs					
35061	Section 35			X							
35063	Basin A/CFS						X	X	Twice in 5 yrs		
35065	Basin A/BANS			X	X	Twice in 5 yrs					
35067	Basin A/CFS						X	X	Twice in 5 yrs		
35068	Basin A/CFS						X	X	Twice in 5 yrs		
35069	Basin A			X							
35079	BANS	X*									
35083	South Plants/CFS						X	X	Twice in 5 yrs		
35087	SCL			X							
35093	Section 35			X							
35304	BANS	X*									
35305	BANS	X*									
35306	BANS	X*									
35504	Section 35			X							
35505	BANS	X*	X								

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		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
35509	BANS	X*									
35510	BANS	X*									
35511	BANS	X*									
35512	BANS			X							
35513	BANS	X*									
35514	BANS	X*									
35515	BANS	X*									
35516	BANS	X*									
35518	BANS	X*									
35519	BANS	X*									
35520	BANS	X*									
35521	BANS	X*									
35522	BANS	X*									
35523	BANS	X*									
35525	BANS	X*	X								
35526	BANS	X*									
35544	BANS	X*									
35549	BANS	X*									
36052	Lime Basins			X							
36054	Lime Basins Dewatering[3]	X[3]		X							
36069	Complex Trenches			X							
36077	Basin A			X							
36080	Complex Trenches Dewatering	X									
36087	South Plants			X							

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		Performance			Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
Well	Location/Network	Water Level (Quarterly)	Water Quality (Annual)	Water Level Tracking (Annual)	Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
36089	Basin A			X							
36092	Basin A			X							
36094	Basin A			X							
36112	Basin A			X							
36113	Basin A/CFS						X	X	Twice in 5 yrs		
36114	Basin A/CFS						X	X	Twice in 5 yrs		
36120	Bedrock Ridge			X							
36123	Basin A			X							
36142	Basin A			X							
36157	Complex Trenches			X							
36158	Complex Trenches			X							
36159	Basin A/CFS						X	X	Twice in 5 yrs		
36168	Lime Basins/Basin A			X							
36169	Basin A			X							
36171	Basin A/CFS						X	X	Twice in 5 yrs		
36181	South Plants			X	X	Once in 5 yrs					
36183	South Plants/CFS						X	X	Twice in 5 yrs		
36186	Basin A			X							
36189	Complex Trenches Dewatering	X									
36200	Complex Trenches			X							
36201	Complex Trenches			X							
36210	Lime Basins			X	X	Twice in 5 yrs					
36212	Lime Basins Dewatering[3]	X[3]		X							
36215	Complex Trenches Dewatering	X									

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Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
36216	Complex Trenches Dewatering (compliance)	X		X							
36217	Complex Trenches Dewatering (compliance)	X		X							
36218	Complex Trenches Dewatering	X									
36219	Complex Trenches Dewatering	X									
36220	Complex Trenches Dewatering	X									
36221	Complex Trenches Dewatering	X									
36222	Shell Trenches	X									
36223	Shell Trenches	X									
36224	Shell Trenches	X									
36525	Shell Trenches	X									
36226	Shell Trenches	X									
36231	Lime Basins Dewatering[3]	X[2]									
36232	Lime Basins Dewatering[3]	X[3]									
36233	Lime Basins Dewatering[3]	X[3]									
36234	Lime Basins Dewatering[3]	X[3]									
36235	Lime Basins Dewatering[3]	X[3]									
36236	Lime Basins Dewatering[3]	X[3]									
36237	Lime Basins Dewatering[3]	X[3]									
36238	Lime Basins Dewatering[3]	X[3]									
36239	Lime Basins Dewatering[3]	X[3]									
36240	Lime Basins Dewatering[3]	X[3]									
36241	Lime Basins Dewatering[3]	X[3]									

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Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance: Water Level (Quarterly)	Performance: Water Quality (Annual)	Water Level Tracking (Annual)	Water Quality Tracking: Monitored	Water Quality Tracking: Frequency	Denver UFS/CFS: Water Level (Annual)	Confined Flow System (CFS): Water Quality Monitored	Confined Flow System (CFS): Water Quality Frequency	Off-Post CSRG Exceedance: Monitored	Off-Post CSRG Exceedance: Frequency
36301	Complex Trenches Dewatering	X									
36302	BRES	X									
36303	BRES	X									
36304	BRES	X									
36305	Complex Trenches Dewatering	X									
36306	BRES	X									
36315	Lime Basins Dewatering[3]	X[3]									
36316	Lime Basins Dewatering[3]	X[3]									
36317	Lime Basins Dewatering[3]	X[3]									
36318	Lime Basins Dewatering[3]	X[3]									
36319	Lime Basins Dewatering[3]	X[3]									
36320	Lime Basins Dewatering[3]	X[3]									
36502	BRES	X		X							
36521	Shell Trenches			X							
36528	Shell Trenches	X									
36529	Shell Trenches	X									
36530	Shell Trenches	X									
36531	Shell Trenches	X									
36532	Shell Trenches	X									
36533	Shell Trenches	X									
36535	Shell Trenches	X									
36536	Shell Trenches	X									
36537	Shell Trenches	X									
36538	Basin A			X							

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36541	Basin A			X							
36552	Bedrock Ridge/BRES			X	X	Twice in 5 yrs					
36555	BRES	X	X								
36556	BRES	X									
36557	BRES	X									
36558	BRES	X									
36559	BRES	X									
36560	BRES	X									
36561	BRES	X									
36562	BRES	X									
36563	BRES	X									
36564	BRES	X									
36565	BRES	X	X								
36566	BRES	X	X								
36567	BRES	X	X								
36568	BRES	X									
36569	BRES	X									
36570	BRES	X									
36571	BRES	X	X								
36572	BRES	X	X								
36573	BRES	X									
36574	BRES	X									
36575	BRES	X	X	X							
36576	BRES	X									
36577	BRES	X									

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Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
36578	BRES	X	X								
36579	BRES	X									
36580	BRES	X									
36594	Bedrock Ridge/BRES			X	X	Twice in 5 yrs					
36595	Bedrock Ridge			X							
36627	Basin A Source			X	X	Once in 5 yrs					
36628	Basin A Source			X							
36629	Basin A Source			X	X	Once in 5 yrs					
36630	Basin A Source			X	X	Once in 5 yrs					
36631	Basin A Source			X	X	Once in 5 yrs					
36632	Basin A Source			X	X	Once in 5 yrs					
36633	Basin A Source			X	X	Once in 5 yrs					
37008	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37009	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37010	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37011	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37012	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37013	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37014	Northern Pathway	X*									
37015	Northern Pathway	X*									
37016	Northern Pathway	X*									
37017	Northern Pathway	X*									
37018	Northern Pathway	X*									
37019	Northern Pathway	X*									
37020	Northern Pathway	X*									

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		Performance			Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
Well	Location/Network	Water Level (Quarterly)	Water Quality (Annual)	Water Level Tracking (Annual)	Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
37021	Northern Pathway	X*									
37022	Northern Pathway	X*									
37023	Northern Pathway	X*									
37024	Northern Pathway	X*									
37025	Northern Pathway	X*									
37026	Northern Pathway	X*									
37027	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37028	Northern Pathway	X*									
37029	Northern Pathway	X*									
37030	Northern Pathway	X*									
37031	Northern Pathway	X*									
37032	Northern Pathway	X*									
37033	Northern Pathway	X*									
37034	Northern Pathway	X*									
37035	Northern Pathway	X*									
37037	Northern Pathway	X*									
37038	Northern Pathway	X*									
37039	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37041	First Creek Pathway			X						X	Twice in 5 yrs
37045	First Creek Pathway	X*									
37048	First Creek Pathway	X*									
37050	First Creek Pathway	X*									
37054	First Creek Pathway	X*									
37058	First Creek Pathway	X*									
37059	First Creek Pathway	X*									

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Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
37060	First Creek Pathway	X*									
37061	First Creek Pathway	X*									
37062	First Creek Pathway	X*		X							
37063	First Creek Pathway	X*		X							
37064	First Creek Pathway	X*									
37065	First Creek Pathway	X*		X						X	Twice in 5 yrs
37066	First Creek Pathway	X*									
37067	First Creek Pathway	X*									
37068	First Creek Pathway	X*									
37069	First Creek Pathway	X*									
37070	First Creek Pathway			X						X	Twice in 5 yrs
37071	First Creek Pathway	X*		X							
37072	First Creek Pathway	X*									
37073	First Creek Pathway	X*		X							
37074	First Creek Pathway	X*	X	X						X	Twice in 5 yrs
37075	First Creek Pathway	X*	X	X							
37076	First Creek Pathway	X*	X	X						X	Twice in 5 yrs
37080	Northern Pathway	X*		X						X	Twice in 5 yrs
37081	NBCS/ First Creek Pathway			X						X	Twice in 5 yrs
37083	First Creek Pathway	X*	X	X						X	Twice in 5 yrs
37084	First Creek Pathway	X*	X	X						X	Twice in 5 yrs
37090	First Creek Pathway	X*									
37094	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37095	Northern Pathway	X*	X	X						X	Twice in 5 yrs

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Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
37097	Off-Post			X						X	Twice in 5 yrs
37098	Northern Pathway	X*									
37099	Northern Pathway	X*									
37100	Northern Pathway	X*									
37101	Northern Pathway	X*									
37102	Northern Pathway	X*									
37103	Northern Pathway	X*		X							
37105	First Creek Pathway	X*									
37106	First Creek Pathway	X*									
37107	First Creek Pathway	X*		X							
37108	Off-Post			X						X	Twice in 5 yrs
37110	First Creek Pathway	X*	X	X						X	Twice in 5 yrs
37111	Northern Pathway	X*									
37112	Northern Pathway	X*									
37113	Northern Pathway	X*									
37114	Northern Pathway	X*									
37115	Northern Pathway	X*									
37116	First Creek Pathway	X*									
37117	First Creek Pathway	X*									
37118	First Creek Pathway	X*									
37125	Off-Post/NWBCS			X							
37126	NBCS/ Northern Pathway			X						X	Twice in 5 yrs
37127	First Creek Pathway	X*									
37128	First Creek Pathway	X*									
37130	First Creek Pathway	X*									

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Well	Location/Network	Performance Water Level (Quarterly)	Performance Water Quality (Annual)	Water Level Tracking (Annual)	Water Quality Tracking Monitored	Water Quality Tracking Frequency	Denver UFS/CFS Water Level (Annual)	Confined Flow System (CFS) Water Quality Monitored	Confined Flow System (CFS) Water Quality Frequency	Off-Post CSRG Exceedance Monitored	Off-Post CSRG Exceedance Frequency
37131	First Creek Pathway	X*									
37132	First Creek Pathway	X*									
37133	First Creek Pathway	X*									
37135	First Creek Pathway	X*									
37136	First Creek Pathway	X*									
37137	First Creek Pathway	X*									
37138	First Creek Pathway	X*									
37139	First Creek Pathway	X*									
37140	First Creek Pathway	X*									
37141	First Creek Pathway	X*									
37142	First Creek Pathway	X*									
37150[4]	Northern Pathway			X						X	Twice in 5 yrs
37151[5]	Northern Pathway			X						X	Twice in 5 yrs
37313	First Creek Pathway	X*									
37320	Northern Pathway			X						X	Twice in 5 yrs
37323	NBCS/First Creek Pathway			X							
37327	Off-Post			X							
37328	NBCS/First Creek Pathway			X						X	Twice in 5 yrs
37330	NWBCS OS	X	X								
37331	NWBCS OS	X	X								
37332	NWBCS OS	X	X								
37333	NWBCS OS	X	X								
37334	Off-Post/NWBCS			X							
37335	Off-Post/NWBCS			X							

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Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
37336	Off-Post/NWBCS			X							
37337	Off-Post/NWBCS			X							
37338	NBCS			X						X	Twice in 5 yrs
37339	NBCS			X						X	Twice in 5 yrs
37341	Off-Post			X							
37342	Off-Post			X						X	Twice in 5 yrs
37343	First Creek Pathway	X*	X	X						X	Twice in 5 yrs
37346	Off-Post			X							
37347	Off-Post			X						X	Twice in 5 yrs
37348	Off-Post			X							
37349	Off-Post			X						X	Twice in 5 yrs
37350	Off-Post			X							
37351	Off-Post			X						X	Twice in 5 yrs
37353	Off-Post			X						X	Twice in 5 yrs
37361	Off-Post			X							
37362	NBCS		X	X							
37363	Off-Post			X							
37367	Northern Pathway			X						X	Twice in 5 yrs
37368	Northern Pathway	X*		X						X	Twice in 5 yrs
37369	NBCS/ First Creek Pathway			X						X	Twice in 5 yrs
37370	First Creek Pathway	X*	X	X						X	Twice in 5 yrs
37373	First Creek Pathway	X*	X	X							
37374	Off-Post			X						X	Twice in 5 yrs
37377	Northern Pathway			X						X	Twice in 5 yrs

[1] Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
[2] Well 24126 replaced 24063.
[3] Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
[4] Well 37150 replaced 37403.
[5] Well 37151 replaced 37040.
[6] Sampling frequency is biannual, during even years.
[7] Sampling frequency is biannual, during odd years.
[8] NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
* BANS and OGITS Performance Water Level Monitoring frequency is annual.

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
37378	Northern Pathway			X						X	Twice in 5 yrs
37379	Off-Post			X						X	Twice in 5 yrs
37385	Off-Post/NWBCS			X							
37387	Off-Post			X							
37389	NBCS/N. Pathway			X						X	Twice in 5 yrs
37391	Northern Pathway			X						X	Twice in 5 yrs
37392	Northern Pathway			X						X	Twice in 5 yrs
37395	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37396	First Creek Pathway	X*		X						X	Twice in 5 yrs
37397	Northern Pathway	X*		X						X	Twice in 5 yrs
37404	Northern Pathway	X*	X	X						X	Twice in 5 yrs
37405	Northern Pathway	X*		X						X	Twice in 5 yrs
37407	First Creek Pathway	X*		X						X	Twice in 5 yrs
37419	First Creek Pathway	X*									
37422	First Creek Pathway	X*									
37426	First Creek Pathway	X*									
37427	First Creek Pathway	X*									
37428	First Creek Pathway			X						X	Twice in 5 yrs
37429	First Creek Pathway			X						X	Twice in 5 yrs
37430	Off-Post			X							
37440	Off-Post			X							
37441	Off-Post/NWBCS			X							
37442	Off-Post			X							
37451	Northern Pathway	X*		X							
37452	Northern Pathway	X*	X	X						X	Twice in 5 yrs

1 Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
2 Well 24126 replaced 24063.
3 Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
4 Well 37150 replaced 37403.
5 Well 37151 replaced 37040.
6 Sampling frequency is biannual, during even years.
7 Sampling frequency is biannual, during odd years.
8 NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
* BANS and OGITS Performance Water Level Monitoring frequency is annual.

Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
37453	Northern Pathway	X*									
37454	Northern Pathway	X*									
37455	Northern Pathway	X*									
37456	Northern Pathway	X*									
37457	Northern Pathway	X*	X	X							
37458	Northern Pathway	X*	X								
37459	Northern Pathway	X*									
37460	Northern Pathway	X*									
37461	Northern Pathway	X*									
37462	Northern Pathway	X*		X							
37463[3]	Northern Pathway	X*		X							
37464[3]	Northern Pathway	X*									
37465[3]	Northern Pathway	X*									
37469	Northern Pathway	X*	X								
37470	Northern Pathway	X*									
37471	Northern Pathway	X*	X								
37472	Northern Pathway	X*		X							
37473	Northern Pathway	X*	X								
37474	Northern Pathway	X*	X								
37475	Northern Pathway	X*									
37476	Northern Pathway	X*									
37477	Northern Pathway	X*									
37478	Northern Pathway	X*									
37479	Northern Pathway	X*									
37480	Northern Pathway	X*									

[1] Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
[2] Well 24126 replaced 24063.
[3] Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
[4] Well 37150 replaced 37403.
[5] Well 37151 replaced 37040.
[6] Sampling frequency is biannual, during even years.
[7] Sampling frequency is biannual, during odd years.
[8] NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
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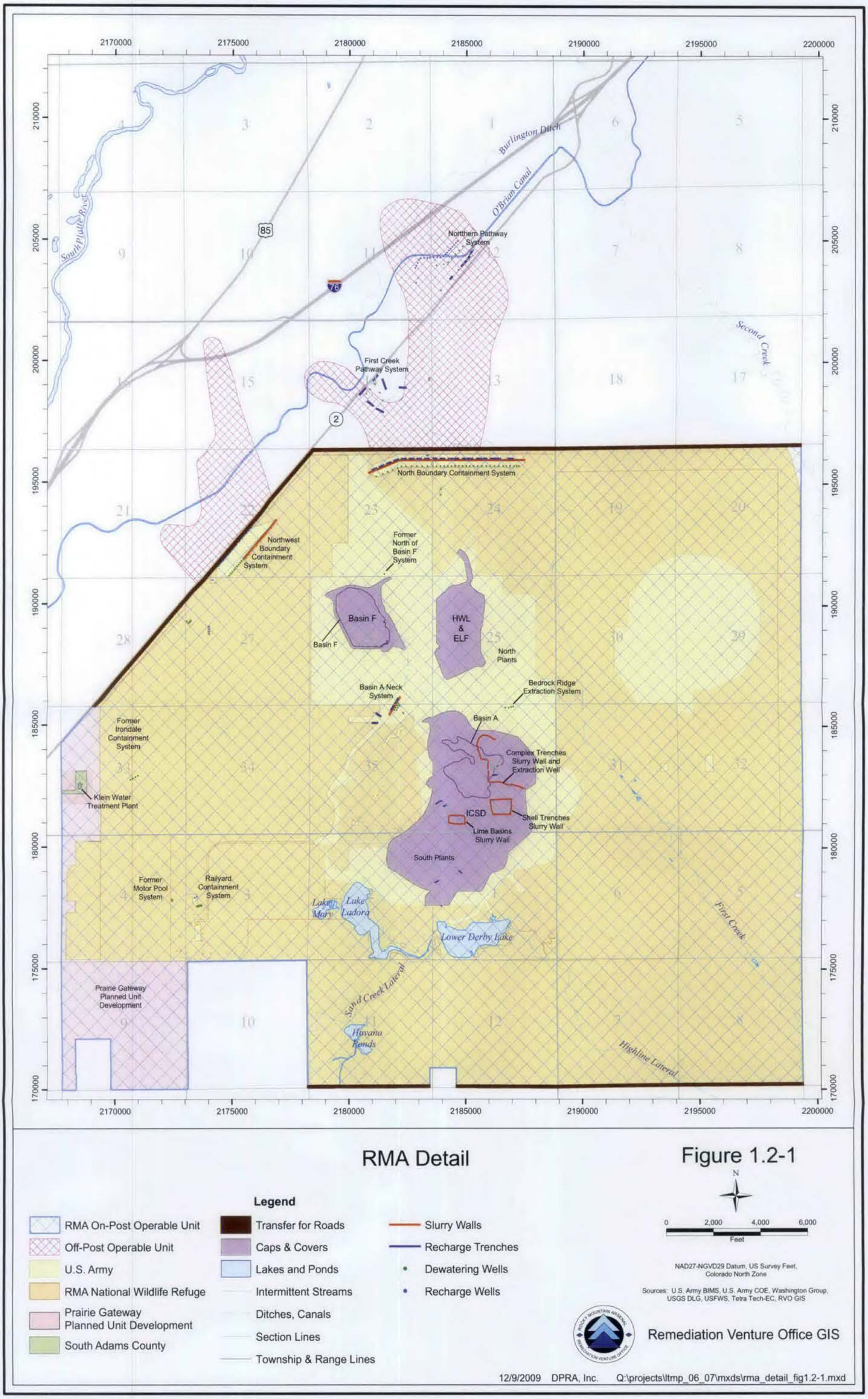
Table 6.3-1. LTMP Well Networks

Well	Location/Network	Performance		Water Level Tracking (Annual)	Water Quality Tracking		Denver UFS/CFS	Confined Flow System (CFS)		Off-Post CSRG Exceedance	
		Water Level (Quarterly)	Water Quality (Annual)		Monitored	Frequency	Water Level (Annual)	Water Quality Monitored	Water Quality Frequency	Monitored	Frequency
37481	Northern Pathway	X*									
37482	Northern Pathway	X*									
37484	Northern Pathway	X*									
37485	Northern Pathway	X*									
37487	Northern Pathway	X*									
37488	Northern Pathway	X*									
37494	Northern Pathway	X*									
37495	Northern Pathway	X*									
37496	Northern Pathway	X*									
37600	NWBCS OS	X	X								
37800	First Creek Pathway	X*									
37803	First Creek Pathway	X*									
37804	First Creek Pathway	X*									
37811	Northern Pathway	X*									
37817	Northern Pathway	X*									
37818	Northern Pathway	X*									
37819	Northern Pathway	X*									
37820	Northern Pathway	X*									
37821	Northern Pathway	X*									
37822	Northern Pathway	X*									
EPA-4	Northern Pathway (replaces 37470 for Performance Water Quality)	X*	X								

[1] Alternate confined flow system wells for South Plants monitored if primary wells cannot be sampled.
[2] Well 24126 replaced 24063.
[3] Monitoring frequency will be quarterly during the first year of operation (anticipated to begin in FY09) and then re-evaluated.
[4] Well 37150 replaced 37403.
[5] Well 37151 replaced 37040.
[6] Sampling frequency is biannual, during even years.
[7] Sampling frequency is biannual, during odd years.
[8] NBCS Denver UFS/CFS performance well sampling frequency is once in 5 years.
* BANS and OGITS Performance Water Level Monitoring frequency is annual.

FIGURES



RMA Detail

Figure 1.2-1

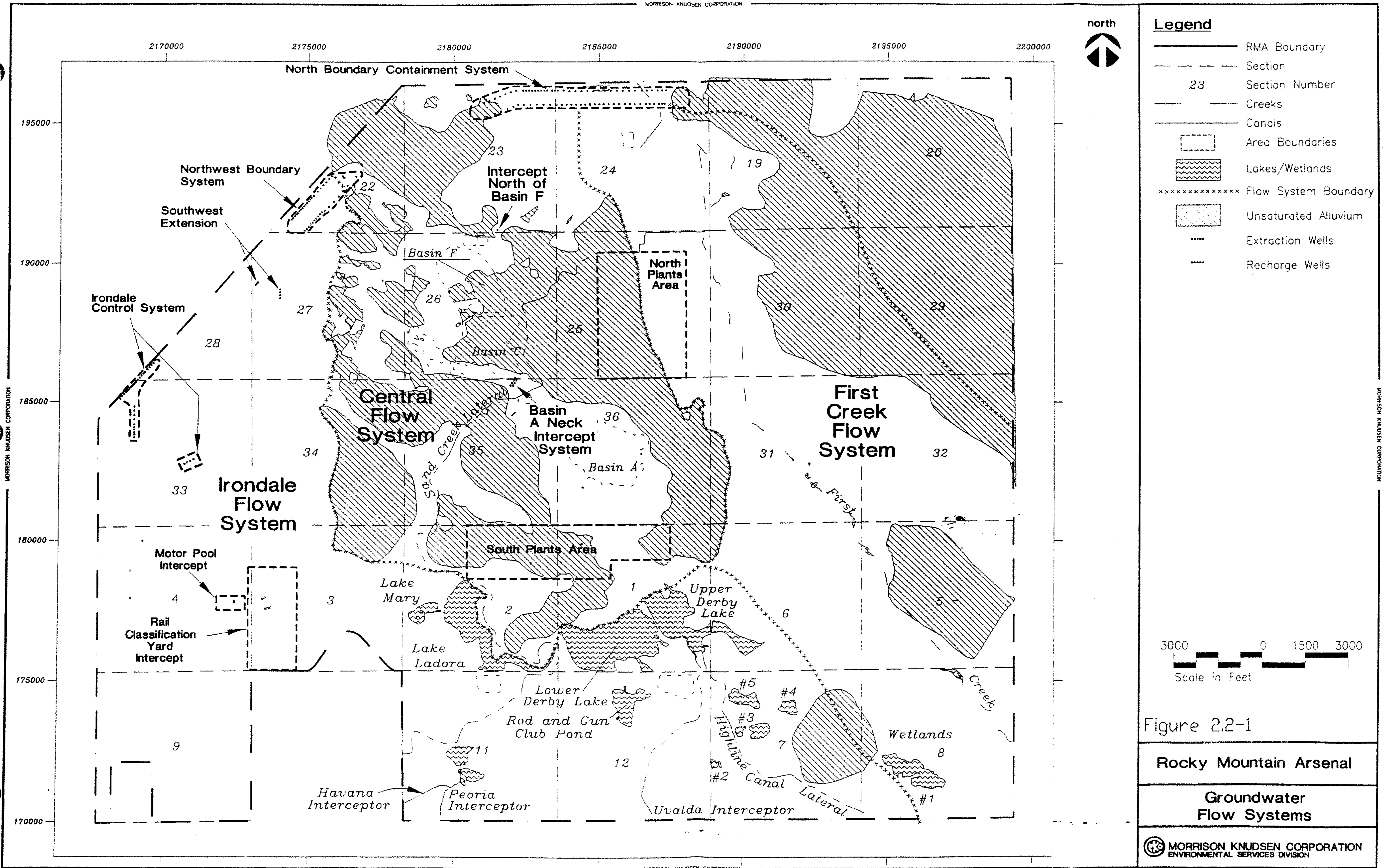


Figure 2.2-1

Rocky Mountain Arsenal

Groundwater Flow Systems

MORRISON KNUDSEN CORPORATION
ENVIRONMENTAL SERVICES DIVISION

<CFN: 0190M018.DWG> <CPD: 09/17/93>

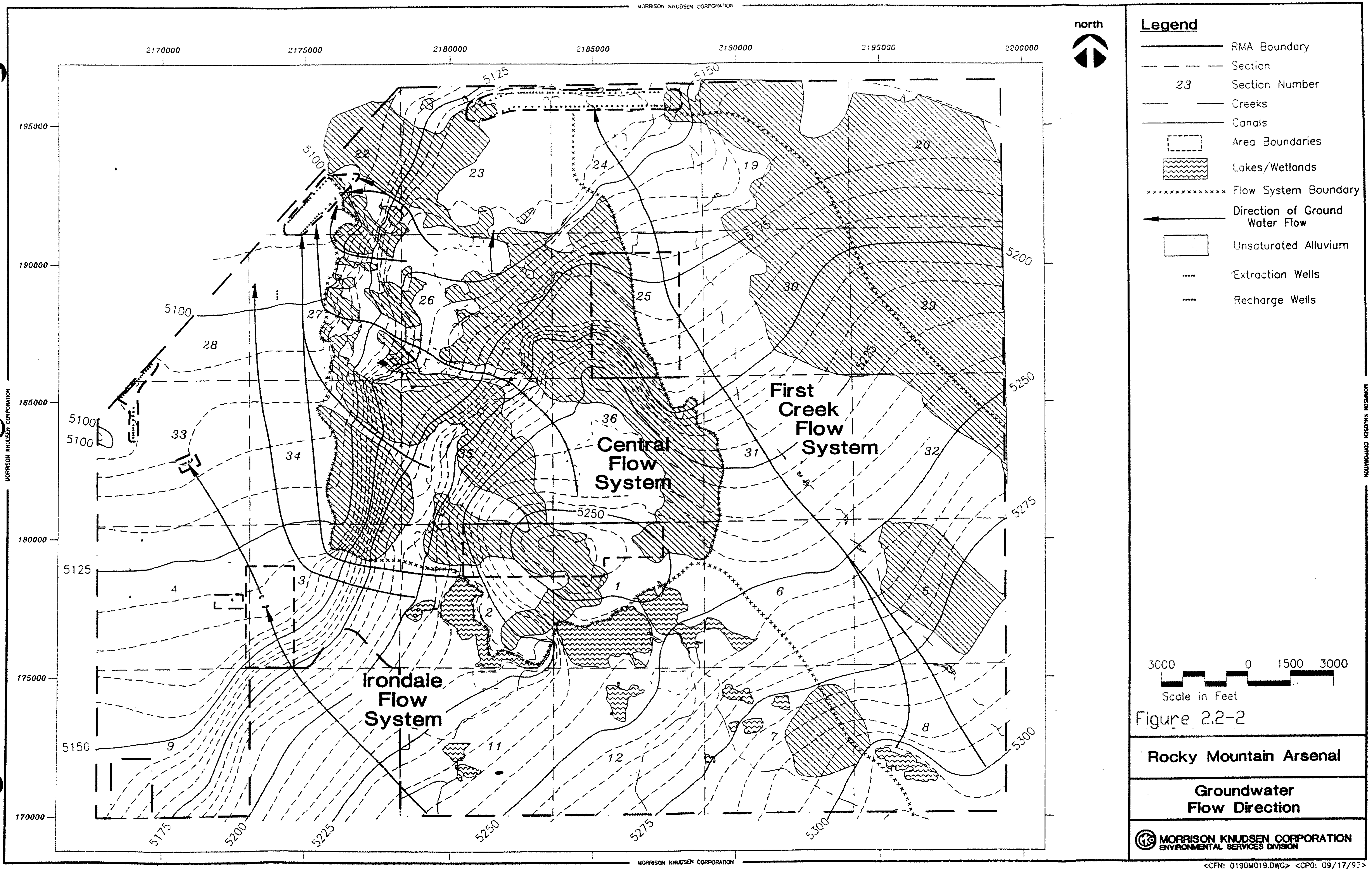


Figure 2.2-2

Rocky Mountain Arsenal

Groundwater Flow Direction

MORRISON KNUDSEN CORPORATION
ENVIRONMENTAL SERVICES DIVISION

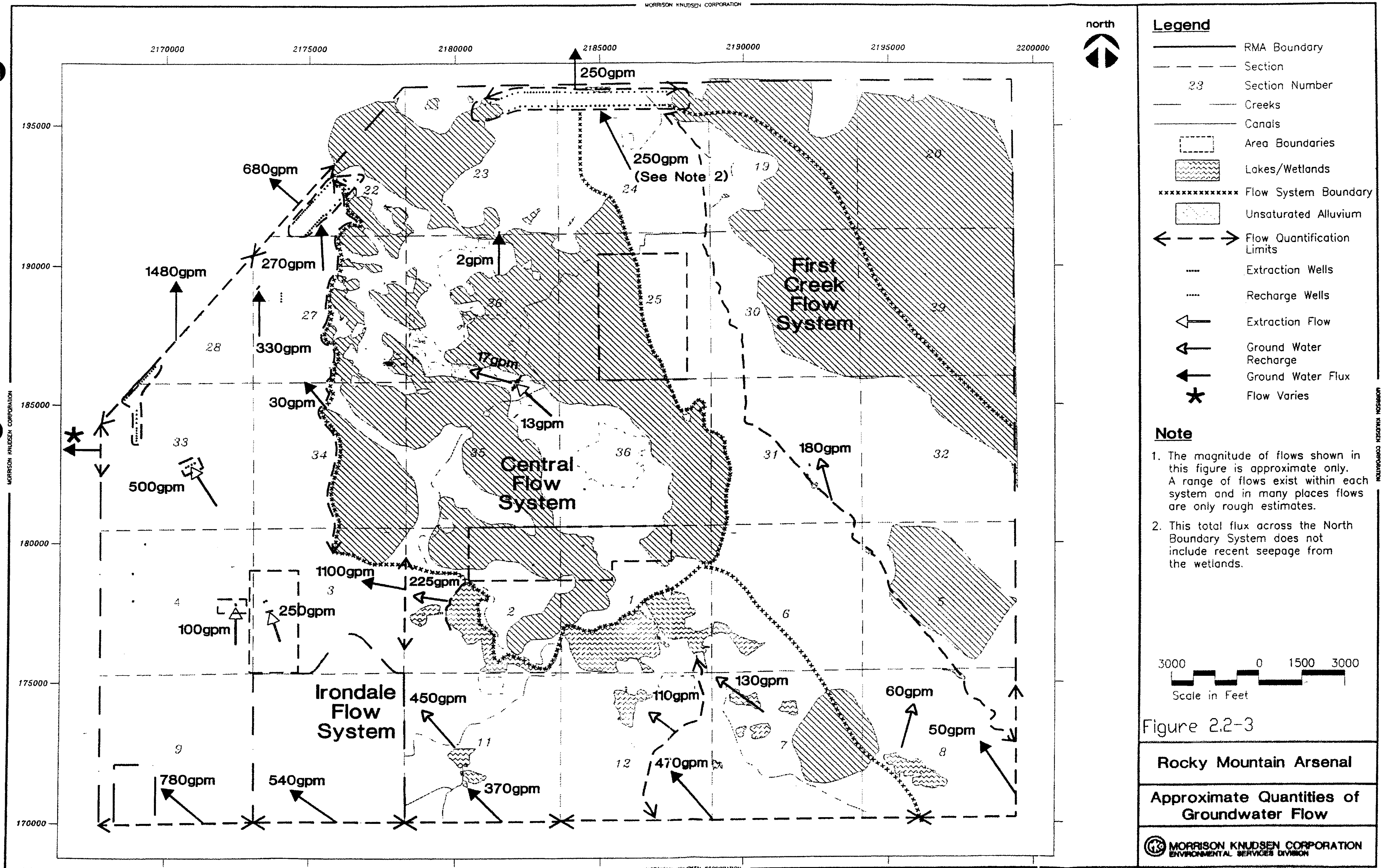
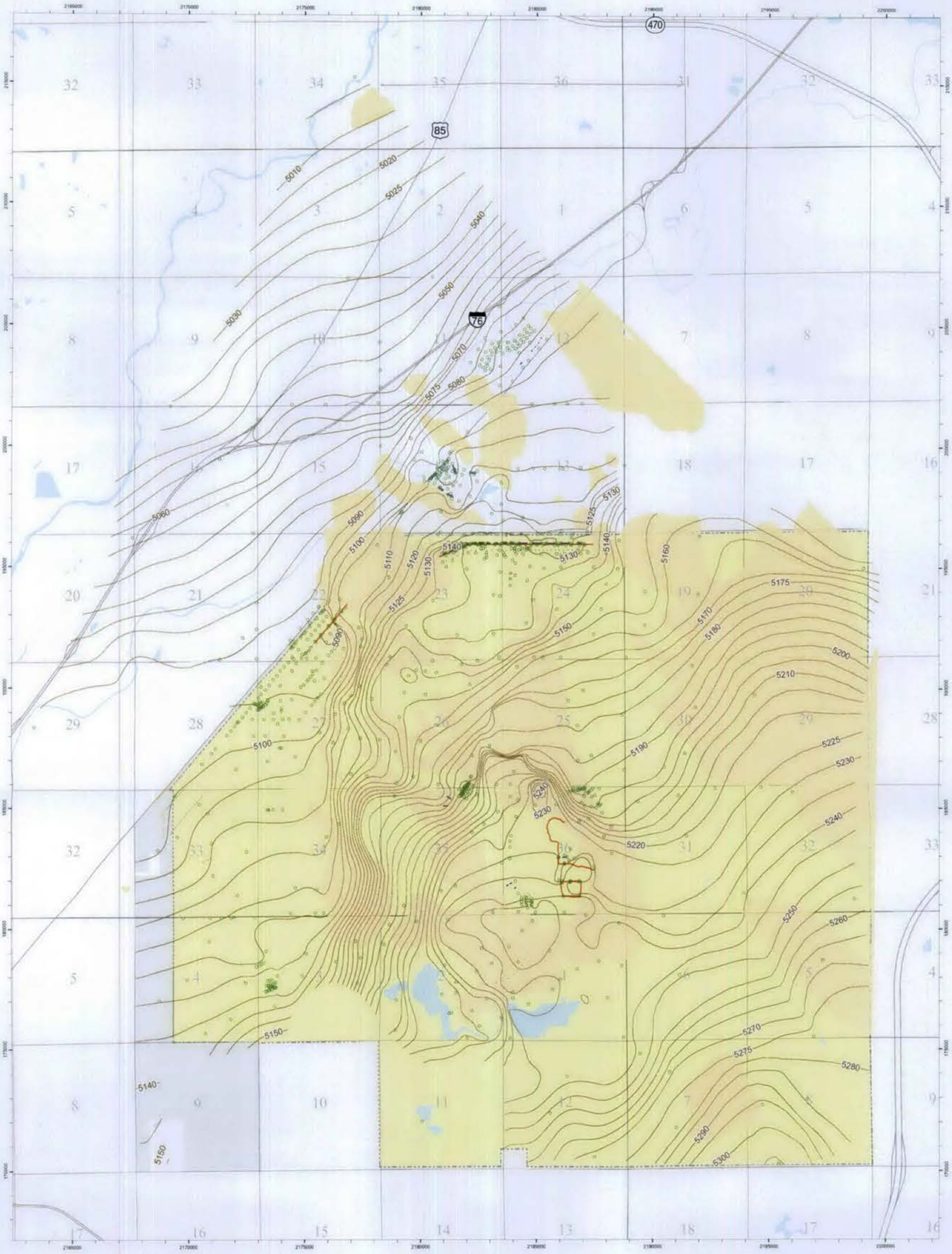


Figure 2.2-3

Rocky Mountain Arsenal

Approximate Quantities of Groundwater Flow

<CFN: 0190M020.DWG> <CPG: 09/20/93>



2004 Water Levels
Figure 2.2-4

Legend

- Rocky Mountain Arsenal (On-Post Operable Unit)
- Western Tier and Other Transfer Areas
- Lakes, Ponds, Rivers
- 2004 Dry Alluvium
- Primary Roads
- Slurry Wall
- Trench
- Intermittent Streams
- Ditches and Canals
- Section Lines
- Township & Range Lines
- Water Level Contour - 2004
- Approximate Water Level Contour - 2004
- Wells Used for Groundwater Contouring - 2004
- Extraction Wells
- Recharge Wells

N

0 1,000 2,000 4,000 6,000 8,000
Feet

NAD27 NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: U.S. Army BIMS, U.S. Army COE, Washington Group, USGS DLG, USFWS, Foster Wheeler, RVO GIS

Remediation Venture Office GIS

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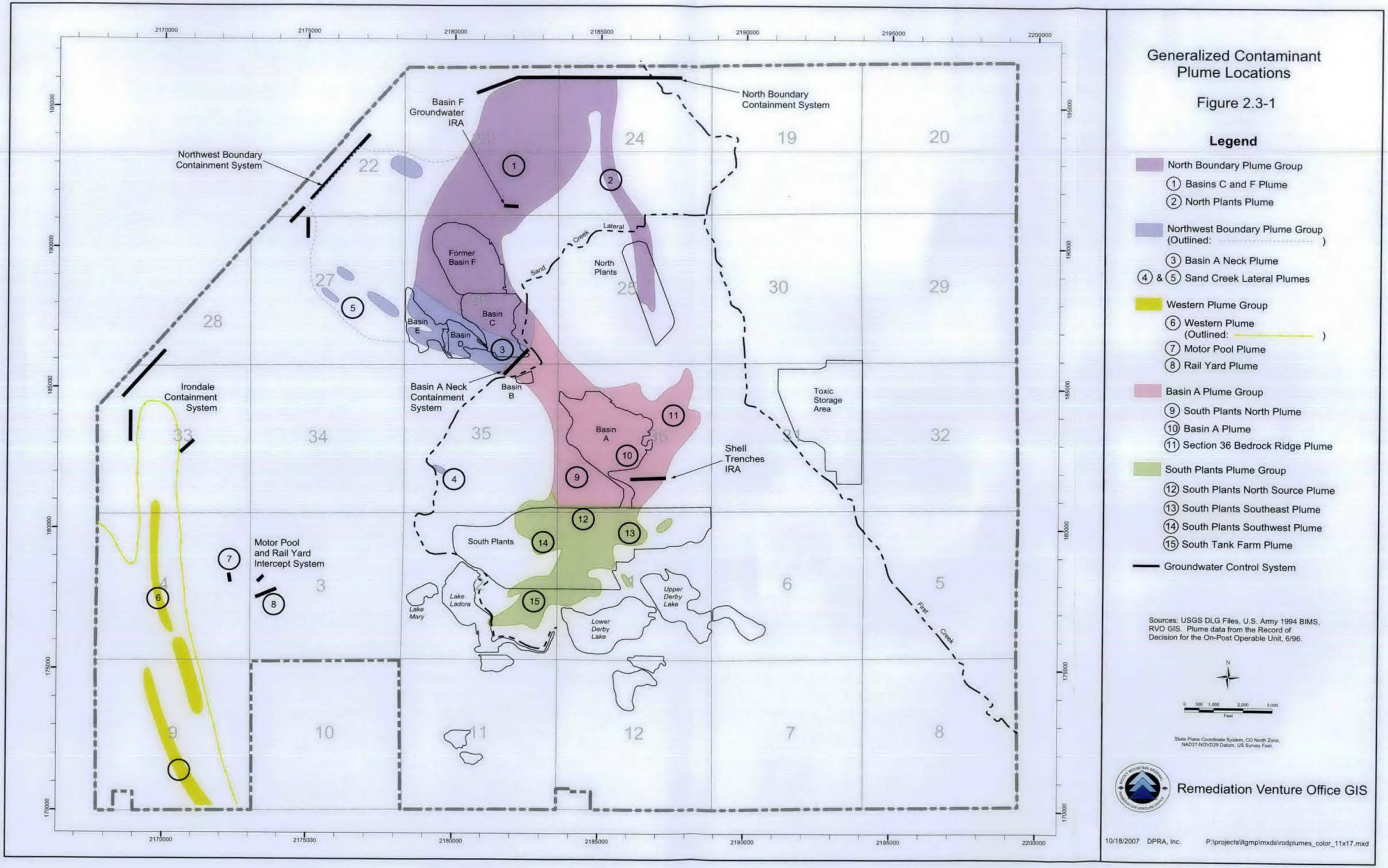
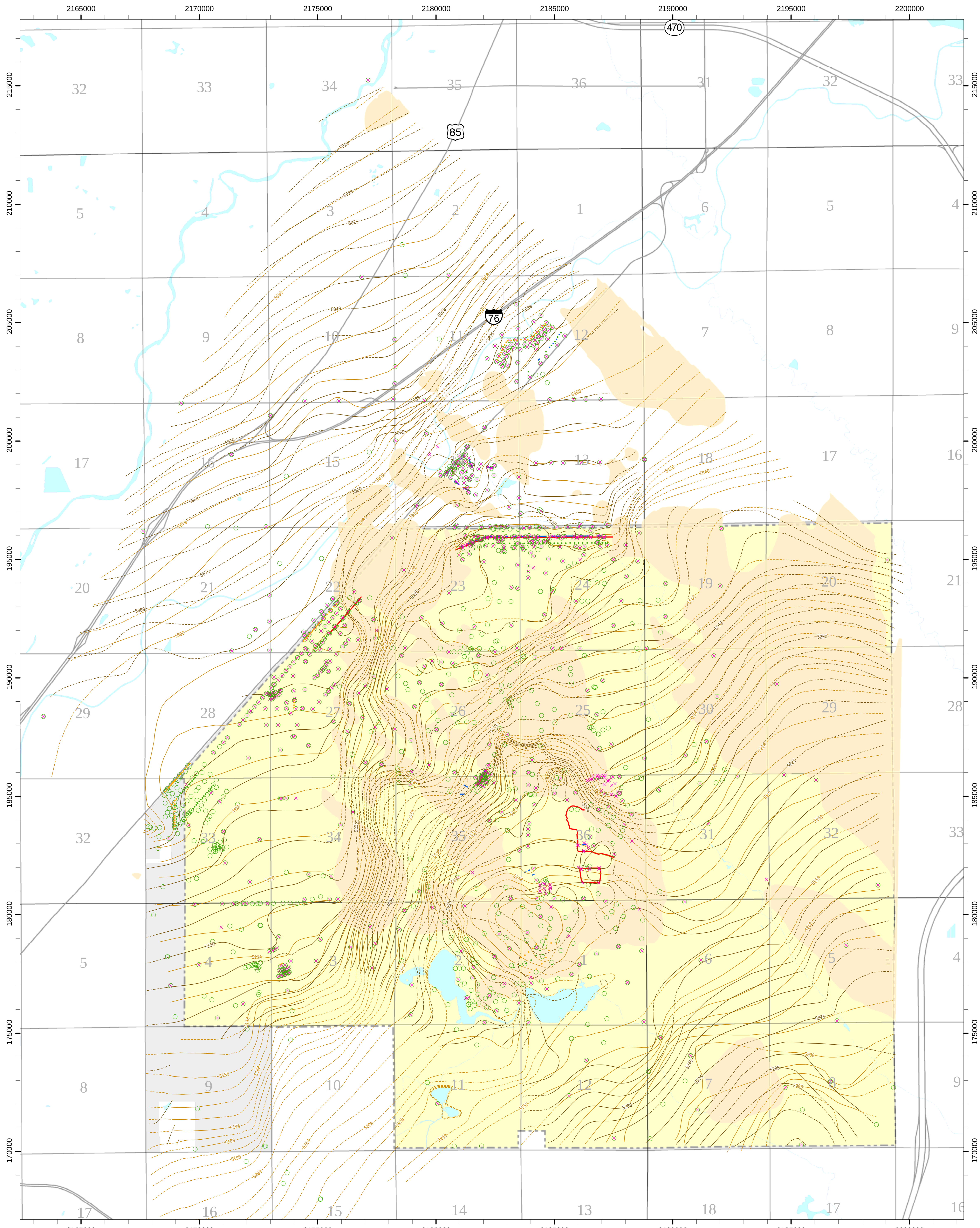


Generalized Contaminant Plume Locations

Figure 2.3-1



Water Level Comparison
Water Years 1999 and 2004
Figure 2.2-5

Legend

Rocky Mountain Arsenal (On-Post Operable Unit)
Western Tier and Other Transfer Areas
Lakes, Ponds, Rivers
2004 Dry Alluvium
Primary Roads
Slurry Wall
Trench
Intermittent Streams
Ditches and Canals
Section Lines
Township & Range Lines
Water Level Contour - 1999
Approximate Water Level Contour - 1999
Water Level Contour - 2004
Approximate Water Level Contour - 2004
Wells Used for Groundwater Contouring - 1999
Wells Used for Groundwater Contouring - 2004
Extraction Wells
Recharge Wells

N

0 1,000 2,000 4,000 6,000 8,000
Feet

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: U.S. Army BIMS, U.S. Army COE, Washington Group, USGS DLG, USFWS, Foster Wheeler, RVO GIS

Remediation Venture Office GIS

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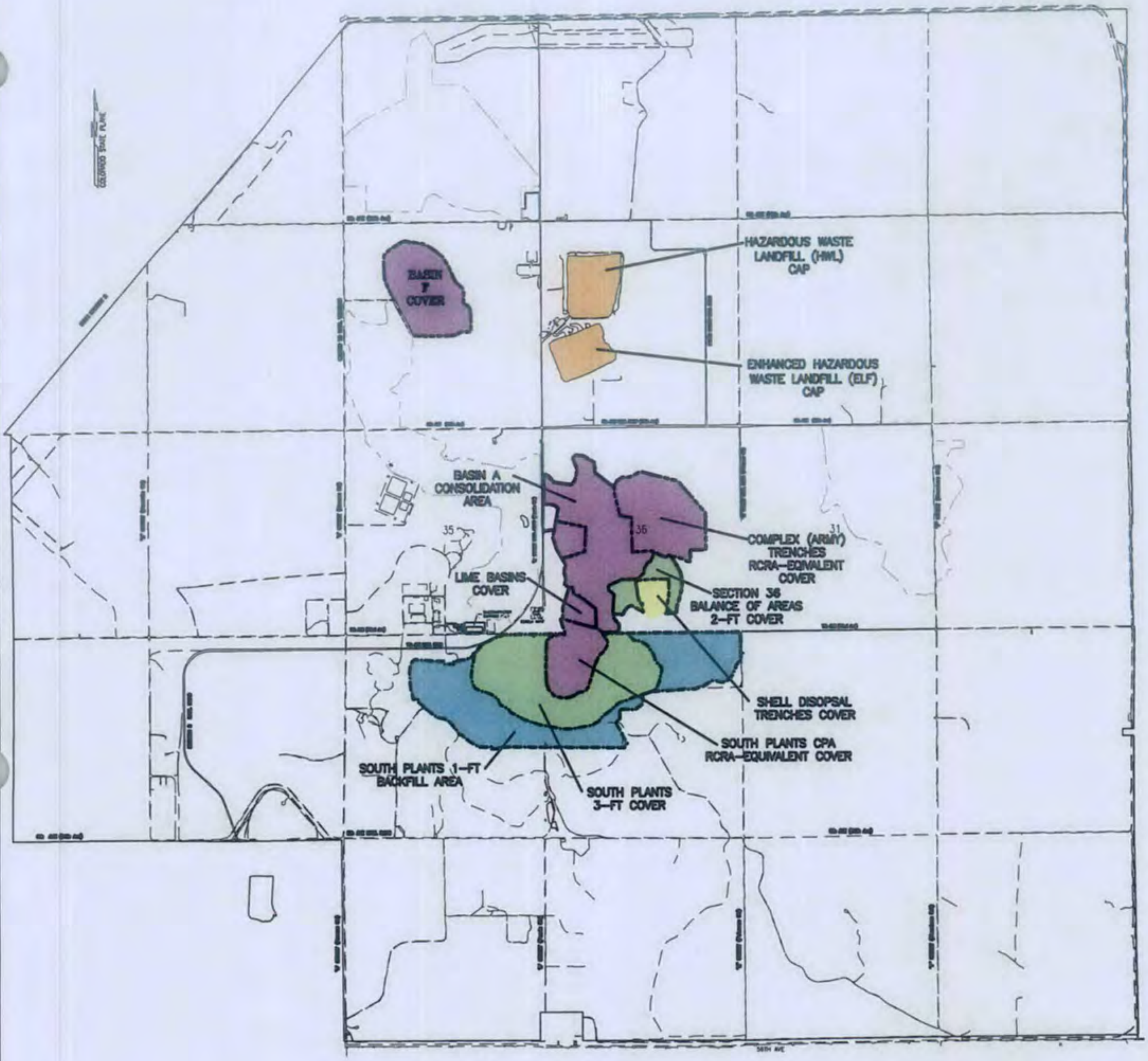

LEGEND

- HWL AND ELF RCRA CAPS
- INTEGRATED COVER SYSTEM AND BASIN F RCRA-EQUIVALENT COVER
- INTEGRATED COVER SYSTEM 2-FT/3-FT COVER
- INTEGRATED COVER SYSTEM 1-FT BACKFILL
- COMPLETED SHELL DISPOSAL TRENCHES RCRA-EQUIVALENT COVER

Program Manager Rocky Mountain Arsenal

U.S. Army

ROCKY MOUNTAIN ARSENAL
COMMERCE CITY, COLORADO

TETRA TECH EC

PROJECT NAME: LTMP

TITLE: RMA FINAL CAPS AND COVERS

CAD FILE:	DATE	FIGURE NUMBER
RMA COVERS.DWG	10.17.07	2.4-1

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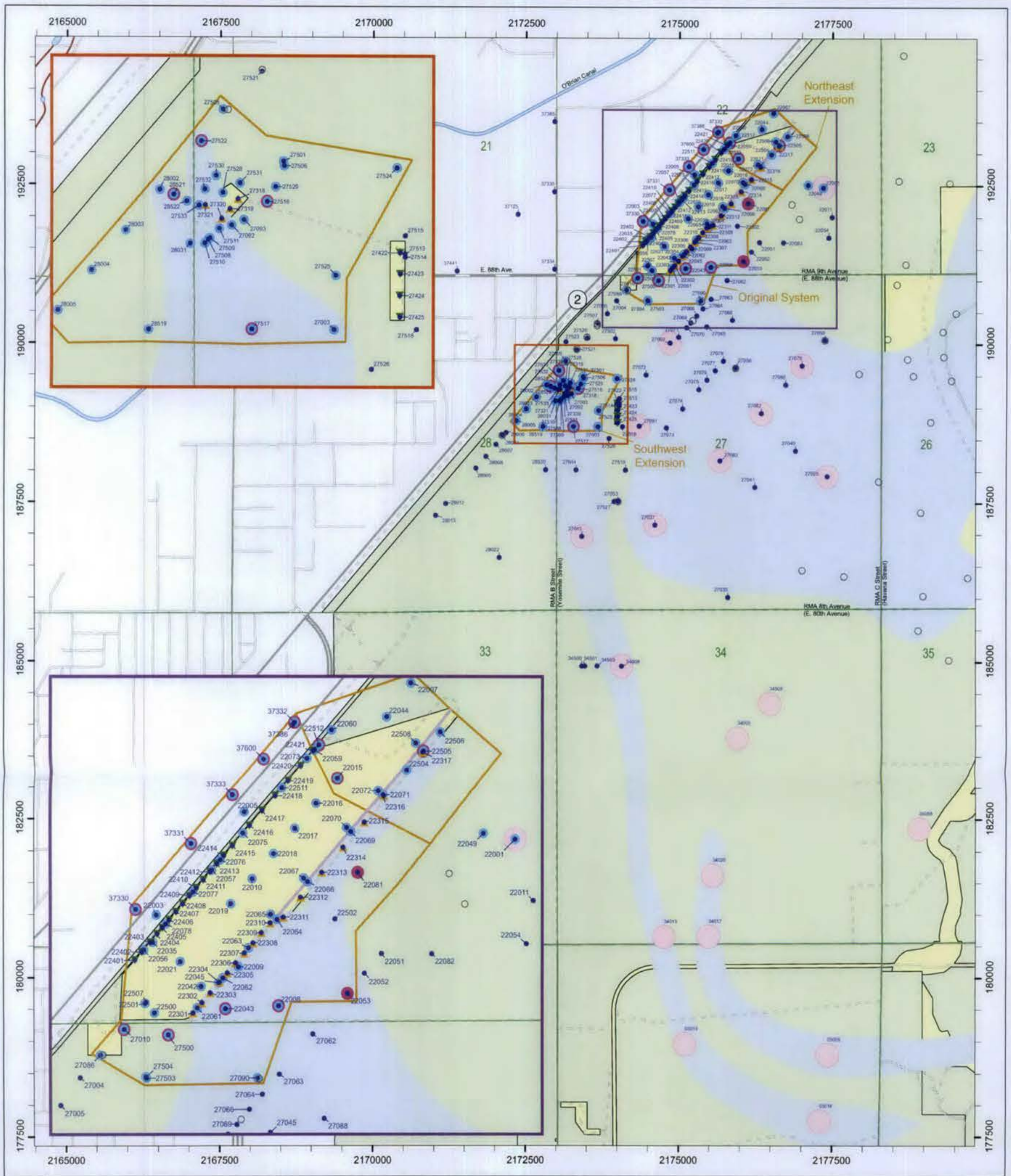

Figure 4.3-1: Northwest Boundary Containment System LTMP Wells

Legend

- Open Wells not in LTMP
- LTMP Wells
  - Operational Water Level
  - Extraction Wells
  - Recharge Wells
  - Performance Water Level
  - Performance Water Quality
  - Water Quality Tracking
- NWBCS Components
- Lakes, Ponds, Rivers
- Slurry Walls
- Local Roads
- Secondary Roads
- Primary Roads
- Ditches
- Section Lines
- Unimproved Roads
- 1994 Dieldrin Plume
- RMA National Wildlife Refuge
- Rocky Mountain Arsenal

N

0 500 1,000 2,000
Feet

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: USGS, DPRA, Inc., URS - Washington Division, RMA Environmental Database, U.S. Army, Shell Chemical

Remediation Venture Office GIS

10/8/2009 DPRA, Inc.
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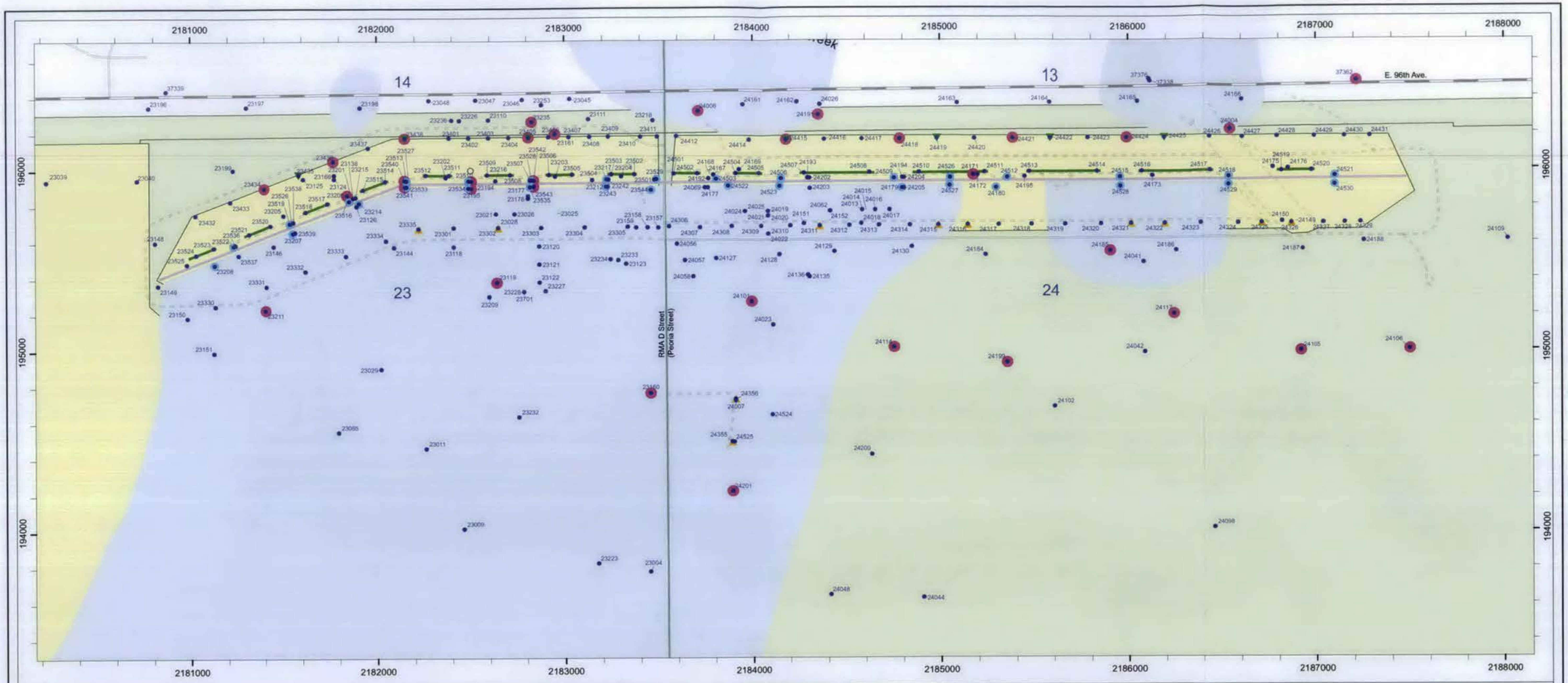

Figure 4.4-1: North Boundary Containment System LTMP Wells

Legend

- Rocky Mountain Arsenal
- RMA National Wildlife Refuge
- Section Lines
- 1994 Dieldrin Plume
- Lakes, Ponds, Rivers
- Local Roads
- Secondary Roads
- Primary Roads
- Unimproved Roads
- Ditches
- Slurry Walls
- Recharge Trench
- Open Wells not in LTMP
- Operational Water Level
- Extraction Wells
- Recharge Wells
- Performance Water Level
- Performance Water Quality

N

0 250 500 Feet

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: USGS, DPRA, Inc., URS - Washington Division, RMA Environmental Database, U.S. Army, Shell Chemical

Remediation Venture Office GIS

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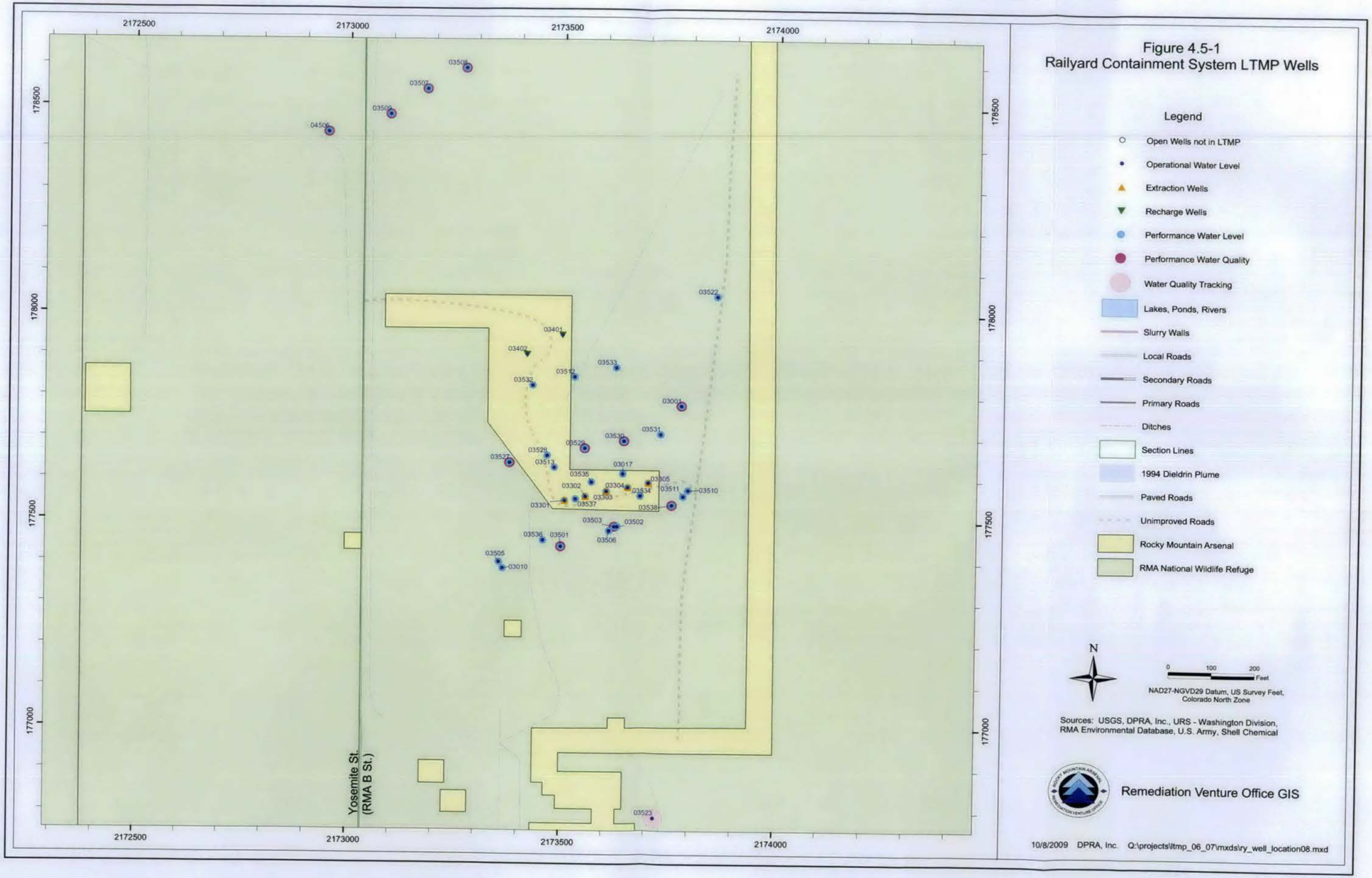

Figure 4.5-1
Railyard Containment System LTMP Wells
Legend
Open Wells not in LTMP
Operational Water Level
Extraction Wells
Recharge Wells
Performance Water Level
Performance Water Quality
Water Quality Tracking
Lakes, Ponds, Rivers
Slurry Walls
Local Roads
Secondary Roads
Primary Roads
Ditches
Section Lines
1994 Dieldrin Plume
Paved Roads
Unimproved Roads
Rocky Mountain Arsenal
RMA National Wildlife Refuge
N
0 100 200 Feet
NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone
Sources: USGS, DPRA, Inc., URS - Washington Division, RMA Environmental Database, U.S. Army, Shell Chemical
Remediation Venture Office GIS
10/8/2009 DPRA, Inc. Q:\projects\ltmp_06_07\mxds\ry_well_location08.mxd
Yosemite St. (RMA B St.)
2172500
2173000
2173500
2174000
178500
178000
177500
177000
03508
03507
03509
04505
03522
03401
03402
03533
03512
03532
03001
03531
03530
03529
03528
03527
03513
03017
03535
03305
03302
03304
03534
03511
03510
03303
03537
03301
03538
03503
03502
03506
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03501
03505
03010
03523

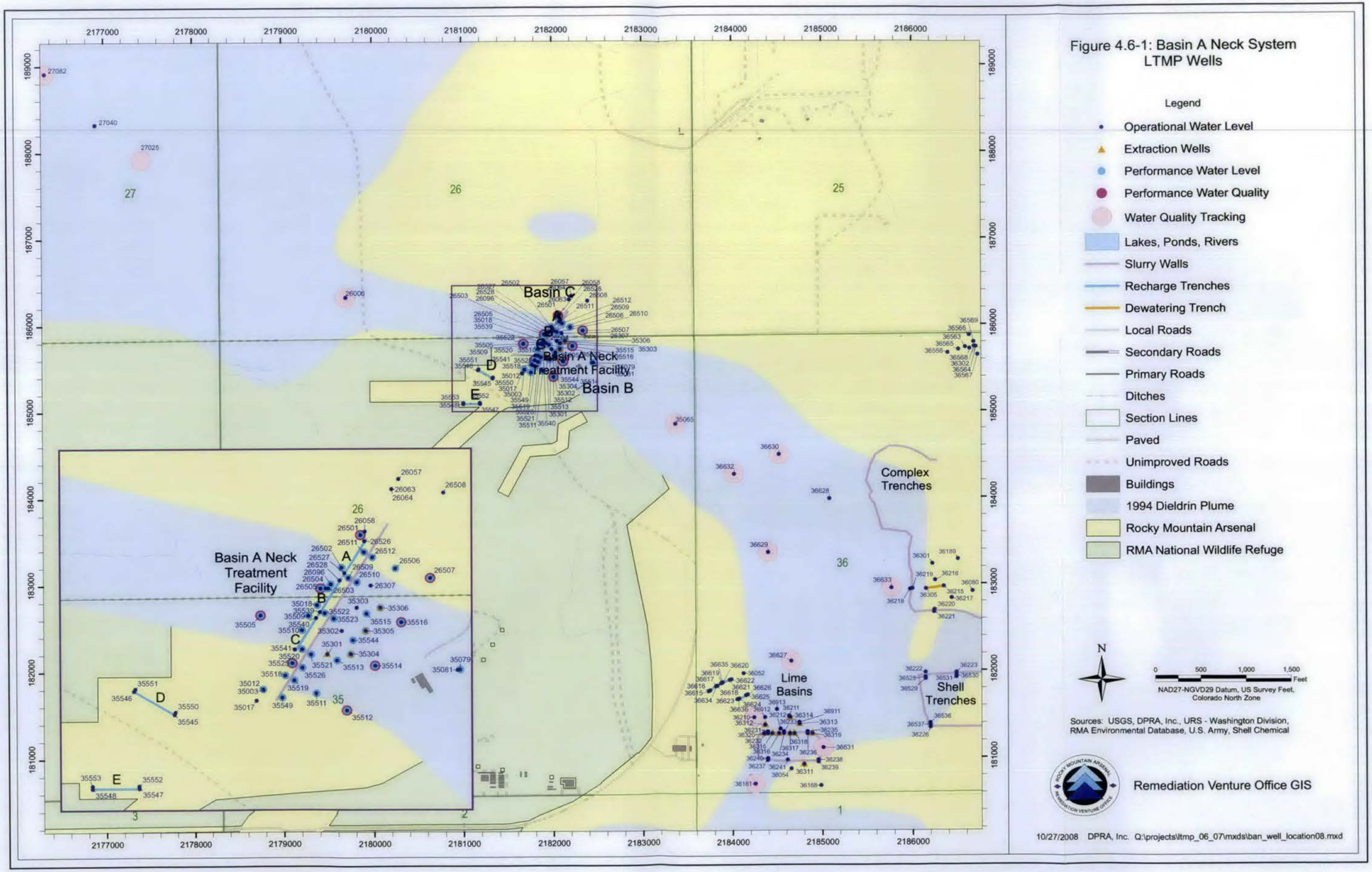


Figure 4.6-1: Basin A Neck System LTMP Wells
Legend
Operational Water Level
Extraction Wells
Performance Water Level
Performance Water Quality
Water Quality Tracking
Lakes, Ponds, Rivers
Slurry Walls
Recharge Trenches
Dewatering Trench
Local Roads
Secondary Roads
Primary Roads
Ditches
Section Lines
Paved
Unimproved Roads
Buildings
1994 Dieldrin Plume
Rocky Mountain Arsenal
RMA National Wildlife Refuge
Basin C
Basin A Neck Treatment Facility
Basin B
Complex Trenches
Lime Basins
Shell Trenches
NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone
Sources: USGS, DPRA, Inc., URS - Washington Division, RMA Environmental Database, U.S. Army, Shell Chemical
Remediation Venture Office GIS
10/27/2008 DPRA, Inc. Q:\projects\ltmp_06_07\mxds\ban_well_location08.mxd

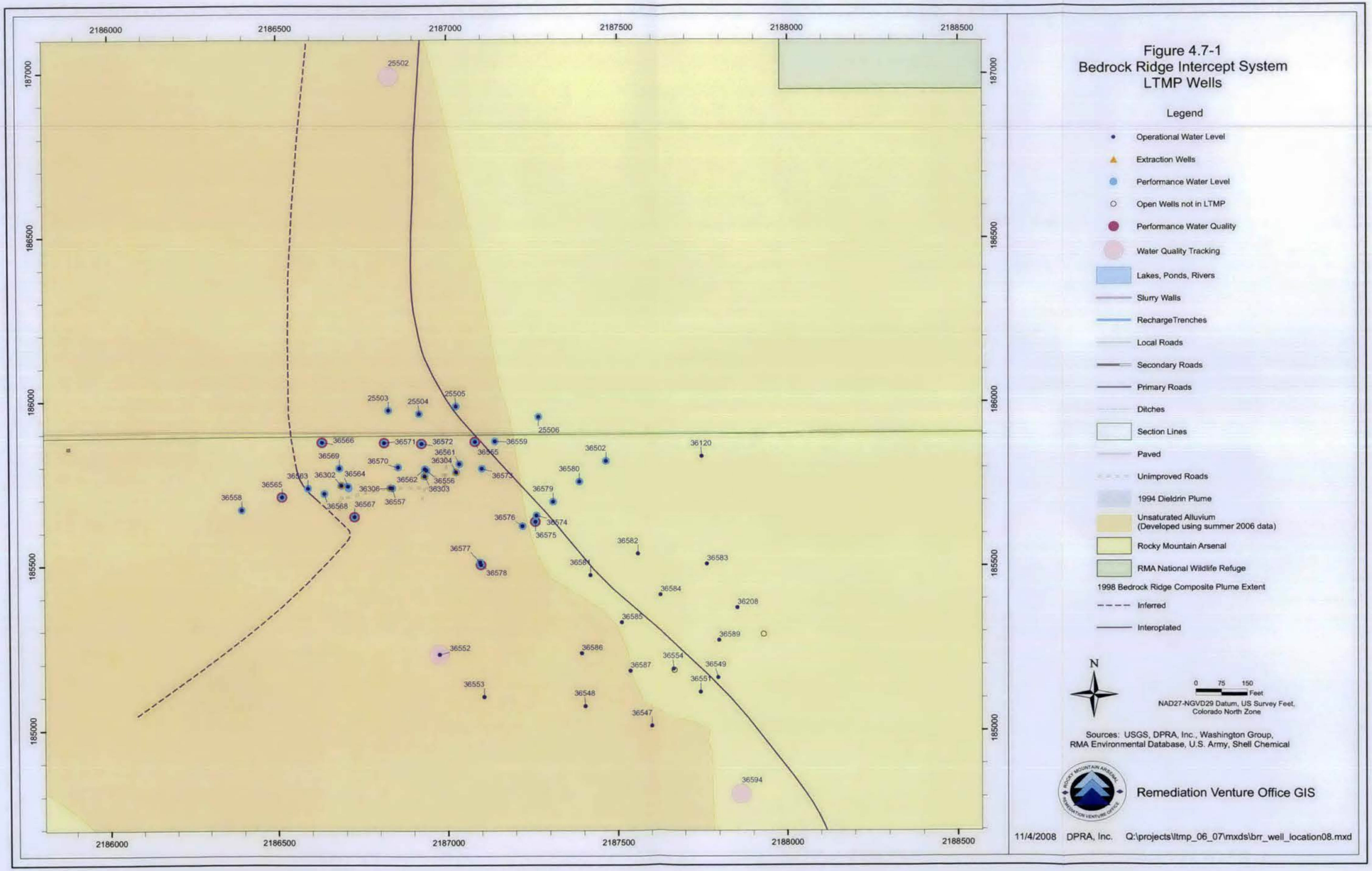


Figure 4.7-1
Bedrock Ridge Intercept System
LTMP Wells

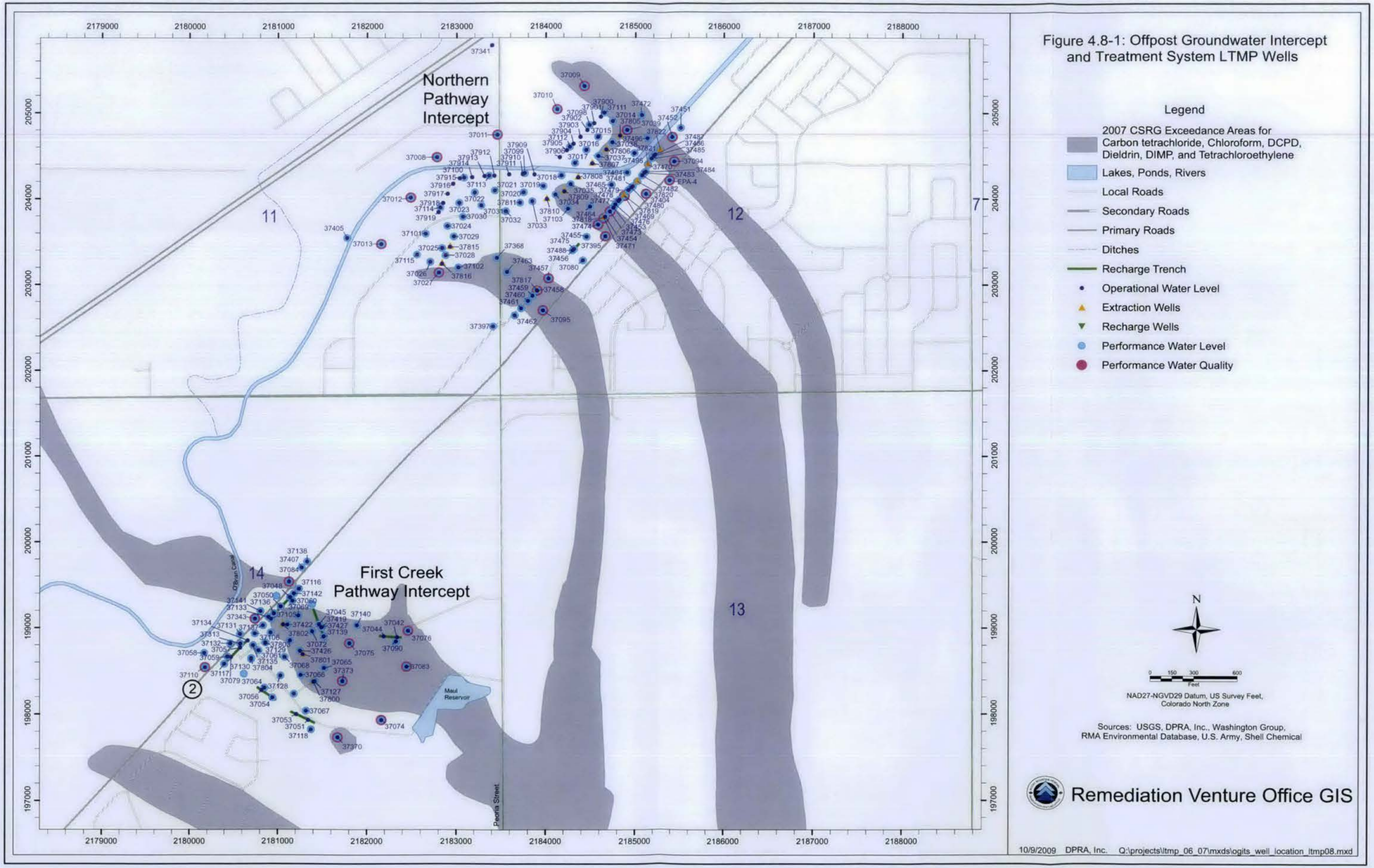
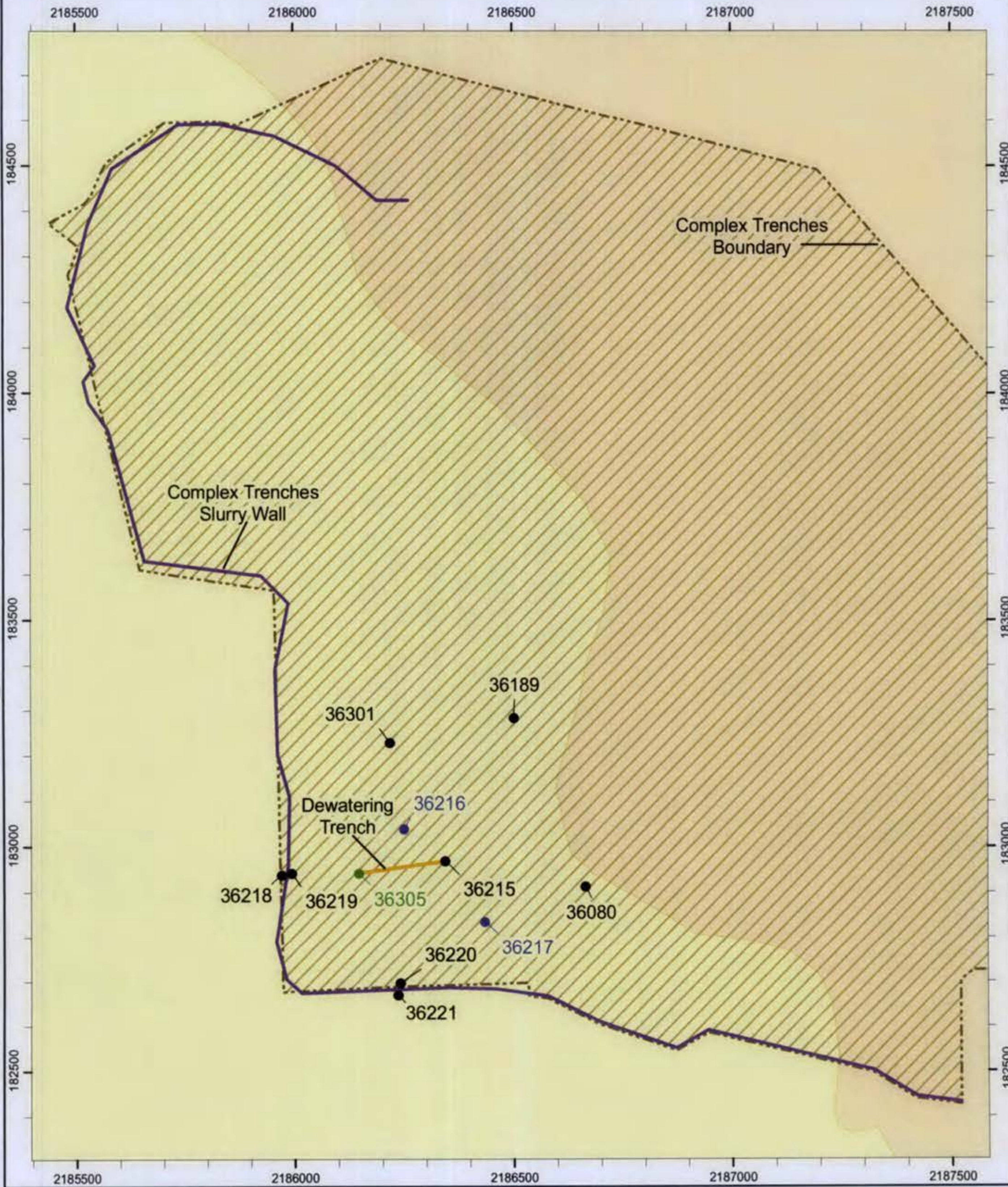


Figure 4.8-1: Offpost Groundwater Intercept and Treatment System LTMP Wells
Legend
2007 CSRG Exceedance Areas for Carbon tetrachloride, Chloroform, DCPD, Dieldrin, DIMP, and Tetrachloroethylene
Lakes, Ponds, Rivers
Local Roads
Secondary Roads
Primary Roads
Ditches
Recharge Trench
Operational Water Level
Extraction Wells
Recharge Wells
Performance Water Level
Performance Water Quality
N
NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone
Sources: USGS, DPRA, Inc., Washington Group, RMA Environmental Database, U.S. Army, Shell Chemical
Remediation Venture Office GIS
10/9/2009 DPRA, Inc. Q:\projects\ltmp_06_07\mxds\ogits_well_location_ltmp08.mxd
Northern Pathway Intercept
First Creek Pathway Intercept
Maul Reservoir
Peoria Street
O'Brian Canal
11
12
13
14
7
2
2179000
2180000
2181000
2182000
2183000
2184000
2185000
2186000
2187000
2188000
205000
204000
203000
202000
201000
200000
199000
198000
197000



Complex (Army) Trenches Dewatering System Well Locations

Legend

- Monitoring Wells
- Compliance Wells
- Dewatering Well
- Dewatering Trench
- Complex Trenches Slurry Wall
- Complex Trenches Area
- Unsaturated Alluvium (Developed using summer 2005 data)
- Rocky Mountain Arsenal

N

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

0 150 300 Feet

Figure 5.1-1

Sources: U.S. Army BIMS, Washington Group, Tetra Tech, RVO GIS

Remediation Venture Office GIS

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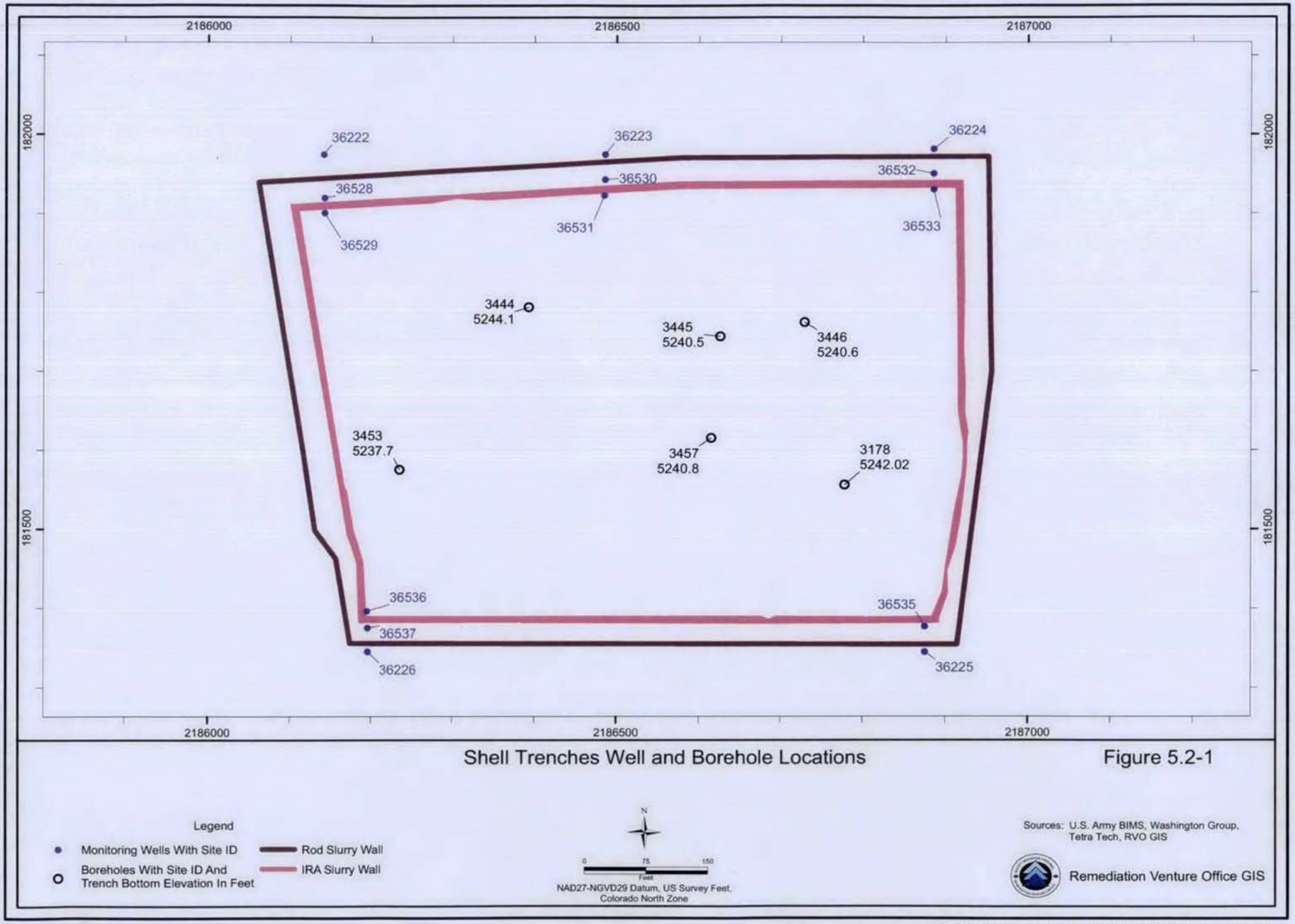

Shell Trenches Well and Borehole Locations

Figure 5.2-1

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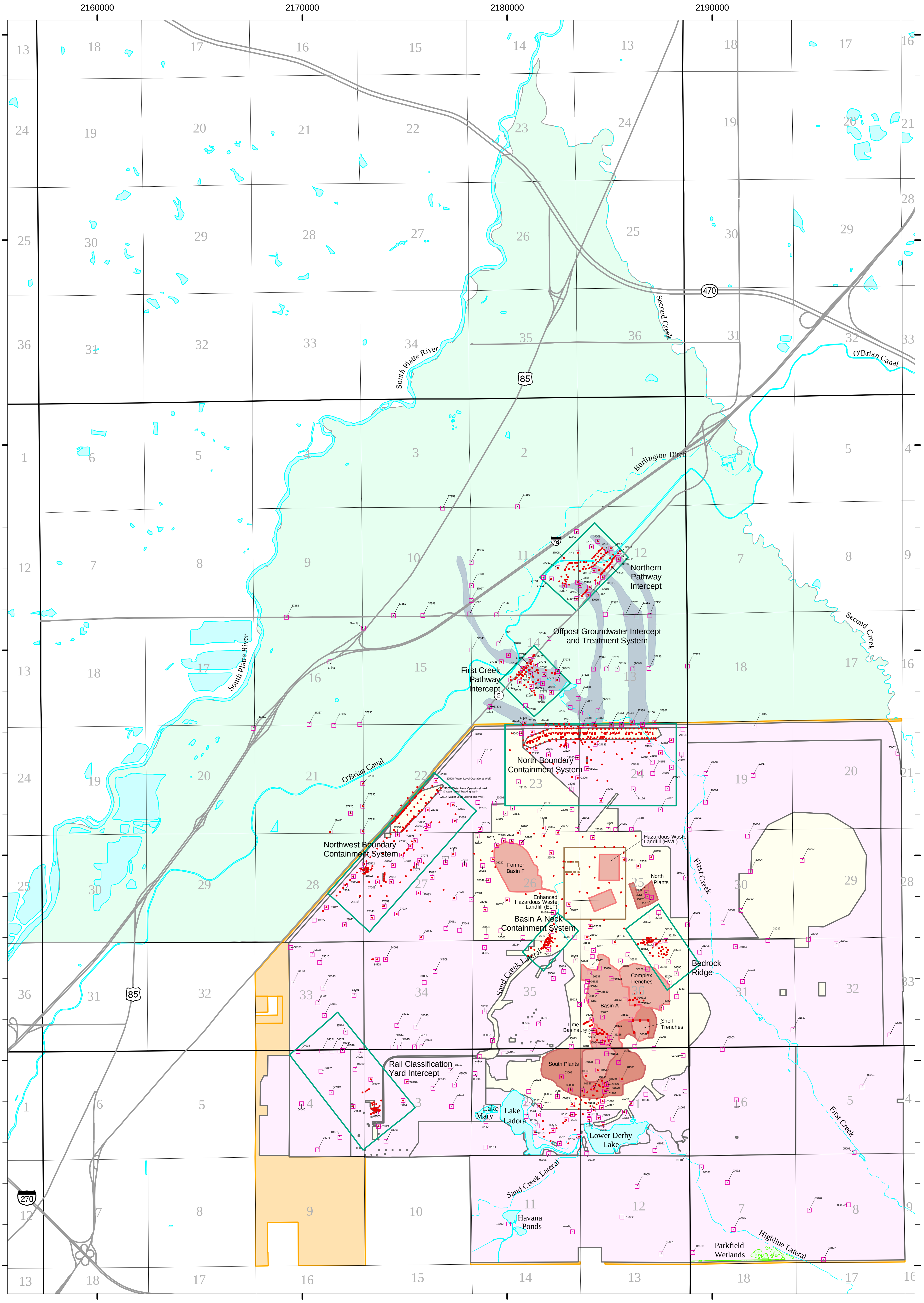

Water Level Tracking Wells
Figure 6.1-1

Legend

- Water Level Tracking Wells
- Water Level Operational Wells
- Primary Roads
- Wetlands
- Operational Areas
- LWTS Basins
- CAMU Boundary
- Section Lines
- Township & Range Lines
- Intermittent Streams
- Ditches, Canals
- Lakes, Ponds, Rivers
- Off-Post Study Area
- Caps
- Soil Covers
- Western Tier and Other Transfer Areas
- 2007 CSRG Exceedance Areas for Carbon tetrachloride, Chloroform, DCPD, Dieldrin, DIMP, and Tetrachloroethylene
- Rocky Mountain Arsenal
- RMA National Wildlife Refuge

N

0 1,750 3,500 7,000 Feet

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: U.S. Army BIMS, U.S. Army COE, Washington Group, USGS DLG, USFWS, Foster Wheeler, RVO GIS

Remediation Venture Office GIS

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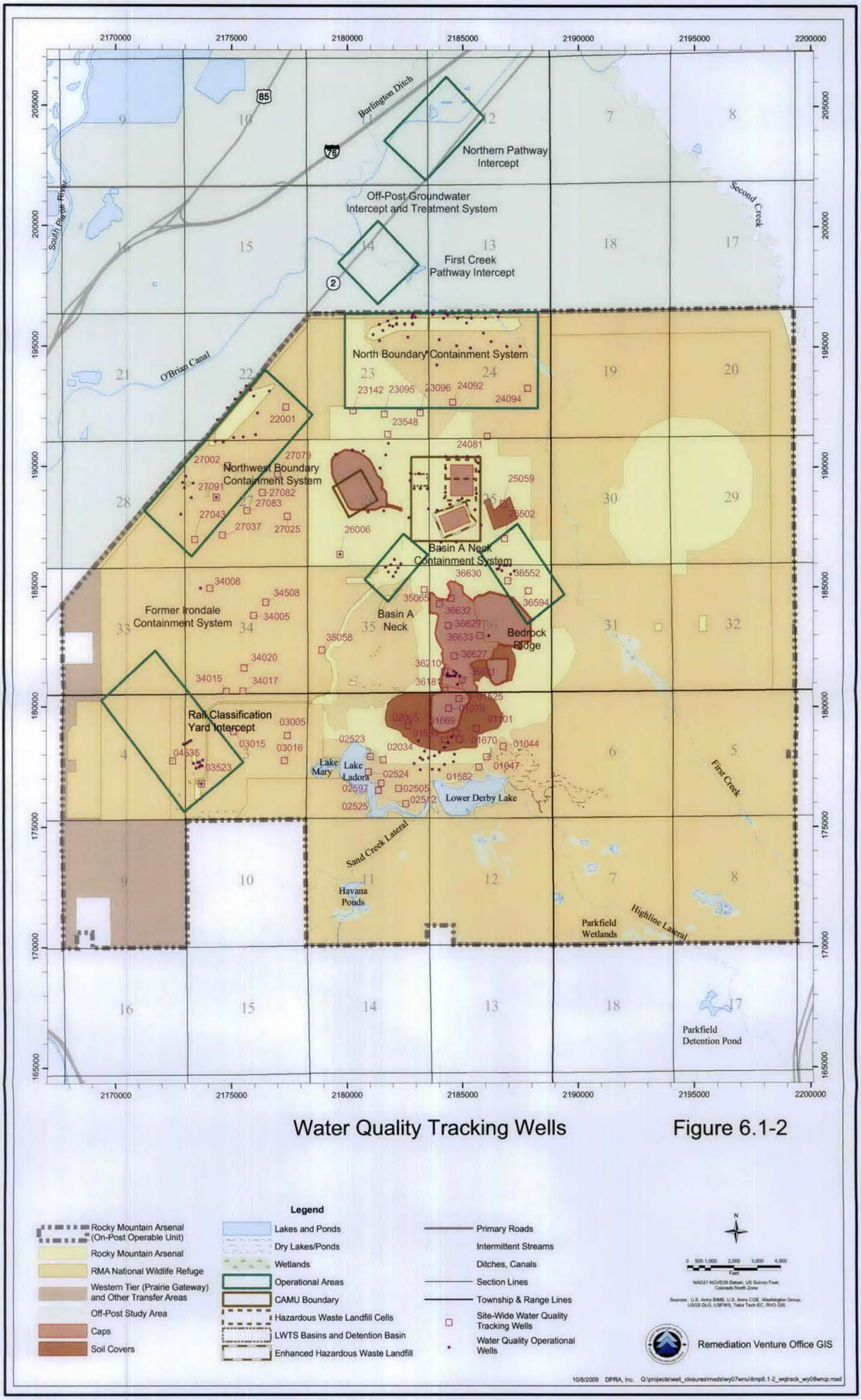
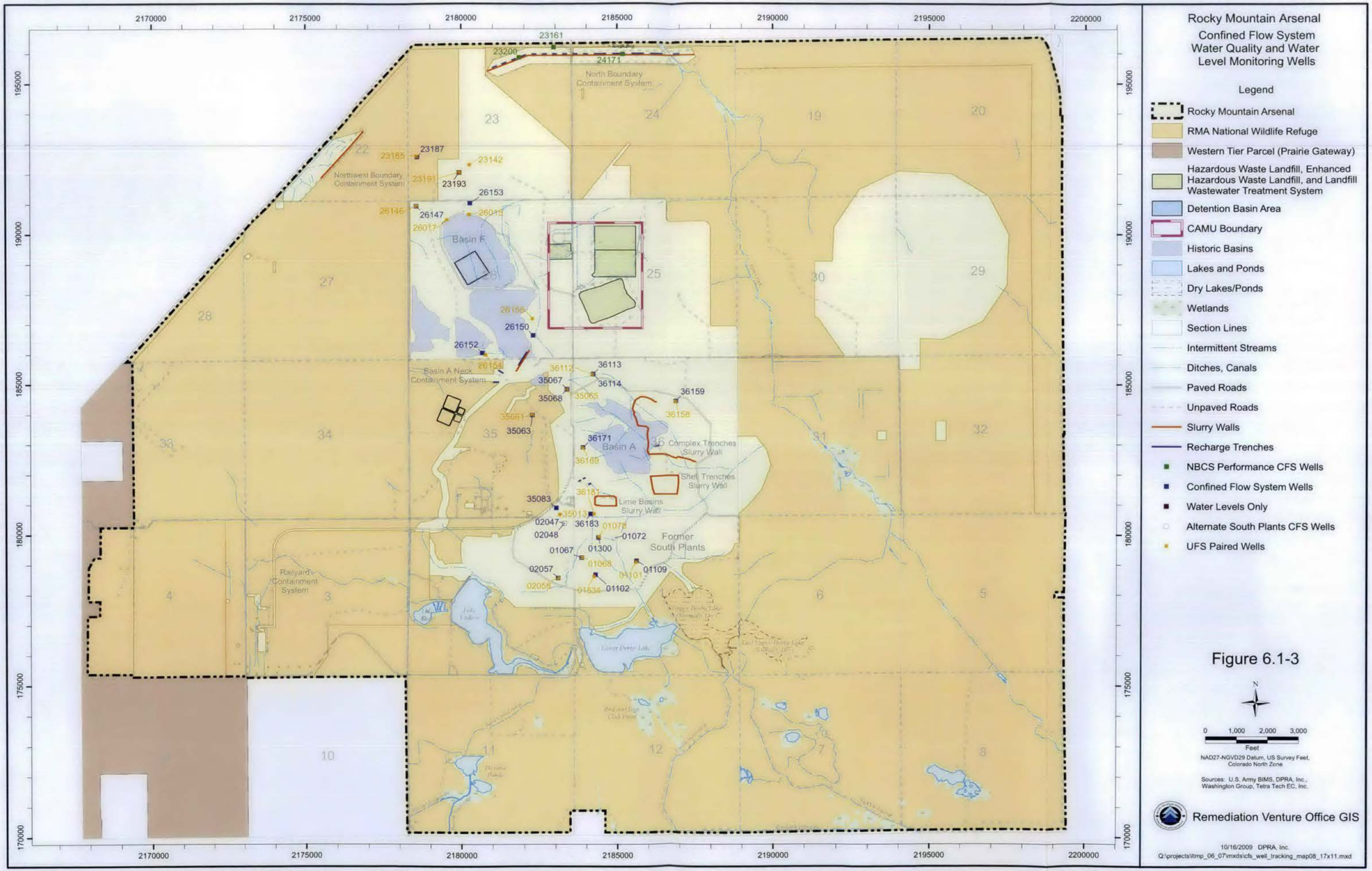


Water Quality Tracking Wells

Figure 6.1-2



Rocky Mountain Arsenal
Confined Flow System Water Quality and Water Level Monitoring Wells
Legend
Rocky Mountain Arsenal
RMA National Wildlife Refuge
Western Tier Parcel (Prairie Gateway)
Hazardous Waste Landfill, Enhanced Hazardous Waste Landfill, and Landfill Wastewater Treatment System
Detention Basin Area
CAMU Boundary
Historic Basins
Lakes and Ponds
Dry Lakes/Ponds
Wetlands
Section Lines
Intermittent Streams
Ditches, Canals
Paved Roads
Unpaved Roads
Slurry Walls
Recharge Trenches
NBCS Performance CFS Wells
Confined Flow System Wells
Water Levels Only
Alternate South Plants CFS Wells
UFS Paired Wells
North Boundary Containment System
Northwest Boundary Containment System
Basin F
Basin A Neck Containment System
Basin A
Complex Trenches Slurry Wall
Shell Trenches Slurry Wall
Lime Basins Slurry Wall
Former South Plants
Railyard Containment System
Lower Derby Lake
0 1,000 2,000 3,000
Feet
NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone
Sources: U.S. Army BIMS, DPRA, Inc., Washington Group, Tetra Tech EC, Inc.
Remediation Venture Office GIS
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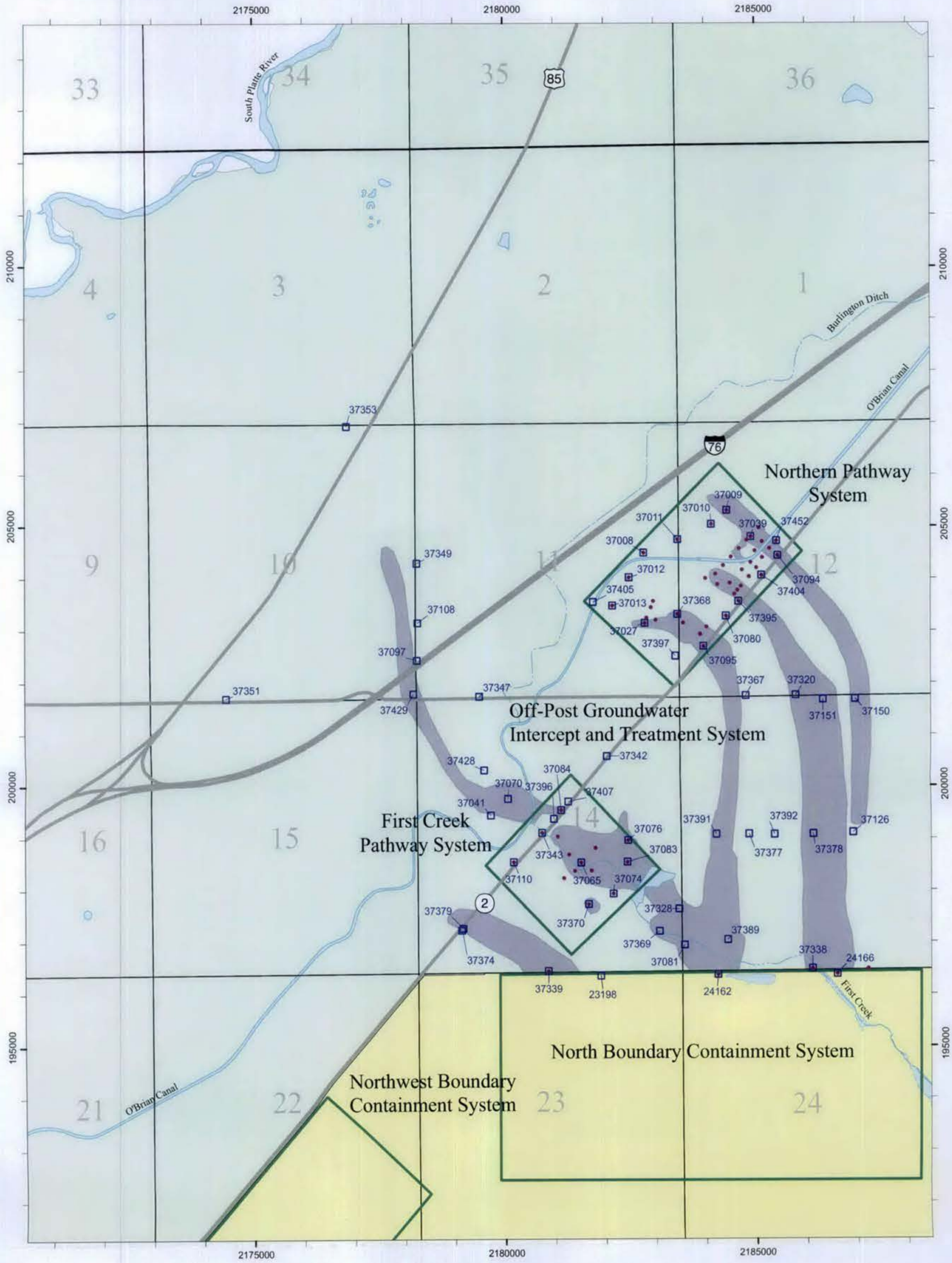
Figure 6.1-3



Exceedance Monitoring Wells
Figure 6.2-1

Legend

- Rocky Mountain Arsenal (On-Post Operable Unit)
- Off-Post Study Area
- Operational Areas
- 2007 CSRG Exceedance Areas for Carbon tetrachloride, Chloroform, DCPD, Dieldrin, DIMP, and Tetrachloroethylene
- Lakes, Ponds, Rivers
- Intermittent Streams
- Ditches, Canals
- Primary Roads
- Section Lines
- Township & Range Lines
- CSRG Exceedance Monitoring Wells
- Water Quality Operational Wells

N

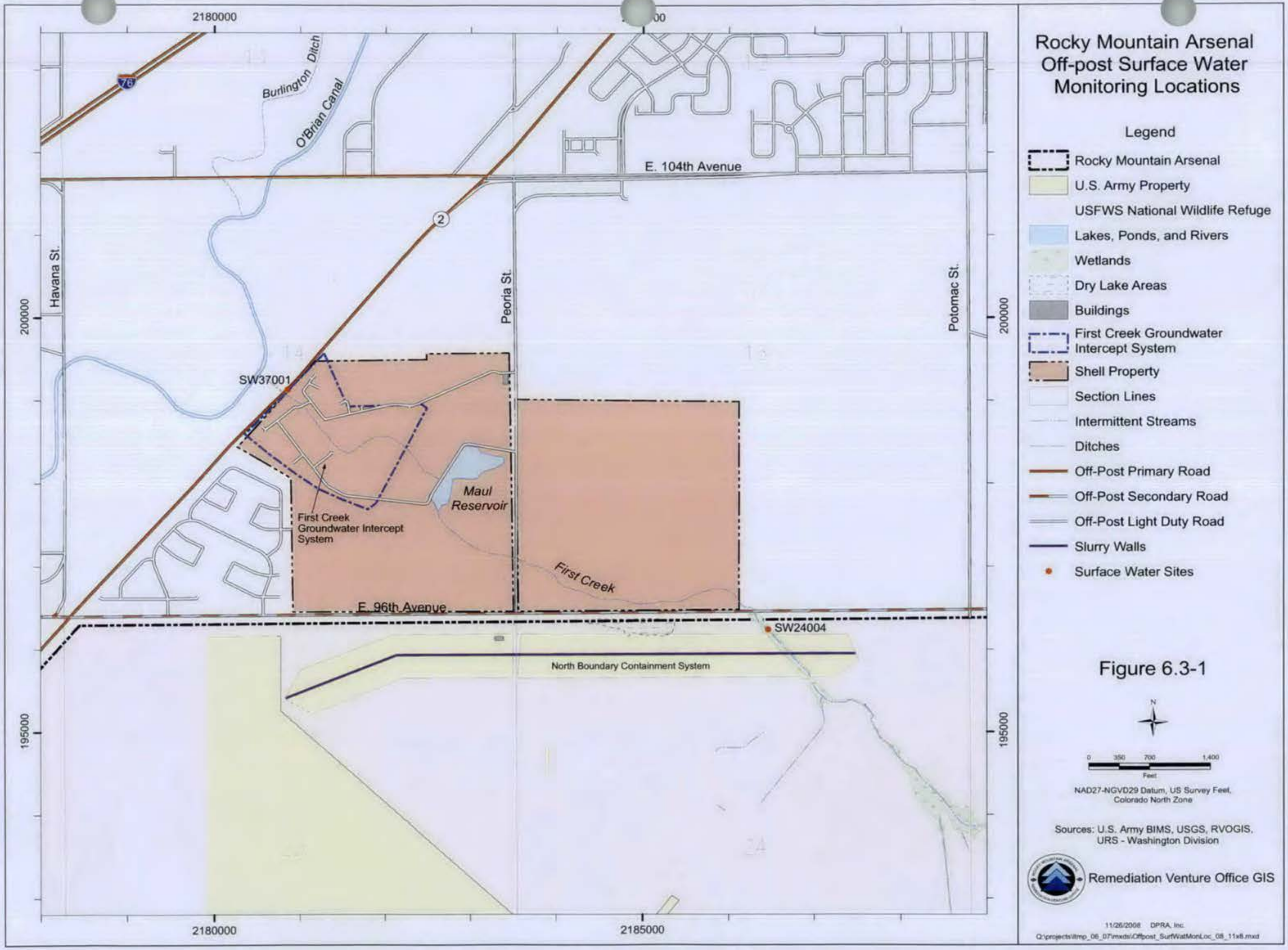
0 500 1,000 2,000 3,000
Feet

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: U.S. Army BIMS, U.S. Army COE, Washington Group, USGS DLG, USFWS, Tetra Tech-EC, RVO GIS

Remediation Venture Office GIS

10/13/2009 DPRA, Inc. Q:\projects\well_closures\mxds\wy07wnu\op_exceed_wy07wnu08.mxd


Rocky Mountain Arsenal
Off-post Surface Water
Monitoring Locations
Legend
Rocky Mountain Arsenal
U.S. Army Property
USFWS National Wildlife Refuge
Lakes, Ponds, and Rivers
Wetlands
Dry Lake Areas
Buildings
First Creek Groundwater Intercept System
Shell Property
Section Lines
Intermittent Streams
Ditches
Off-Post Primary Road
Off-Post Secondary Road
Off-Post Light Duty Road
Slurry Walls
Surface Water Sites
Figure 6.3-1
N
0 350 700 1,400
Feet
NAD27-NGVD29 Datum, US Survey Feet,
Colorado North Zone
Sources: U.S. Army BIMS, USGS, RVOGIS,
URS - Washington Division
Remediation Venture Office GIS
11/26/2008 DPRA, Inc.
2180000
2185000
200000
195000
Burlington Ditch
O'Brian Canal
76
2
E. 104th Avenue
Havana St.
Peoria St.
Potomac St.
SW37001
First Creek Groundwater Intercept System
Maul Reservoir
First Creek
E. 96th Avenue
SW24004
North Boundary Containment System

APPENDIX A

GROUNDWATER TRAVEL TIMES, AND AQUIFER TEST AND PROPERTY DATA

APPENDIX A
GROUNDWATER TRAVEL TIMES, AND AQUIFER TEST AND PROPERTY DATA

A.1 INTRODUCTION

Section 3.1.2.1 in the Long-Term Monitoring Plan (LTMP) text discusses groundwater travel times for various contaminant migration pathways at Rocky Mountain Arsenal (RMA). Section A.2 in this appendix is included to provide more information on the input values and assumptions used to derive those estimates.

Extraction system area-of-influence groundwater travel times are calculated in Section A.3 to evaluate proposed shut-off monitoring frequencies when the extraction systems are turned off. The shut-off monitoring frequencies are quarterly during the first year and last year, and annual during the intervening years for the containment systems, and quarterly during the first year and semiannual during the second year for mass removal systems. Retardation of the contaminants representing the range of mobility of the contaminants present at each system is included in the analysis.

Aquifer test results and aquifer property data have been compiled from RMA documents and reports as a reference for hydrogeologic evaluations and are presented in Section A.4. These data are used to estimate groundwater velocities and travel times in the LTMP and include hydraulic conductivity, effective porosity, and aquifer sediment organic carbon.

References are listed in Section A.5.

A.2 GROUNDWATER TRAVEL TIMES FOR CONTAMINANT MIGRATION PATHWAYS

Groundwater velocities and travel times are estimated for contaminant migration pathways using hydraulic conductivity data compiled in Table A-19, which is attached at the end of Appendix A, and are compared to estimates in the Water Remedial Investigation (RI) (Ebasco 1989). Where available, hydraulic conductivity data from aquifer pumping or injection tests are preferred to slug or falling head tests because they are more representative of conditions in larger areas of the aquifer. The test types are indicated in Table A-19. Hydraulic gradients are from the 2006 regional water table map unless indicated otherwise. Effective porosity data are either measured or assumed values as discussed in Section A.3.

A.2.1 South Plants Pathways

Groundwater pathways in the former South Plants have historically radiated from the centrally located water table mound in this area. The primary pathways associated with contaminant migration include the north pathway from South Plants toward Basin A and a second pathway trending southwest toward Lake Ladora.

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GROUNDWATER TRAVEL TIMES, AND AQUIFER TEST AND PROPERTY DATA

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Section 3.1.2.1 in the Long-Term Monitoring Plan (LTMP) text discusses groundwater travel times for various contaminant migration pathways at Rocky Mountain Arsenal (RMA). Section A.2 in this appendix is included to provide more information on the input values and assumptions used to derive those estimates.

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Groundwater velocities and travel times are estimated for contaminant migration pathways using hydraulic conductivity data compiled in Table A-19, which is attached at the end of Appendix A, and are compared to estimates in the Water Remedial Investigation (RI) (Ebasco 1989). Where available, hydraulic conductivity data from aquifer pumping or injection tests are preferred to slug or falling head tests because they are more representative of conditions in larger areas of the aquifer. The test types are indicated in Table A-19. Hydraulic gradients are from the 2006 regional water table map unless indicated otherwise. Effective porosity data are either measured or assumed values as discussed in Section A.3.

A.2.1 South Plants Pathways

Groundwater pathways in the former South Plants have historically radiated from the centrally located water table mound in this area. The primary pathways associated with contaminant migration include the north pathway from South Plants toward Basin A and a second pathway trending southwest toward Lake Ladora.

A.2.1.1 South Plants North

Groundwater in the north pathway flows primarily through saturated alluvium with lesser flow through the unconfined bedrock. The average linear velocity for alluvial flow is estimated to range from 0.3 to 9 feet per day (ft/day) (Ebasco 1989). Using the faster flow velocity, the travel time in the alluvial flow path from the center of the groundwater mound to the center of Basin A is approximately 1 year. This estimate using 1989 assumptions appears to be unrealistic under current conditions. The alluvium is unsaturated in South Plants and the hydraulic gradient is extremely flat (Segment 1 below). Within South Plants, the travel time in Segment 1 is estimated to be greater than 100 years, but the 2006 gradient probably is not representative due to transient conditions. From the north end of South Plants, where the alluvium is saturated, to the middle of Basin A, the travel time is estimated to be approximately 28 years (Segment 2). The water elevation in the middle of Basin A is estimated because it is based on contours derived from wells located at the edges of the basin. This calculation may be refined when monitoring commences in the Basin A wells, which were installed in 2008, and are inside the Basin A footprint.

Table A-1. South Plants North Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
Segment 1	
01515 (DEN)	1.73
01602 (DEN)	3.6
	Average = 2.7
Segment 2	
36058 (A/D)	11.4
36070 (ALL)	19.8
36300 (A/D)	4.25
	Average = 11.8

Segment 1

SV= Ki/n where:
Average K = 2.7 ft/day
2006 Hydraulic gradient, i = 0.0001 ft/ft
Porosity, n = 0.05 (assumed)
Seepage Velocity, SV = 0.005 ft/day
Distance, D = 600 ft (well 01078 to 01525)
Travel time, T = D/SV ≥100 years

Segment 2

SV= Ki/n where:
Average K = 11.8 ft/day
2006 Hydraulic gradient, i = 0.0055 ft/ft (estimate)
Porosity, n = 0.25 (assumed)
Seepage Velocity, SV = 0.26 ft/day
Distance, D = 2,700 ft (well 01525 to middle of Basin A)
Travel time, T = D/SV = 28 years

A.2.1.2 South Plants Southwest

Groundwater in the southwest pathway flows through both alluvium and bedrock. Average linear velocity in alluvium ranged from 0.017 to 2.1 ft/day (Ebasco 1989). The shortest travel time in the alluvial flow path from the center of the groundwater mound to Lake Ladora is estimated to be 2.8 years. Significantly less flow occurs in the unconfined bedrock. The alluvium is unsaturated in most of this pathway; thus, the estimated alluvial travel time likely is not representative.

An estimate of the groundwater travel time between the South Tank Farm (STF) Groundwater Mass Removal (GWMR) System was made in the GWMR Design Analysis Report (Washington Group 2005). The average groundwater flow velocity was estimated to range from 95 to 162 ft/year (0.26 to 0.44 ft/day). Over a distance of 1,200 feet (ft) downgradient of the STF plume, the travel time was estimated to range from 12.6 to 7.4 years using hydraulic gradients in 2004 and 2005. Using the 2006 gradient and the information below, the travel time is estimated as 8.7 years.

Table A-2. South Plants Southwest Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
02029 (DEN)	1.0
02505 (DEN)	3.4
02598 (DEN)	1.26
	Average = 1.9

SV= Ki/n where:
Average K = 1.9 ft/day
2006 Hydraulic gradient, i = 0.01 ft/ft
Porosity, n = 0.05 (assumed)
Seepage Velocity, SV = 0.38 ft/day
Distance, D = 1,200 ft (well 02522 to 02505)
Travel time, T = D/SV = 8.7 years

A.2.2 Basin A to Basin A Neck System (BANS) Pathway

Groundwater in Section 36 flows through both the alluvium and bedrock. Average linear velocity in alluvium ranged from 0.04 to 11.7 ft/day in the Water RI. Corresponding travel times from the center of Basin A to the downgradient end of Basin D ranged from 1.5 to 44.5 years.

More recent data provided below indicate that the travel time from the south end of Basin A to the BANS is approximately 20 years. The water elevation at the south end of Basin A is estimated because it is based on contours derived from wells located at the edges of the basin. In the future, as remediation is completed and the Integrated Cover System is installed, local recharge feeding the Basin A aquifer will be significantly reduced, resulting in further flattening of the hydraulic gradient in the Basin A aquifer and further reducing the groundwater velocity and contaminant migration rates and increasing the travel times.

Table A-3. Basin A to BANS Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
26503 (ALL)	52.2
35509 (A/D)	27.8
36123 (A/D)	13.2
36300 (A/D)	4.25
36301 (ALL)	2.84
36599 (ALL)	11.9
	Average = 18.7

SV= Ki/n where:
Average K = 18.7 ft/day
2006 Hydraulic gradient, i = 0.009 ft/ft
Porosity, n = 0.25 (assumed)
Seepage Velocity, SV = 0.67 ft/day
Distance, D = 5,000 ft (from south end of Basin A to BANS)
Travel time, T = D/SV = 20 years

A.2.3 BANS to Northwest Boundary Containment System (NWBCS) Pathway

A continuation of the Basin A Neck pathway extends from beneath Basin D to the northwest boundary. Flow in this area is primarily through alluvial deposits. Saturated thickness typically is 10 ft or less; however, a north-trending channel with a saturated thickness of 20 to 30 ft is located in the western part of Section 27. Hydraulic conductivity estimates from aquifer tests near the NWBCS indicate much higher values than in the Basin A Neck channel as indicated in Table A-3 below. The average hydraulic conductivity in the Basin A Neck channel from two pumping tests at the BANS is estimated to be 40 ft/day. No representative aquifer tests are available in the Basin A Neck channel downgradient of the BANS. Similar hydraulic gradients in the Basin A Neck channel suggest that the hydraulic conductivity is similar to that estimated at the BANS. Travel times from the downgradient end of Basin D to the NWBCS were estimated in the Water RI to range from 0.2 to 41 years. Using the more recent data below to narrow the range in estimated travel times, the groundwater velocity in the Basin A Neck channel is estimated to be approximately 2 ft/day, and 4.9 ft/day in Section 27, upgradient of the NWBCS. Thus, the groundwater travel time from the BANS to the NWBCS is estimated to be approximately 11 years.

Table A-4. BANS to NWBCS Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
A-Neck	
26503 (ALL)	52.2
35509 (A/D)	27.8
	Average = 40
NWB	
22068 (ALL)	587
27067 (ALL)	1134
	Average = 861

A Neck channel
SV= Ki/n where:
Average K = 40 ft/day
2006 Hydraulic gradient, i = 0.013 ft/ft
Porosity, n = 0.25 (assumed)
Seepage Velocity, SV = 2.1 ft/day
Distance, D = 7,200 ft (35505 to 27079)
Travel time, T = D/SV = 9.4 years

Northwest Boundary (NWB) pathway
SV= Ki/n where:
Average K = 861 ft/day
2006 Hydraulic gradient, i = 0.002 ft/ft
Porosity, n = 0.35 (measured)
Seepage Velocity, SV = 4.9 ft/day
Distance, D = 2,500 ft (27079 to 22502)
Travel time, T = D/SV = 1.4 year

Total Travel Time = 10.8 years

A.2.4 Other NWBCS Pathways

Other contaminant migration pathways from sources upgradient of the NWBCS include the South Plants West plume (Original System) and South Plants Southwest plume (Southwest Extension [SWE]), and travel time calculations are provided below.

A.2.4.1 South Plants to NWBCS Original System (from Section 3 well 03005)

The travel time for the South Plants West plume from Section 3 to the NWBCS is estimated to be approximately 3.5 years. The flow path is divided into two segments with different hydraulic conductivities and gradients.

Table A-5. South Plants to NWBCS Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
Segment 1	
03505 (ALL)	130.4
03506 (A/D)	258
03510 (A/D)	723
	Average = 370.5
Segment 2	
22020 (ALL)	835
27067 (ALL)	1134
	Average = 985

Segment 1
SV= Ki/n where:
Average K = 370.5 ft/day
2006 Hydraulic gradient, i = 0.02 ft/ft
Porosity, n = 0.30
Seepage Velocity, SV = 24.7 ft/day
Distance, D = 2,000 ft (03005+2000 ft)
Travel time, T = D/SV = 0.2 years

Segment 2
SV= Ki/n where:
Average K = 985 ft/day
2006 Hydraulic gradient, i = 0.0036 ft/ft
Porosity, n = 0.35
Seepage Velocity, SV = 10.1 ft/day
Distance, D = 12,000 ft (+2000 ft to 22008)
Travel time, T = D/SV = 3.3 years

Total Travel Time = 3.5 years

A.2.4.2 Lake Mary to NWBCS SWE

The travel time for the South Plants Southwest plume downgradient of Lake Mary in Section 3 to the NWBCS is estimated to be approximately 2.4 years. The flow path is divided into two segments with different hydraulic conductivities and gradients.

Table A-6. Lake Mary to NWBCS SWE Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
Segment 1	
03505 (ALL)	130.4
03506 (A/D)	258
03510 (A/D)	723
	Average = 370.5
Segment 2	
27507 (A/D)	1134
27508 (A/D)	1672
27512 (A/D)	935
	Average = 1,247

Segment 1
SV= Ki/n where:
Average K = 370.5 ft/day
2006 Hydraulic gradient, i = 0.017 ft/ft
Porosity, n = 0.30
Seepage Velocity, SV = 21 ft/day
Distance, D = 2,500 ft (03016 to 03015)
Travel time, T = D/SV = 0.3 years

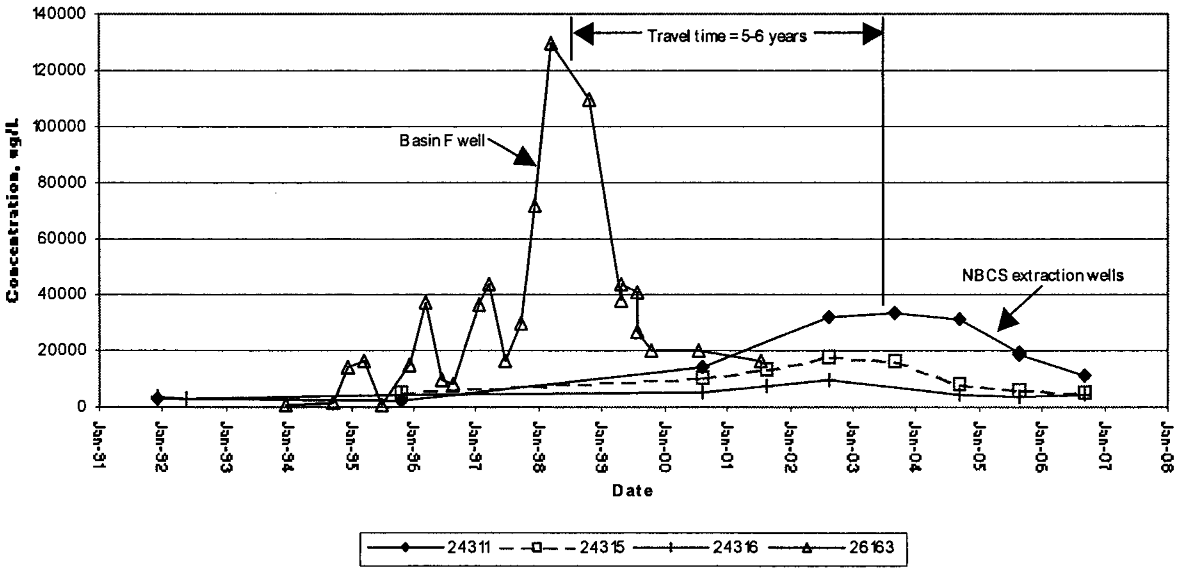
Segment 2
SV= Ki/n where:
Average K = 1247 ft/day
2006 Hydraulic gradient, i = 0.0037 ft/ft
Porosity, n = 0.35
Seepage Velocity, SV = 13.2 ft/day
Distance, D = 10,350 ft (03015 to 27510)
Travel time, T = D/SV = 2.1 years

Total Travel Time = 2.4 years

A.2.5 Basin F Pathway

Contaminant migration from Basin C and Basin F occurs in alluvial material and weathered bedrock. The Basin F pathway extends north and northeast to the North Boundary Containment System (NBCS). Estimated average linear velocity ranged from 0.17 to 15.6 ft/day in the Water RI. Travel time from the northeast corner of Basin F to the NBCS ranged from 1.1 to 99 years. Based on more recent data and a short-term increase in nitrate concentrations that could be tracked in wells from the northeast corner of Basin F (well 26163) to the NBCS (extraction wells 24311, 24315, and 24316), the travel time from Basin F to the NBCS is estimated to be 5 to 6 years (Figure A-1). Nitrate is a conservative compound and migrates at a similar rate as the groundwater. The NBCS extraction wells are sampled annually, so it is not possible to narrow the estimate based on these wells. The NBCS influent is sampled more frequently and the peak in concentrations in the influent occurred in the second quarter of Fiscal Year 2003 (FY03). Thus, the travel time is estimated to be approximately 5 years based on these data.

Figure A-1
Travel Time from Basin F to NBCS
Based on Nitrate Concentrations



Based on a seepage velocity calculation using the assumptions below, the travel time from Basin F to the NBCS is estimated to be about 6 years. These two estimates are very similar and the estimate based on nitrate concentrations may be more accurate because it is similar to a tracer test and is a more direct estimate with fewer assumptions.

Table A-7. Basin F Pathway Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
23049 (ALL)	964
23096 (ALL)	992
23237 (A/D)	244
24013 (ALL)	170
24025 (ALL)	224
24043 (ALL)	207
	Average = 467

SV= Ki/n where:
Average K = 467 ft/day
2006 Hydraulic gradient, i = 0.0019 ft/ft
Porosity, n = 0.25 (assumed)
Seepage Velocity, SV = 3.5 ft/day
Distance, D = 7,800 ft (well 26163 to 24316)
Travel time, T = D/SV = 6.1 years

A.2.6 North Plants Pathway

The travel time from North Plants to the NBCS is estimated to be approximately 6 years based on the assumptions below.

Table A-8. North Plants Pathway Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
24013 (ALL)	170.1
24025 (ALL)	224
24043 (ALL)	207
24092 (ALL)	177
25062 (A/D)	196
	Average = 195

SV= Ki/n where:
Average K = 195 ft/day
2006 Hydraulic gradient, i = 0.0059 ft/ft
Porosity, n = 0.30 (assumed)
Seepage Velocity, SV = 3.8 ft/day
Distance, D = 8,300 ft (well 25059 to 24130)
Travel time, T = D/SV = 6 years

A.2.7 Western Tier Pathway

Contaminant migration from the Railyard and Motor Pool occurs in coarse-grained alluvial sand and gravel. Average linear velocity along the Railyard and Motor Pool pathway was estimated to range from 3.0 to 60 ft/day in the Water RI. If the Railyard Containment System (RYCS) is shut down, the groundwater travel time from the Motor Pool/Railyard area to the former Irondale Containment System (ICS) was estimated between 0.44 and 8.6 years (Ebasco 1989). Using hydraulic conductivity data from more recent aquifer tests in wells located in or near the groundwater flow path (i.e., wells 03505, 03506, 03510, 04507, 33302, 33304, and 33305) (Table A-10), a July 2007 hydraulic gradient of 0.0037 ft/ft, and an effective porosity of 0.3, the travel time was calculated. The distance between the Railyard extraction system and the RMA boundary is approximately 7,800 ft. The travel time is estimated to be 2.5 years (Estimate 1).

The aquifer test for well 33302 was re-analyzed (WCC 1991) and the estimated hydraulic conductivity was reduced from 1,786 ft/day to 806 ft/day. Averaging the re-analyzed hydraulic conductivity for well 33302, the average groundwater velocity is estimated to be 6.8 ft/day, and the average groundwater travel time is 3.1 years (Estimate 2). Thus, the average groundwater travel time from the Railyard extraction system to the RMA boundary is estimated to range from 2.5 to 3.1 years.

Table A-9. Western Tier Pathway Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
Estimate 1	
03505 (ALL)	130.4
03506 (A/D)	258
03510 (A/D)	723
04507 (A/D)	194
33302 (A/D)	1786
33304 (A/D)	1145
33305 A/D)	587
	Average = 689
Estimate 2	
03505 (ALL)	130.4
03506 (A/D)	258
03510 (A/D)	723
04507 (A/D)	194
33302 (A/D)	806 (re-analyzed)
33304 (A/D)	1145
33305 (A/D)	587
	Average = 549

Estimate 1
SV= Ki/n where:
Average K = 689 ft/day
2007 Hydraulic gradient, i = 0.0037 ft/ft
Porosity, n = 0.30 (calculated)
Seepage Velocity, SV = 8.5 ft/day
Distance, D = 7,800 ft (RYCS to 33060)
Travel time, T = D/SV = 2.5 years

Estimate 2
SV= Ki/n where:
Average K = 549 ft/day
2007 Hydraulic gradient, i = 0.0037 ft/ft
Porosity, n = 0.30 (calculated)
Seepage Velocity, SV = 6.8 ft/day
Distance, D = 7,800 ft (RYCS to 33060)
Travel time, T = D/SV = 3.1 years

A.2.8 Off-Post First Creek and Northern Pathways

Contaminant migration in the Northern pathways occurs in fine- to coarse-grained sands that comprise most of the saturated alluvium, overlain by finer grained materials (silts or silty or clayey sands). Contaminant migration in the First Creek pathway occurs in coarser grained sands interfingered with lenses or layers of finer grained silts, silty sands, or clayey sands. The average linear velocity in the Northern pathway is estimated to be 3.3 ft/day with a travel time from the NBCS to the Northern pathway portion of Off-Site Groundwater Intercept and Treatment System (OGITS) of 5.2 years. Average linear velocity in the First Creek pathway is estimated to be 3 ft/day with a travel time from the NBCS to the First Creek portion of OGITS of 2.9 years.

A.2.8.1 Aquifer Tests

The focus of aquifer testing is to estimate aquifer characteristics to be used during the design of treatment systems, including transmissivity, hydraulic conductivity, and storage coefficient, and to estimate well efficiency. These tests can be used to assist in the development of monitoring programs for treatment systems. The test methods used typically include (in order) a step-drawdown test, recovery, a 24-hour constant-rate pumping test, and recovery monitoring. The information obtained through the pumping and recovery stages of the test is analyzed by one of three standard methods to compute transmissivity and average hydraulic conductivity of the aquifer.

The First Creek and Northern pathway systems underwent aquifer testing in 1990 (HLA 1990), yielding the following estimates of hydraulic conductivity, hydraulic gradient, and aquifer cross-section area:

Parameter	**First Creek Pathway**	**Northern Pathway**
Hydraulic Conductivity (centimeters per second [cm/sec])	4.6×10^{-2}	6.2×10^{-2}
Hydraulic Gradient	0.005	0.005
Aquifer Cross-Section Area (square feet [ft^2])	39,000	43,600

The hydraulic conductivity values estimated from the test data fall within the range reported for unconsolidated silty sand to clean sand aquifers. Total groundwater flows through the First Creek and Northern pathways have been estimated at 130 and 200 gallons per minutes (gpm), respectively. As mentioned previously, aquifer test results are compiled in Appendix A.

A.2.9 Off-Post First Creek and Northern Pathway Systems to the South Platte River

Since contaminant plumes were present downgradient of the OGITS before it was installed in 1993, groundwater travel times from the FCS and NPS to the South Platte River are estimated. Except near OGITS, the hydraulic conductivity test data are sparse, and there are no test wells downgradient of the FCS and NPS within the respective flow paths (Figure A-1). Furthermore, there is a wide range in the available hydraulic conductivities used in the calculations (from 20 to 1300 feet/day). Consequently, it is uncertain whether the average hydraulic conductivities used in the estimates are representative for the flow paths. Therefore, two estimates are developed for each flow path to provide a range for the travel time estimates.

Development of gravel pits for surface water storage near the South Platte River has changed the hydraulic gradients and hydrology near the river. Slurry walls were installed around some of the gravel pits and some have systems to pump the groundwater into the gravel pit. The flow paths downgradient of the FCS and NPS either intersect or pass near these gravel pits. Consequently, the groundwater in these flow paths may no longer discharge into the river. Thus, a 1994 hydraulic gradient is used in the calculations, which pre-dates the gravel pit development.

For the FCS, the groundwater travel time for the flow path downgradient from the central portion of the FCS (well 37343) was estimated below. Two travel-time estimates are calculated to provide a range due to the uncertainty discussed above. Estimate 1 uses the average hydraulic conductivity for 4 aquifer tests; 2 wells in the FCS, and 2 private wells farther off-post. Estimate

2 uses the average hydraulic conductivity for the 2 FCS wells. The groundwater travel time from the FCS to the river is estimated to range from 2.6 to 10.7 years.

Table A-10. FCS Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
Estimate 1	
1213B (ALL)	1,040
490C (ALL)	1,300
37802 (A/D)	150
37422 (ALL)	173
	Average = 666
Estimate 2	
37802 (A/D)	150
37422 (ALL)	173
Estimate 2	Average = 162

Estimate 1
SV= Ki/n where:
Average K = 666 ft/day
1994 Hydraulic gradient, i = 0.0068 ft/ft
Porosity, n = 0.30 (assumed)
Seepage Velocity, SV = 15.1 ft/day
Distance, D = 14,500 ft (well 37343 to River)
Travel time, T = D/SV = 2.6 years

Estimate 2
SV= Ki/n where:
Average K = 162 ft/day
1994 Hydraulic gradient, i = 0.0068 ft/ft
Porosity, n = 0.30 (assumed)
Seepage Velocity, SV = 3.7 ft/day
Distance, D = 14,500 ft (well 37343 to River)
Travel time, T = D/SV = 10.7 years

For the NPS, the groundwater travel time for the flow path downgradient from the northeast end of the NPS (well 37009) was estimated below. Two travel-time estimates also are calculated for the NPS to provide a range. Estimate 1 uses the average hydraulic conductivity for 6 aquifer tests; 4 wells in the NPS, and 2 private wells farther off-post. Estimate 2 uses the average hydraulic conductivity for 2 of the NPS wells. The groundwater travel time from the NPS to the river is estimated to range from 3.3 to 9.2 years.

Table A-11 Northern Pathway Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
Estimate 1	
1213B (ALL)	1,040
490C (ALL)	1,300
37806 (A/D)	140
37807 (A/D)	190
37901 (A/D)	20
37902 (A/D)	46
	Average = 456
Estimate 2	

Well (aquifer)	Hydraulic Conductivity, K, ft/day
37806 (A/D)	140
37807 (A/D)	190
	Average = 165

Estimate 1
SV= Ki/n where:
Average K = 456 ft/day
1994 Hydraulic gradient, i = 0.0067 ft/ft
Porosity, n = 0.30 (assumed)
Seepage Velocity, SV = 10.2 ft/day
Distance, D = 12,400 ft (well 37009 to River)
Travel time, T = D/SV = 3.3 years

Estimate 2
SV= Ki/n where:
Average K = 165 ft/day
1994 Hydraulic gradient, i = 0.0067 ft/ft
Porosity, n = 0.30 (assumed)
Seepage Velocity, SV = 3.7 ft/day
Distance, D = 12,400 ft (well 37009 to River)
Travel time, T = D/SV = 9.2 years

A. 3 EXTRACTION SYSTEM AREA OF INFLUENCE TRAVEL TIMES

A.3.1 Shut-Off Monitoring Frequency

The Record of Decision (ROD) shut-off monitoring frequency of quarterly for 5 years is to be changed to quarterly during the first and last year, with annual monitoring during the intervening years. This section provides information on travel times within the areas of influence of the extraction system that would be most affected by potential rebound of contaminant concentrations after shut-off.

U.S. Environmental Protection Agency (EPA) (1996) described six stages of pump-and-treat remediation and the initial year of shut-off monitoring corresponds to EPA's Stage 4, Post-Termination Monitoring, when monitoring of water levels and contaminant concentrations is conducted to determine when the groundwater flow system is re-established. Potential causes of concentrations to increase after a pump-and-treat system is turned off include rebound and potential migration from continuing sources. Rebound is addressed below and migration from continuing sources will be addressed during the consultative approach for each system when the shut-off and post-shut-off monitoring programs are developed.

Rebound

The term "rebound" pertains to the potential increase in concentrations at an extraction system immediately after extraction wells are turned off. It is caused by the return to the natural flow conditions and gradient. Contaminant concentrations in higher permeability preferential flow pathways that contained a greater proportion of flow during pumping may have declined faster than in less permeable zones. After pumping ends, residual contamination at higher concentrations migrating in the less permeable zones may then be detected and cause the concentrations in monitoring wells to increase. Desorption of contaminants from the aquifer sediments may also cause concentrations to increase when pumping ends and the groundwater flow returns to the natural gradient. Thus, rebound primarily occurs in the area of influence of the system where steeper hydraulic gradients have been induced.

To address potential rebound, the following approach will be used:

- More frequent shut-off monitoring will be conducted during the initial, first year of the shutdown period to monitor rebound.
- Monitoring frequency will be quarterly as this is an accepted standard frequency that addresses seasonal variations in groundwater levels and conditions, and allows adequate time for normal analytical analysis, quality assurance (QA), and evaluation of the data.
- Groundwater velocity and travel time within the area of influence of each system or discrete portions of a system will be estimated to determine when the groundwater flow system is re-established and confirm that quarterly water quality monitoring for 1 year is adequate during the initial stage when rebound is most likely.
- The ranges of retardation factors for the contaminants present are also calculated to compare contaminant migration rates to the proposed sampling frequencies.

A.3.2 NWBCS

The NWBCS is divided into three components: the Original System, Northeast Extension (NEE), and SWE. Due to the thin saturated zone and low flows at the NEE, it is not included in this section.

A.3.2.1 NWBCS Original System

An upgradient area of influence of 150 ft is conservatively determined from the FY06 Operational Assessment Report (OAR) water table map. Upgradient of this distance, the hydraulic gradient returns to the regional gradient. This appears to be a representative distance for the hydraulic barrier portion of the system.

A pre-NWBCS gradient of 0.002 ft/ft from July–August 1981 (PMRMA 1987) is used to calculate the groundwater velocity after shut-off. The groundwater travel time is estimated as approximately 31 days. Chloroform and dieldrin are the most prevalent of the Containment System Remediation Goal (CSRG) analytes at the NWBCS. Chloroform and dieldrin retardation factors are estimated to be 1.02 and 3.5, respectively. These estimates are consistent with retardation factor ranges for the NWBCS in the Off-Post Endangerment Assessment/Feasibility Study (EA/FS) (HLA 1992b), which were 1 to 4 for chloroform 2 to 5 for dieldrin. The chloroform and dieldrin travel times within the area of influence are estimated to be 32 and 109 days, respectively. Thus, quarterly shut-off monitoring for the first year is appropriate.

Table A-12. NWBCS Hydraulic Conductivity and Fractional Organic Carbon

Well (aquifer)	Hydraulic Conductivity, K, ft/day
22068 (ALL)	587
27067 (ALL)	1134
	Average = 861
Well (aquifer)	Fractional Organic Carbon, foc
27088 (ALL)	0.000052
27090 (ALL)	0.00014
27091 (A/D)	0.00001
	Average = 0.000067

SV= Ki/n where:
Average K = 861 ft/day
Hydraulic gradient, i = 0.002 ft/ft
Porosity, n = 0.35 (measured, WCC 1991))
Seepage Velocity, SV = 4.9 ft/day
Distance, D = 150 ft (FY06 OAR water table)
Travel time, T = D/SV = 31 days

Chloroform Retardation
$R_f = 1+D_b(Koc)(foc)/n$ where:
Bulk density, Db = 1.8 g/cm^3 (Ebasco 1992)
Koc = 44.7 L/mg (Ebasco 1992)
Average foc = 0.000067
Porosity, n = 0.35
$R_f = 1.02$

Dieldrin Retardation
$R_f = 1+D_b(Koc)(foc)/n$ where:
Bulk density, D_b = 1.8 g/cm^3 (Ebasco 1992)
Koc = 7244 L/mg (Ebasco 1992)
Average foc = 0.000067
Porosity, n = 0.35
$R_f = 3.5$

Chloroform Travel Time
Groundwater travel time, T_{GW} = 31 days
Chloroform retardation, R = 1.02
Chloroform travel time,
$T_{CHCL3} = T_{GW} \times R_f$ = 32 days

Dieldrin Travel Time
Groundwater travel time, T_{GW} = 31 days
Dieldrin retardation, R_f = 3.5
Dieldrin travel time,
$T_{DLDRN} = T_{GW} \times R_f$ = 109 days

A.3.2.2 NWBCS SWE

An upgradient area of influence of 150 ft for the SWE was determined from the FY06 OAR water table map. The hydraulic gradient is steeper within this area. Upgradient of this distance, the hydraulic gradient returns to the regional gradient. A pre-SWE gradient of 0.0025 ft/ft from February 1990 (MKES 1990c) is used to calculate the groundwater velocity after shut-off. The groundwater travel time during shut-off is estimated as from 11 to 13 days. Dieldrin is the only Contaminant of Concern (COC) at the SWE. With dieldrin retardation estimated to be 3.5 to 3.9, the dieldrin travel time is estimated to be between 39 and 51 days within the area of influence. Thus, quarterly shut-off monitoring for the first year is more than adequate to monitor rebound.

Table A-13. NWBCS SWE Hydraulic Conductivity and Fractional Organic Carbon

Well (aquifer)	Hydraulic Conductivity, K, ft/day
27508 (A/D)	1672
Well	Fractional Organic Carbon, foc
27088 (ALL)	0.000052
27090 (ALL)	0.00014
27091 (A/D)	0.00001
	Average = 0.000067

Groundwater Travel Time
SV= Ki/n where:
K = 1672 ft/day
Hydraulic gradient, i = 0.0025 ft/ft (27044 to27505 in 1990)
Porosity, n = 0.35 (measured, WCC 1991)
Seepage Velocity, SV = 11.9 ft/day
Distance, D = 150 ft (FY06 OAR water table)
Travel time, T = D/SV = 13 days

Dieldrin Retardation
$R_f = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 7244 (Ebasco 1992)
Average foc = 0.000067
Porosity, n = 0.35
$R_f = 3.5$

Dieldrin Travel Time
Groundwater travel time, $T_{GW} = 13$ days
Dieldrin retardation, $R_f = 3.5$
Dieldrin travel time, $T_{DLDRN} = T_{GW} \times R_f = 46$ days

A.3.3 NBCS

For the purposes of this analysis, the pre-existing hydraulic gradient before the slurry wall was constructed will be used in the calculation. The highest concentrations for the largest number of contaminants occur at extraction wells 24311, 24315, and 24316. Therefore, the estimated travel time in the area of influence is for the area near these three wells. DIMP and dieldrin are selected to represent the range of contaminant mobility for NBCS CSRG analytes. Other compounds may have lower partition coefficients than diisopropylmethyl phosphonate (DIMP) (e.g., 1,2-dichloroethane, chloroform, and n-nitrosodimethylamine [NDMA]), but they are less widespread and would migrate at a rate similar to the groundwater. No aquifer sediment organic carbon data are available in this area. Consequently, an average of 14 alluvial wells, excluding Basin A (Section 36), was used for the calculation of retardation. Using the information below, the retardation factors are 1.4 for DIMP and 2 to 5 for dieldrin. The associated average travel times within a 150-ft area of influence are 59 to 70 days for DIMP and 84 to 250 days for dieldrin. Quarterly shut-off monitoring for the first year therefore, is adequate.

Table A-14. NBCS Hydraulic Conductivity and Fractional Organic Carbon

Well (aquifer)	Hydraulic Conductivity, K, ft/day
24013 (ALL)	170
24025 (ALL)	224
24043 (ALL)	207
	Average = 200
Well	Fractional Organic Carbon, foc
14 wells	Average = 0.00048

SV= Ki/n where:
Average K = 200 ft/day
1979 Hydraulic gradient, i = 0.0045 ft/ft
Porosity, n = 0.25 to 0.30 (assumed)
Seepage Velocity, SV = 3.6 to 3 ft/day
Distance, D = 150 ft (FY06 OAR)
Travel time, T = D/SV = 42 to 50 days

<u>DIMP Retardation</u>
$R_f = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8\ g/cm^3$ (Ebasco 1992)
Koc = 123 (Ebasco 1992)
Average foc = 0.00048
Porosity, n = 0.25 to 0.30
$R_f = 1.4$ to 1.35 ($R_f = 1$ to 2 in Off-Post EA/FS, HLA 1992b)

<u>Dieldrin Retardation</u>
$R_f = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8\ g/cm^3$ (Ebasco 1992)
Koc = 7244 L/mg (Ebasco 1992)
Average foc = 0.00048
Porosity, n = 0.25 to 0.3
$R_f = 25$ to 22 ($R_f = 2$ to 5 in Off-Post EA/FS, HLA 1992b)

The retardation estimate for dieldrin appears too high based on observed migration. Since the total organic carbon concentration in Table A-12 is an average of wells in other areas, using foc of 0.00048 probably is not appropriate. The Off-Post EA/FS (HLA 1992b) used a range of retardation factors for dieldrin of 2 to 5. Since the aquifer sediments at NBCS and off post are similar, the Off-Post EA/FS retardation factors were used in the dieldrin calculations. The range of DIMP retardation factors of 1 to 2 in the Offpost EA/FS agree with the calculated values of 1.4 to 1.35. Thus, retardation of 1.4 for DIMP is used in the estimate of DIMP travel time.

DIMP Travel Time
Groundwater travel time, T_{GW} = 42 to 50 days
DIMP retardation, R = 1.4
DIMP travel time, $T_{DIMP} = T_{GW} \times R_f$ = 59 to 70 days

Dieldrin Travel Time
Groundwater travel time, T_{GW} = 42 to 50 days
Dieldrin retardation, R_f = 2 to 5 (Off-Post EA/FS, HLA 1992b)
Dieldrin travel time, $T_{DLDRN} = T_{GW} \times R_f$ = 84 to 250 days

A.3.4 RYCS
An upgradient area of influence of 180 feet for the RYCS was determined from the FY06 OAR water table map. The hydraulic gradient is steeper within this area and the hydraulic gradient upgradient of this distance returns to the regional gradient. A pre-RYCS gradient of 0.0078 ft/ft from July 1989 (MKE 1989) is used to calculate the groundwater velocity after shut-off. The groundwater travel time during shut-off is estimated as 19 to 22 days. Dibromochloropropane (DBCP) is the only COC at the RYCS. No aquifer sediment organic carbon data are available in this area. Consequently, an average of 14 alluvial wells, excluding Basin A (Section 36), was used for the calculation of retardation. Based on the coarse-grained sands and gravels and low fines contents in the Railyard, the organic carbon content likely is lower than the average used in the calculation. With DBCP retardation estimated to be 1.7 to 1.6, the DBCP travel time is estimated to be between 32 and 35 days within the area of influence. Thus, quarterly shut-off monitoring for the first year is more than adequate to monitor rebound.

Table A-15. RYCS Hydraulic Conductivity and Fractional Organic Carbon

Well (aquifer)	Hydraulic Conductivity, K, ft/day
03505 (ALL)	130.4
03506 (A/D)	258
03510 (A/D)	723
	Average = 370
Alluvial wells outside of Section 36	Fractional Organic Carbon, foc
14 wells	Average = 0.00048

SV= Ki/n where:
Average K = 370 ft/day
1989 Hydraulic gradient, i = 0.0078 ft/ft
Porosity, n = 0.30 to 0.35
Seepage Velocity, SV = 9.6 to 8.2 ft/day
Distance, D = 180 ft (2006 OAR)
Travel time, T = D/SV = 19 to 22 days

DBCP Retardation
$R = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 257 (Ebasco 1992)
Average foc = 0.00048
Porosity, n = 0.30 to 0.35
$R_f = 1.7$ to 1.6

DBCP Travel Time
Groundwater travel time, $T_{GW} = 19$ to 22 days
DBCP retardation, $R_f = 1.7$ to 1.6
DBCP travel time, $T_{DBCP} = T_{GW} \times R_f = 32$ to 35 days

A.3.5 BANS
The area of influence upgradient of the extraction system is estimated to be 50 feet in FY06. For the purposes of this analysis, the pre-existing hydraulic gradient (i.e., in 1989) before the slurry wall was constructed will be assumed.

NDMA and dieldrin are selected to represent the range of contaminant mobility for BANS CSRG analytes. The alluvial aquifer foc was measured in two wells in Basin A (36163 and 36165). Well 36163 is located near the Shell Trenches and well 36165 is located in Basin A. The foc data for well 36165 will be used for this calculation; however, the average foc for both wells is similar (i.e., 0.0039 and 0.004). The retardation for NDMA is estimated to be 1 and dieldrin is estimated to be between 3 and 6. The corresponding travel times are estimated to be 21 days for NDMA and between 63 and 126 days for dieldrin.

Table A-16. BANS Hydraulic Conductivity and Fractional Organic Carbon

Well (aquifer)	Hydraulic Conductivity, K, ft/day
26503 (ALL)	52.2
35509 (A/D)	27.8
	Average = 40
Well (aquifer)	Fractional Organic Carbon, foc
36165 (ALL)	0.0054
	0.0059
	0.0007
	Average = 0.004

SV= Ki/n where:
Average K = 40 ft/day
1989 Hydraulic gradient, i = 0.015 ft/ft (35079 to 26154)
Porosity, n = 0.25 (assumed)
Seepage Velocity, SV = 2.4 ft/day
Distance, D = 50 ft (FY06 OAR)
Travel time, T = D/SV = 21 days

NDMA Retardation
$R = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 0.1 (Ebasco 1992)
Average foc = 0.004
Porosity, n = 0.25 (assumed)
$R_f = 1.0$

Dieldrin Retardation
$R_f = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 7244 (Ebasco 1992)
Average foc = 0.004
Porosity, n = 0.25 (assumed)
$R_f = 210$

This retardation estimate for dieldrin appears too high based on observed migration. Dieldrin was first produced in 1951 and would have been disposed in Basin A. It was detected at the NWBCS via the Basin A Neck channel at least by 1985, which is 34 years. Using a 1979 hydraulic gradient, the groundwater travel time from the location of BANS to the NWB is estimated as approximately 11 years, which yields a retardation factor of approximately 3 (plume travel time/groundwater travel time). The gradients were probably higher when Basin A was used for waste disposal. If the gradient in Basin A Neck was twice that in 1979, the travel time to the NWB would have been about 6 years, which gives a retardation factor of 6. Hence dieldrin retardation of 3 to 6 will be assumed in the calculation below. The presence of dissolved organic carbon in the groundwater and colloidal transport have been hypothesized to facilitate the transport sorptive compounds such as dieldrin, and may explain the reduced retardation relative to the calculated value above.

NDMA Travel Time
Groundwater travel time, $T_{GW} = 21$ days
NDMA retardation, $R_f = 1$
NDMA travel time, $T_{NDMA} = T_{GW} \times R_f = 21$ days

Dieldrin Travel Time
Groundwater travel time, $T_{GW} = 21$ days
Dieldrin retardation, $R_f = 3$ to 6
Dieldrin travel time, $T_{DLDRN} = T_{GW} \times R_f = 63$ to 126 days

A.3.6 Bedrock Ridge

The area of influence upgradient of the extraction system is estimated to be 50 ft in FY06. The groundwater travel time is estimated to be 128 days. No foc data are available for Denver Formation sandstones at RMA and it would be speculative to assume retardation factors for the Bedrock Ridge Extraction System (BRES).

Table A-17. BRES Hydraulic Conductivity

Well (aquifer)	Hydraulic Conductivity, K, ft/day
36556 (DEN)	19.8
36560 (DEN)	11.1
	Average = 15.5

SV= Ki/n where:
Average K = 15.5 ft/day
1998 Hydraulic gradient, i = 0.005 ft/ft
Porosity, n = 0.20 (assumed)
Seepage Velocity, SV = 0.39 ft/day
Distance, D = 50 ft (FY06 OAR)
Travel time, T = D/SV = 128 days

A.3.7 OGITS

The areas of influence are estimated to be 200 ft for well 37802 in the First Creek System (FCS) and 100 feet in the Northern Pathway System (NPS) from the FY06 OAR water table map. A pre-OGITS regional gradient of 0.005 ft/ft is used to calculate the groundwater velocity after shut-off. The groundwater travel time in the FCS is estimated as approximately 68 days, and 34 days in the NPS. Contaminants representing the range of mobility of the CSRG analytes are 1,2-dichloroethylene (12DCLE) and DCPD at the FCS, and DIMP and dieldrin at the NPS. The retardation factors range from 1.1 to 5. The retardation factors for DCPD and dieldrin are calculated higher than 5 based on available information, but dieldrin, which is more sorptive than DCPD, was estimated to range from 2 to 5 in the Off-Post EA/FS, thus 5 is assumed to be the maximum value. The estimated contaminant travel times within the areas of influence range from 37 and 340 days.

Table A-18. OGITS Hydraulic Conductivity and Fractional Organic Carbon

System	Hydraulic Conductivity, K, ft/day
FCS	130
NPS	176
Well (aquifer)	Fractional Organic Carbon, foc
FCS	
37343 (ALL)	0.001
NPS	
37344 (ALL)	0.00018

A.3.7.1 First Creek System (FCS)

SV= Ki/n where:
Average K = 130 ft/day
1989 Hydraulic gradient, i = 0.005 ft/ft
Porosity, n = 0.30 (assumed)

Seepage Velocity, SV = 2.2 ft/day
Distance, D = 150 ft (FY06 OAR)
Travel time, T = D/SV = 68 days

<u>1,2-Dichloroethylene Retardation</u>
$R_f = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 15.8 (Ebasco 1992)
Average foc = 0.001
Porosity, n = 0.30 (assumed)
$R_f = 1.1$

<u>DCPD Retardation</u>
$R = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 977 (Ebasco 1992)
Average foc = 0.001
Porosity, n = 0.30 (assumed)
$R_f = 6.9$ (Dieldrin R = 2 to 5 in Offpost EA/FS)

<u>1,2-Dichloroethylene Travel Time</u>
Groundwater travel time, $T_{GW} = 68$ days
12DCLE retardation, $R_f = 1.1$
12DCLE travel time, $T_{12DCLE} = T_{GW} \times R_f = 75$ days

<u>DCPD Travel Time</u>
Groundwater travel time, $T_{GW} = 68$ days
DCPD retardation, $R_f = 2$ to 5 (assumed for dieldrin)
DCPD travel time, $T_{DCPD} = T_{GW} \times R_f = 136$ to 340 days

<u>A.3.7.2 Northern Pathway System (NPS)</u>

SV= Ki/n where:
Average K = 176 ft/day
1989 Hydraulic gradient, i = 0.005 ft/ft
Porosity, n = 0.30 (assumed)
Seepage Velocity, SV = 2.9 ft/day
Distance, D = 100 ft (FY06 OAR)
Travel time, T = D/SV = 34 days

<u>DIMP Retardation</u>
$R = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 123 (Ebasco 1992)
Average foc = 0.00018
Porosity, n = 0.30 (assumed)

$R_f = 1.1$ ($R_f = 1$ to 2 in Off-Post EA/FS HLA 1992b)

Dieldrin Retardation
$R = 1+D_b(Koc)(foc)/n$ where:
Bulk density, $D_b = 1.8$ g/cm^3 (Ebasco 1992)
Koc = 7244 (Ebasco 1992)
Average foc = 0.00018
Porosity, n = 0.30 (assumed)
$R_f = 8.8$ ($R_f = 2$ to 5 in Off-Post EA/FS HLA 1992b)

DIMP Travel Time
Groundwater travel time, $T_{GW} = 34$ days
DIMP retardation, $R_f = 1.1$
DIMP travel time, $T_{DIMP} = T_{GW} \times R_f = 37$ days

Dieldrin Travel Time
Groundwater travel time, $T_{GW} = 34$ days
DLDRN retardation, $R_f = 2$ to 5 (assumed)
DLDRN travel time, $T_{DLDRN} = T_{GW} \times R_f = 68$ to 170 days

A.4 AQUIFER TEST AND AQUIFER PROPERTY DATA

Data included in this section include hydraulic conductivity, effective porosity, and aquifer sediment organic carbon. Approximately 370 aquifer tests have been conducted on post and off post near RMA to determine the hydraulic conductivity of the aquifers. The results of these aquifer tests have been compiled from RMA documents and reports (Table A-19). Although Table A-19 is a comprehensive listing, the results of every aquifer test conducted at or near RMA may not be included. Hydraulic conductivity is one of the parameters used to estimate groundwater velocity and travel time. Other parameters used in the calculation are the hydraulic gradient and effective porosity of the aquifer sediments. The hydraulic gradient is determined from water level monitoring at RMA. Effective porosity of the aquifer sediments may be measured from soil samples or determined during groundwater tracer tests. Effective porosity may also be assumed based on literature values for different lithologies when borehole lithology descriptions are available. The organic carbon content data provided in Table A-20 are used to estimate retardation factors for the groundwater contaminants, which is a determination of the relative migration rate of the contaminants to the groundwater velocity.

Measurements of other parameters used to estimate groundwater velocity and retardation are more limited and are provided in Appendix E of the Remedial Investigation Summary Report (RISR) (Ebasco 1992). RISR Appendix E contains assumed bulk density and effective porosity, literature-derived partition coefficients, and calculated retardation factors for a range of measured organic carbon contents for the RMA COCs in saturated unconfined aquifer sediments and saturated lakebed sediments and soils. The organic carbon content data for aquifer sediments in RISR Appendix E are from wells in Basin A. As indicated in Table A-20, the organic carbon content of the alluvial aquifer is higher in Basin A than in other areas of RMA.

Consequently, the retardation factors in other areas of RMA may be lower than those listed in RISR Appendix E. In order to better estimate the retardation factors in other areas, the organic carbon content data for aquifer sediments have been compiled from RMA documents and reports and are provided in Table A-20.

A.4.1 Hydraulic Conductivity

Table A-19 contains a compilation of hydraulic conductivity data derived from well and packer tests and includes information such as test type, analysis method, test reference, and other pertinent information where possible. It is grouped by flow system (i.e., unconfined monitoring wells and private wells, questionable, and confined). Within flow system groups, the table is ordered by well ID. The test locations are shown on Figure A-2.

A.4.2 Effective Porosity

Effective porosity measurements in the alluvial aquifer are limited to the NWBCS and Irondale areas. In the coarse-grained sand and gravel of the alluvium in the western part of RMA, the effective porosity was estimated to range from 0.31 to 0.35 (WCC 1991). Elsewhere, the porosity likely is lower due to the finer grained nature of the alluvial sands, and may be assumed to range from 0.20 to 0.30 depending on the grain size and grading/sorting of the sands as described in the lithologic logs for wells and boreholes. Effective porosity in the Denver Formation is lower than in the alluvium with porosity of approximately 0.2 in the sandstones and 0.05 to 0.10 in the weathered claystones. In the STF plume area of South Plants, the porosity in the weathered Denver Formation was estimated to range from a total porosity of approximately 0.50 based on laboratory analyses of soil samples, to an effective porosity of 0.001 based on a field tracer test (Foster Wheeler 1996).

A.4.3 Organic Carbon

Table A-20 is a compilation of organic carbon concentration data for saturated zone alluvial and Denver sediment samples and is ordered by well ID. The test well locations are shown on Figure A-3.

A.5 REFERENCES

Black & Veatch Consulting Engineers

1980 (April) *Final Design Analysis, Liquid Waste Facility, North Boundary Expansion, Rocky Mountain Arsenal, Commerce City, Colorado.*

Bopp, F. and Kolmer, J.R.

1979 (Sept.) *Hydrogeology and Water Quality of Basin A Neck Area, Rocky Mountain Arsenal,* Denver, *Colorado.* U.S. Army Waterways Experiment Station.

Broughton, J.D., Miller, W.O., and Mitchell, G.B

1979 (June) *Geology and Groundwater Definition, Basin A Area, Rocky Mountain Arsenal, Denver, Colorado.* U.S. Army Waterways Experiment Station.

Chadwick, D.G

2005 *Results of North Boundary Enhancement/HRC Project Pumping Test.* Personal Communication.

Ebasco Services Incorporated

1992 (Jan.) Final Remedial Investigation Summary Report.

1989 (July) Water Remedial Investigation Report.

Ertec Western, Inc.

1981 Hydraulic Conductivity and the Unified Soils Classification System at Rocky Mountain Arsenal, Denver, Colorado. November.

Environmental Science and Engineering, Inc. (ESE)

1988a Task 25 Study Report.

1988b (Sept.) Determination of Partition Coefficients for the Primary Contaminant Sources of Section 36, Draft Final Report, Version 2.2, Task No. 23.

1987 (April) Rocky Mountain Arsenal, Offpost Assessment Contamination Assessment Report, Volume 1, Draft Final Report.

Environmental Science and Engineering, Inc. (ESE), Ebasco Services, Inc., Applied Environmental, Inc., CH2M Hill, DataChem, Inc., R.L. Stollar & Associates, Inc.

1990 (Aug.) Boundary Control Systems Assessment Remedial Investigation, A Hydrogeologic Interpretation and Contamination Assessment at the North and Northwest Boundaries, Final Report.

Finch, W.C. and Mathews, R.D.

1971 (Feb.) Hydro-Geological Investigation of Waste Water Evaporation Pond Site. Shell Oil Company.

Foster Wheeler Environmental Corporation (FWENC)

1996 (Jan.) South Tank Farm Plume In Situ Biotreatability Study, Final, Version 3.0.

Harding Lawson Associates (HLA)

1999 (June) Final Groundwater Monitoring Report for the Eighth Round of Pre-operational Monitoring for the Double-lined Landfill, Rocky Mountain Arsenal, Commerce City, Colorado.

1994 (Sept.) Final Fiscal Year 1993 Operational Assessment Report for the Offpost Treatment System, Rocky Mountain Arsenal, Commerce City, Colorado.

1992a (Sept.) Results of Treatability Studies for Groundwater Containment and/or Control and Subsurface Drains, Final Report.

1992b Offpost Endangerment Assessment/Feasibility Study for the Offpost Operable Unit, Rocky Mountain Arsenal.

Harding Lawson Associates (HLA) and Malcolm Pirnie, Inc.

1990 (June) Results of Pilot- Scale Hydraulic and Treatment Testing North of Rocky Mountain Arsenal, Interim Response A, Draft Final Report.

Knaus, J.H.
1982 (Aug. 5) Shell letter to RMA Commander transmitting South Plants pumping test results.

May, J.H., Thompson, D.W., Law, P.K., and Wahl, R.E.
1980 (Jan.) Hydrogeologic Assessment of Denver Sands Along North Boundary of Rocky Mountain Arsenal. U.S. Army Waterways Experiment Station.

May, J.H.
1982 (July) Regional Groundwater Study of Rocky Mountain Arsenal, Denver Colorado, Report 1, Hydrogeological Definition. Geotechnical Laboratory, U.S. Army Waterways Experiment Station.

May, J.H., Crabtree, J.D., Hunt, R.W., and Murphy, W.L.
1983 (Sept.) Hydrogeology of Basin A/South Plants Area, Rocky Mountain Arsenal, Denver Colorado, Phase 1. Geotechnical Laboratory, U.S. Army Waterways Experiment Station.

Mitchell, G.B.
1976 Interim Containment System RMA Memorandum for Record. Prepared for Decontamination Systems Technical Working Group. U.S. Army Corps of Engineers Waterways Experiment Station.

MK Environmental Services (MKES)
1994 (April) White Paper, Evaluation of the Denver Formation at Rocky Mountain Arsenal.

1990a (May) Hydrogeologic and Water Quality Conditions, South Tank Farm Plume, RMA.

1990b (June) Preliminary Engineering Design Package for Rail Classification Yard/Motor Pool Area Interim Response Action.

1990c (June) Report of Field Investigations, Assessment, and Final Decision Document for the Northwest Boundary System Short-Term Improvements Interim Response Action.

1990d Northwest Boundary System Short-Term Improvements Interim Response Action Project File.

Morrison-Knudsen Corporation (MK)
1999 (March) Section 36 Bedrock Ridge Groundwater Plume Extraction System, 100 Percent Design Package.

1989 (Feb.) Preliminary Engineering Design Package for the Basin A Neck Groundwater Intercept and Treatment System Interim Response Action. .

Morrison-Knudsen Services (MKE)
1989 Final Alternatives Assessment For Other Contamination Sources Interim Response Action, Rail Classification Yard, RMA.

Program Manager Rocky Mountain Arsenal (PMRMA)
1987 (Dec.) Northwest Boundary Containment/Treatment System Baseline Conditions, System Startup, and Operational Assessment Report for FY 85/86.

Rocky Mountain Arsenal Remediation Venture Office (RVO)
1997 (Sept.) Complex Trenches and Shell Section 36 Trenches Groundwater Barrier Project, 100 Percent Design Package.

Tetra Tech EC, Inc.
2007 (Mar. 29) Rocky Mountain Arsenal, Section 36 Lime Basins Soil Remediation Project, Slurry/Barrier Wall Design, 100 Percent Design Package, Design Analysis.

U. S. Army Corps of Engineers (USACE)
1986 (March) Construction Foundation Report, Northwest Boundary, RMA Containment/Treatment System.

1953 (July) Report on Water Supply Investigation, Rocky Mountain Arsenal, Denver, CO.

U.S. Army Engineer Waterways Experiment Station (WES)
1979 (Aug.) Basin F Containment Hydrogeology Assessment, Rocky Mountain Arsenal, Denver Colorado, Report on Results of Deep Drilling Activities.

U. S. Environmental Protection Agency (EPA)
1996 Methods for Evaluating Pump and Treat Systems.

USATHAMA
1961 (Jan.) Analysis of Well Tests Near Rocky Mountains Arsenal, RMA RIC# 81266R58.

Vispi, M.A.
1978 (Sept.) Report of Finding, Rocky Mountain Arsenal Pumping Tests. U.S.Army Corps of Engineers, Waterways Experiment Station.

Washington Group
2005 (Dec.) Groundwater Mass Removal Project Groundwater Extraction/Recharge System Design Analysis Report Final, Prepared for Rocky Mountain Arsenal Remediation Venture Office.

Woodward-Clyde Consultants (WCC)
1991 (June) Northwest Boundary System Long-Term Improvements Interim Response Action B (ii) Final Assessment Document.

1982 (June) Report of Groundwater Model of Hydraulic Barrier, Northwest Boundary Containment Treatment System PN-37, Rocky Mountain Arsenal, Denver, Colorado. Omaha, Nebraska.

TABLE A-19. RMA Aquifer Tests

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
UNCONFINED FLOW SYSTEM								
01008	FH	DEN	U	8.090E-04	2.293E+00	Broughton et al. 1979		CL
01014	FH	DEN	U	3.040E-04	8.617E-01	Broughton et al.1979		CL
01017	FH	A/D	U	7.410E-04	2.100E+00	Broughton et al. 1979		CL
01088	SLUG	DEN	U	2.000E-03	5.669E+00	HLA 1992a		
01089	PUMP	DEN	U	2.800E-03	7.937E+00	HLA 1992a		
01099	SLUG	DEN	U	7.700E-04	2.183E+00	HLA 1992a		
01100	SLUG	DEN	U	1.400E-03	3.969E+00	HLA 1992a		
01101	SLUG	DEN	U	5.600E-05	1.587E-01	HLA 1992a		
01104	PUMP	A/D	U	3.800E-03	1.077E+01	HLA 1992a		
01515	SLUG	DEN	U	6.100E-04	1.729E+00	HLA 1992a		
01516	SLUG	DEN	U	5.200E-04	1.474E+00	HLA 1992a		
01521	SLUG	DEN	U	2.300E-03	6.520E+00	HLA 1992a		
01523	SLUG	DEN	U	1.600E-03	4.535E+00	HLA 1992a		
01530	SLUG	DEN	U	4.000E-03	1.134E+01	HLA 1992a		
01569	SLUG	DEN	U	1.500E-03	4.252E+00	HLA 1992a		
01580	INJ	A/D	U	3.700E-04	1.049E+00	MKES 1990a		
01601	PUMP	A/D	U	6.100E-03	1.729E+01	Knaus 1982		
01602	PUMP	DEN	U	1.270E-03	3.600E+00	Knaus 1982		
01603	PUMP	DEN	U	1.200E-03	3.402E+00	Knaus 1982		
02003	FH	DEN	U	2.150E-04	6.094E-01	Broughton et al. 1979		CL
02029	PUMP	DEN	U	3.493E-04	9.900E-01	Foster Wheeler 1996		
02065	PUMP	DEN	U	5.700E-03	1.616E+01	HLA 1992a		
02068	SLUG	DEN	U	1.300E-03	3.685E+00	HLA 1992a		
02505	INJ	DEN	U	1.200E-03	3.402E+00	MKES 1990a		
02562	SLUG	DEN	U	4.800E-04	1.361E+00	HLA 1992a		
02573	SLUG	DEN	U	1.800E-03	5.102E+00	HLA 1992a		
02582	SLUG	DEN	U	3.800E-04	1.077E+00	HLA 1992a		
02583	SLUG	DEN	U	1.200E-04	3.402E-01	HLA 1992a		
02598	INJ	DEN	U	4.450E-04	1.261E+00	MKES 1990a		
03505	INJ	ALL	U	4.600E-02	1.304E+02	MKES 1990b		
03506	INJ	A/D	U	9.100E-02	2.580E+02	MKES 1990b		
03510	INJ	A/D	U	2.550E-01	7.228E+02	MKES 1990b		
04304	PUMP	ALL	U	1.370E-01	3.883E+02	USACE 1953		
04507	INJ	A/D	U	6.840E-02	1.939E+02	MKES 1990		
19001	FH/RH	DEN	U	1.910E-03	5.414E+00	Ertec 1981		SM
19002	FH/RH	DEN	U	1.740E-04	4.932E-01	Ertec 1981		SM
19004	FH/RH	A/D	U	2.820E-03	7.994E+00	Ertec 1981		SP
19005	FH/RH	DEN	U	6.020E-04	1.706E+00	Ertec 1981		CH & CL

TABLE A-19. RMA Aquifer Tests

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
19006	FH/RH	DEN	U	1.230E-03	3.487E+00	Ertec 1981		CL
19007	FH/RH	A/D	U	1.620E-04	4.592E-01	Ertec 1981		SM & CH
22020	PUMP	ALL	U	7.986E-01	2.264E+03	May 1982	Jacob	NW-11, SW to SP
22020	PUMP	ALL	U	2.946E-01	8.350E+02	WCC 1991	Neuman	NW-11 Reanalyzed using Neuman method
22068	PUMP	ALL	U	2.071E-01	5.870E+02	WCC 1982/USACE 1986	Boulton	W-5
22301	PUMP	ALL	U	4.727E-02	1.340E+02	WCC 1991	Neuman	Tracer Test
23024	PUMP	A/D	U			Mitchell 1976		
23024	PUMP	A/D	U	4.200E-02	1.191E+02	ESE 1990		Mitchel test reanalyzed
23049	PUMP	ALL	U	4.660E-01	1.321E+03	Vispi 1978	Theis/Jacob/Chow	SP-GP. Use 23237 instead (falling WLs)
23049	PUMP	ALL	U	3.400E-01	9.638E+02	ESE et al. 1990		Vispi test reanalyzed
23067	PUMP	A/D	U	7.920E-02	2.245E+02	Vispi 1978	Theis/Jacob/Chow	SP-GP
23067	PUMP	A/D	U	9.400E-02	2.665E+02	ESE et al. 1990		Vispi test reanalyzed
23096	PUMP	ALL	U	4.240E-01	1.202E+03	Vispi 1978	Theis/Jacob/Chow	SP-GP
23096	PUMP	ALL	U	3.500E-01	9.921E+02	ESE et al. 1990		Vispi test reanalyzed
23142	FH/RH	A/D	U	4.500E-04	1.276E+00	Ertec 1981		CH & CL
23144	FH/RH	A/D	U	5.460E-05	1.548E-01	Ertec 1981		CH
23145	FH/RH	A/D	U	1.330E-03	3.770E+00	Ertec 1981		SP&CH
23146	FH/RH	A/D	U	3.950E-03	1.120E+01	Ertec 1981		SP&CH
23147	FH/RH	A/D	U	1.400E-05	3.969E-02	Ertec 1981		SP
23160	FH/RH	A/D	U	1.570E-04	4.450E-01	Ertec 1981		SM & CH
23167	SLUG	DEN	U	1.330E-05	3.770E-02	May et al. 1980		
23176	PUMP	DEN	U	1.200E-04	3.402E-01	Black and Veatch 1980		
23226	SLUG	DEN	U	2.220E-04	6.293E-01	ESE 1988a		
23227	SLUG	DEN	U	2.000E-06	5.669E-03	ESE 1988a		Silty sand
23237	INJ	A/D	U	8.600E-02	2.438E+02	MKE 1989		
23548	PUMP	DEN	U	6.700E-03	1.899E+01	Chadwick 2005		
24013	PUMP	ALL	U			Mitchell 1976		
24013	PUMP	ALL	U	6.000E-02	1.701E+02	ESE et al. 1990		Mitchel test reanalyzed
24025	PUMP	ALL	U			Mitchell 1976		
24025	PUMP	ALL	U	7.900E-02	2.239E+02	ESE et al. 1990		Mitchel test reanalyzed
24029	PUMP	ALL	U	1.540E-01	4.365E+02	Vispi 1978		SM-SP
24029	PUMP	ALL	U	1.400E-01	3.969E+02	ESE et al. 1990		SM-SP, Vispi test reanalyzed
24030	FH/RH	ALL	U	3.860E-05	1.094E-01	Ertec 1981		SP
24031	FH/RH	ALL	U	3.990E-02	1.131E+02	Ertec 1981		CL
24040	PUMP	ALL	U	1.700E-01	4.819E+02	Vispi 1978		
24043	PUMP	ALL	U	3.800E-02	1.077E+02	Vispi 1978		
24043	PUMP	ALL	U	3.800E-02	1.077E+02	May 1982		
24043	PUMP	ALL	U	7.300E-02	2.069E+02	ESE et al. 1990		Vispi test reanalyzed

TABLE A-19. RMA Aquifer Tests

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
24048	SLUG	ALL	U	2.484E-01	7.041E+02	ESE 1988a		SP
24049	SLUG	ALL	U	1.113E-01	3.155E+02	ESE 1988a		SP-GP
24080	FH/RH	DEN	U	4.920E-04	1.395E+00	Ertec 1981		SM & CH
24081	FH/RH	A/D	U	3.560E-03	1.009E+01	Ertec 1981		SM & CH
24082	FH/RH	DEN	U	1.620E-02	4.592E+01	Ertec 1981		SM
24083	FH/RH	DEN	U	6.370E-03	1.806E+01	Ertec 1981		SM & CL
24084	SLUG	ALL	U	9.910E-03	2.809E+01	ESE 1988a		SM
24086	FH/RH	DEN	U	1.850E-02	5.244E+01	Ertec 1981		SM. May be well 26015 based on screen interval
24087	FH/RH	DEN	U	8.680E-03	2.460E+01	Ertec 1981		SM
24088	FH/RH	A/D	U	4.820E-02	1.366E+02	Ertec 1981		Range average, SW
24092	SLUG	ALL	U	6.230E-02	1.766E+02	ESE 1988a		SM
24093	FH/RH	A/D	U	7.840E-04	2.222E+00	Ertec 1981		GC
24094	FH/RH	A/D	U	3.530E-02	1.001E+02	Ertec 1981		SM & CH
24096	FH/RH	A/D	U	9.900E-02	2.806E+02	Ertec 1981		SM & CH
24097	FH/RH	A/D	U	3.000E-02	8.504E+01	Ertec 1981		GM & CL
24098	FH/RH	A/D	U	8.240E-04	2.336E+00	Ertec 1981		SM
24099	FH/RH	A/D	U	6.430E-03	1.823E+01	Ertec 1981		SM & CH
24100	FH/RH	A/D	U	4.880E-03	1.383E+01	Ertec 1981		CL
24101	FH/RH	A/D	U	4.880E-04	1.383E+00	Ertec 1981		GP & CH
24102	FH/RH	A/D	U	1.420E-02	4.025E+01	Ertec 1981		SM & CH
24103	FH/RH	A/D	U	7.000E-07	1.984E-03	Ertec 1981		GH & CH
24105	FH/RH	A/D	U	2.220E-02	6.293E+01	Ertec 1981		CL
24106	FH/RH	A/D	U	1.530E-03	4.337E+00	Ertec 1981		SP & CL
24112	FH/RH	DEN	U	4.420E-03	1.253E+01	Ertec 1981		SM & CL
24113	FH/RH	A/D	U	4.000E-03	1.134E+01	Ertec 1981		SM & CL
24114	FH/RH	A/D	U	1.510E-05	4.280E-02	Ertec 1981		SM-SP
24115	SLUG	A/D	U	1.060E-02	3.005E+01	ESE 1988a		SM & CH
24126	SLUG	A/D	U	1.300E-02	3.685E+01	ESE 1988a		
24127	FH/RH	DEN	U	6.730E-04	1.908E+00	Ertec 1981		SM & CH
24129	SLUG	A/D	U	1.670E-02	4.734E+01	ESE 1988a		SM & CH
24130	FH/RH	DEN	U	4.650E-04	1.318E+00	Ertec 1981		CL
24135	SLUG	DEN	U	1.410E-02	3.997E+01	May et al. 1980		Fine to medium grained sand
24136	SLUG	DEN	U	1.710E-05	4.847E-02	May et al. 1980		
24140	SLUG	DEN	U	1.530E-04	4.337E-01	May et al. 1980		
24150	PUMP	A/D	U	5.856E-02	1.660E+02	Black and Veatch 1980		
24150	PUMP	A/D	U	8.300E-02	2.353E+02	ESE et al. 1990		B&V test reanalyzed
24153	PUMP	A/D	U	8.043E-02	2.280E+02	Black and Veatch 1980		
24153	PUMP	A/D	U	8.300E-02	2.353E+02	ESE et al.1990		B&V test reanalyzed
25022	SLUG	DEN	U	4.000E-04	1.134E+00	HLA 1999		sandstone

TABLE A-19. RMA Aquifer Tests

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
25027	SLUG	DEN	U	1.700E-03	4.819E+00	HLA 1999		sandstone
25028	SLUG	DEN	U	4.900E-06	1.389E-02	HLA 1999		claystone
25062	PUMP	A/D	U	6.900E-02	1.956E+02	HLA 1992a		
25065	SLUG	DEN	U	1.900E-05	5.386E-02	HLA 1999		claystone
25066	SLUG	DEN	U	3.300E-06	9.354E-03	HLA 1999		claystone
25082	SLUG	DEN	U	5.100E-04	1.446E+00	HLA 1999		sandstone
25087	SLUG	DEN	U	3.200E-03	9.071E+00	HLA 1999		sandstone
25089	SLUG	DEN	U	1.700E-03	4.819E+00	HLA 1999		sandstone
26014	FH/RH	ALL	U	3.750E-04	1.063E+00	Ertec 1981		SP-GP
26016	FH/RH	A/D	U	5.990E-03	1.698E+01	Ertec 1981		SP-GP
26017	FH/RH	ALL	U	1.130E-02	3.203E+01	Ertec 1981		SP-GP
26018	FH/RH	ALL	U	7.700E-05	2.183E-01	Ertec 1981		SP-GP
26039	FH/RH	DEN	U	1.790E-03	5.074E+00	Ertec 1981		CH
26063	FH	DEN	U	4.150E-04	1.176E+00	Broughton1979 et al.	Cooper	CH & SP
26066	SLUG	DEN	U	3.497E-04	9.913E-01	Bopp and Kolmer 1979	Cooper	
26070	FH	ALL	U	1.134E-04	3.214E-01	Bopp and Kolmer 1979	Bouwer and Rice	
26071	SLUG	DEN	U	1.153E-03	3.268E+00	Bopp and Kolmer 1979	Cooper	
26073	FH	DEN	U	4.199E-03	1.190E+01	Bopp and Kolmer 1979	Bouwer and Rice	
26081	FH	ALL	U	2.277E-04	6.454E-01	Bopp and Kolmer 1979	Bouwer and Rice	
26083	FH	A/D	U	2.441E-04	6.919E-01	Bopp and Kolmer 1979	Cooper	
26085	FH	ALL	U	9.735E-04	2.760E+00	Bopp and Kolmer 1979	Cooper	
26087	FH	ALL	U	9.735E-04	2.760E+00	Bopp and Kolmer 1979	Cooper	
26088	FH	A/D	U	4.380E-05	1.242E-01	Bopp and Kolmer 1979	Bouwer and Rice	
26089	SLUG	DEN	U	2.280E-03	6.463E+00	Bopp and Kolmer 1979	Cooper	
26090	SLUG	DEN	U	2.132E-03	6.043E+00	Bopp and Kolmer 1979	Cooper	Loosely cemented sand
26092	SLUG	DEN	U	5.509E-04	1.562E+00	Bopp and Kolmer 1979	Cooper	
26093	FH	ALL	U	8.300E-06	2.353E-02	Bopp and Kolmer 1979	Bouwer and Rice	
26094	SLUG	DEN	U	3.866E-04	1.096E+00	Bopp and Kolmer 1979	Cooper	
26123	FH/RH	DEN	U	5.080E-05	1.440E-01	Ertec 1981		CH & CL
26124	FH/RH	DEN	U	3.120E-04	8.844E-01	Ertec 1981		CH
26128	SLUG	DEN	U	1.215E-03	3.444E+00	Bopp and Kolmer 1979	Cooper	
26129	SLUG	DEN	U	1.832E-03	5.193E+00	Bopp and Kolmer 1979	Cooper	
26133	FH/RH	DEN	U	2.040E-05	5.783E-02	Ertec 1981		SM
26140	SLUG	DEN	U	7.100E-03	2.013E+01	WES 1979	Cooper	Medium-coarse grained sand
26166	SLUG	A/D	U	8.150E-03	2.310E+01	HLA 1994		
26168	SLUG	A/D	U	2.300E-04	6.520E-01	HLA 1994		
26169	SLUG	A/D	U	1.450E-02	4.110E+01	HLA 1994		
26171	SLUG	A/D	U	1.450E-02	4.110E+01	HLA 1994		
26501	SLUG	ALL	U	6.710E-03	1.902E+01	MKE 1989		
26503	INJ	ALL	U	1.840E-02	5.216E+01	MKE 1989		

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
27067	PUMP	ALL	U	3.965E-01	1.124E+03	WCC 1982	Boulton	W-4
27067	PUMP	ALL	U	4.036E-01	1.144E+03	USACE 1986	Boulton	W-4
27507	PUMP	A/D	U	4.000E-01	1.134E+03	MKES 1990c		
27508	PUMP	A/D	U	5.900E-01	1.672E+03	MKES 1990d		
27512	PUMP	A/D	U	3.300E-01	9.354E+02	MKES 1990d		
31003	FH	A/D	U	1.120E-03	3.175E+00	Broughton et al. 1979		CL
31522	PUMP	A/D	U	7.260E-02	2.058E+02	Finch and Mathews 1971		
33302	PUMP	A/D	U	6.299E-01	1.786E+03	May 1982	Jacob	W-2
33302	PUMP	A/D	U	2.843E-01	8.060E+02	WCC 1991	Neuman	W-2 Reanalyzed using Neuman method
33304	PUMP	A/D	U	4.040E-01	1.145E+03	USACE 1975		
33305	PUMP	A/D	U	2.070E-01	5.868E+02	USACE 1975		
35016	SLUG	DEN	U	9.850E-04	2.792E+00	Broughton et al. 1979	Cooper	SC
35018	FH	ALL	U	1.600E-04	4.535E-01	Broughton et al. 1979	Cooper	CL & SM
35020	FH	ALL	U	2.080E-04	5.896E-01	Broughton et al. 1979		CL & SM
35023	FH	A/D	U	5.880E-04	1.667E+00	Broughton et al. 1979		CL
35024	SLUG	DEN	U	7.980E-03	2.262E+01	Broughton et al. 1979		SM
35026	FH	ALL	U	7.780E-04	2.205E+00	Broughton et al. 1979		CL
35032	SLUG	DEN	U	7.733E-04	2.192E+00	Bopp and Kolmer 1979	Cooper	
35036	SLUG	DEN	U	3.495E-04	9.907E-01	Bopp and Kolmer 1979	Cooper	
35038	SLUG	DEN	U	2.450E-04	6.945E-01	Bopp and Kolmer 1979	Cooper	
35042	FH	A/D	U	1.190E-03	3.373E+00	Bopp and Kolmer 1979	Cooper	
35049	FH	DEN	U	1.571E-04	4.453E-01	Bopp and Kolmer 1979	Bouwer and Rice	
35506	SLUG	A/D	U	3.000E-05	8.504E-02	MKE 1989		
35509	INJ	A/D	U	9.810E-03	2.781E+01	MKE 1989		
36058	SLUG	A/D	U	4.020E-03	1.140E+01	Broughton et al. 1979		CL
36063	SLUG	A/D	U	3.010E-03	8.532E+00	Broughton et al. 1979		CH
36065	SLUG	ALL	U	1.250E-04	3.543E-01	Broughton et al. 1979		CL
36070	SLUG	ALL	U	7.000E-03	1.984E+01	Broughton et al. 1979		SM
36071	SLUG	DEN	U	5.370E-03	1.522E+01	Broughton et al. 1979		SM
36072	SLUG	DEN	U	3.330E-04	9.439E-01	Broughton et al. 1979		SM
36077	FH	ALL	U	5.510E-04	1.562E+00	Broughton et al. 1979		ML
36082	SLUG	ALL	U	4.450E-03	1.261E+01	Broughton et al. 1979		
36115	PUMP	A/D	U	6.700E-03	1.899E+01	MK 1999	Theis	Bedrock Ridge
36123	PUMP	A/D	U	4.650E-03	1.318E+01	May 1982		
36187	SLUG	ALL	U	2.0E-4 to 3.0E-3		WCC 1991		
36201	SLUG	DEN	U	3.0E-6 to 3.0E-5		WCC 1991		
36300	PUMP	A/D	U	1.500E-03	4.252E+00	HLA 1992a		
36301	PUMP	ALL	U	1.000E-03	2.835E+00	RVO 1997		Army Trenches Design
36544	SLUG	DEN	U	1.400E-05	3.969E-02	RVO 1997		Army Trenches Design

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WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
36545	SLUG	DEN	U	6.800E-05	1.928E-01	RVO 1997		Army Trenches Design
36554	PUMP	ALL	U	4.800E-03	1.361E+01	MK 1999	Theis	Bedrock Ridge
36555	PUMP	DEN	U	1.150E-01	3.260E+02	MK 1999	Theis	Bedrock Ridge
36556	PUMP	DEN	U	7.000E-03	1.984E+01	MK 1999	Theis	Bedrock Ridge
36560	PUMP	DEN	U	3.900E-03	1.106E+01	MK 1999	Theis	Bedrock Ridge
36595	PUMP	DEN	U	9.000E-06	2.551E-02	HLA 1992a		Claystone
36599	PUMP	ALL	U	4.200E-03	1.191E+01	HLA 1992a		
36702	PUMP	DEN	U	2.700E-03	7.654E+00	May et al. 1983	Jacob	Denver sandstone (SP), Test well APT-0 (between 36137 and 36150)
37376	SLUG	DEN	U	1.200E-04	3.402E-01	ESE 1988a		
37379	SLUG	DEN	U	2.220E-04	6.293E-01	ESE 1988a		
37380	SLUG	DEN	U	4.300E-05	1.219E-01	ESE 1988a		
37390	SLUG	DEN	U	2.200E-04	6.236E-01	ESE 1988a		
37408	PUMP	A/D	U	6.400E-02	1.814E+02	HLA and Pirnie 1990	Theis Recovery	
37409	PUMP	A/D	U	5.200E-02	1.474E+02	HLA and Pirnie 1990	Theis Recovery	
37410	PUMP	A/D	U	2.000E-01	5.669E+02	HLA and Pirnie 1990	Jacob Method	
37411	PUMP	A/D	U	6.300E-02	1.786E+02	HLA and Pirnie 1990	Theis	
37412	PUMP	ALL	U	5.300E-02	1.502E+02	HLA and Pirnie 1990	Theis	
37413	PUMP	A/D	U	7.200E-02	2.041E+02	HLA and Pirnie 1990	Theis	
37414	PUMP	A/D	U	3.900E-02	1.106E+02	HLA and Pirnie 1990	Theis	
37415	PUMP	A/D	U	7.400E-02	2.098E+02	HLA and Pirnie 1990	Theis	
37416	PUMP	ALL	U	8.800E-02	2.494E+02	HLA and Pirnie 1990	Theis	
37418	PUMP	A/D	U	3.200E-02	9.071E+01	HLA and Pirnie 1990	Theis Recovery	
37419	PUMP	A/D	U	3.900E-02	1.106E+02	HLA and Pirnie 1990	Theis Recovery	
37420	PUMP	A/D	U	2.600E-02	7.370E+01	HLA and Pirnie 1990	Theis Recovery	
37421	PUMP	A/D	U	5.300E-02	1.502E+02	HLA and Pirnie 1990	Theis	
37422	PUMP	ALL	U	6.100E-02	1.729E+02	HLA and Pirnie 1990	Theis	
37423	PUMP	A/D	U	4.800E-02	1.361E+02	HLA and Pirnie 1990	Theis	
37424	PUMP	A/D	U	5.300E-02	1.502E+02	HLA and Pirnie 1990	Theis	
37425	PUMP	A/D	U	3.000E-02	8.504E+01	HLA and Pirnie 1990	Theis	
37426	PUMP	ALL	U	3.500E-02	9.921E+01	HLA and Pirnie 1990	Theis	
37427	PUMP	A/D	U	5.500E-02	1.559E+02	HLA and Pirnie 1990	Theis	
37800	PUMP	A/D	U	2.858E-02	8.10E+01	HLA 1994	Theis Recovery	
37801	PUMP	A/D	U	2.999E-02	8.50E+01	HLA 1994	Theis	Renumbered from 37420
37802	PUMP	A/D	U	5.292E-02	1.50E+02	HLA 1994	Theis	Renumbered from 37418
37803	PUMP	A/D	U	1.940E-02	5.50E+01	HLA 1994	Theis Recovery	
37804	PUMP	A/D	U	2.505E-02	7.10E+01	HLA 1994	Theis Recovery	
37805	PUMP	A/D	U	3.881E-03	1.10E+01	HLA 1994	Theis Recovery	
37806	PUMP	A/D	U	4.939E-02	1.40E+02	HLA 1994	Theis Recovery	
37807	PUMP	A/D	U	6.703E-02	1.90E+02	HLA 1994	Theis Recovery	

TABLE A-19. RMA Aquifer Tests

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
37808	PUMP	A/D	U	1.411E-03	4.00E+00	HLA 1994	Theis Recovery	
37809	PUMP	A/D	U	1.305E-02	3.70E+01	HLA 1994	Theis Recovery	
37810	PUMP	A/D	U	8.114E-02	2.30E+02	HLA 1994	Theis Recovery	
37811	PUMP	A/D	U	1.094E-01	3.10E+02	HLA 1994	Theis Recovery	
37812	PUMP	DEN	U	1.446E-01	4.10E+02	HLA 1994	Theis Recovery	
37813	PUMP	A/D	U	9.172E-02	2.60E+02	HLA 1994	Theis Recovery	
37814	PUMP	A/D	U	1.552E-01	4.40E+02	HLA 1994	Theis Recovery	
37815	PUMP	A/D	U	1.482E-01	4.20E+02	HLA 1994	Theis Recovery	
37816	PUMP	A/D	U	1.446E-02	4.10E+01	HLA 1994	Theis Recovery	
37900	SLUG	A/D	U	3.528E-05	1.00E-01	HLA 1994	Bouwer Method	
37901	PUMP	A/D	U	7.056E-03	2.00E+01	HLA 1994	Theis Recovery	
37902	PUMP	A/D	U	1.623E-02	4.60E+01	HLA 1994	Theis Recovery	
37903	PUMP	A/D	U	6.350E-02	1.80E+02	HLA 1994	Theis Recovery	
37904	PUMP	A/D	U	4.233E-02	1.20E+02	HLA 1994	Theis Recovery	
37905	PUMP	A/D	U	4.233E-02	1.20E+02	HLA 1994	Theis Recovery	
37906	PUMP	A/D	U	1.446E-02	4.10E+01	HLA 1994	Theis Recovery	
37907	PUMP	A/D	U	5.997E-03	1.70E+01	HLA 1994	Theis Recovery	
37908	PUMP	A/D	U	1.517E-02	4.30E+01	HLA 1994	Theis Recovery	
37909	PUMP	A/D	U	1.693E-02	4.80E+01	HLA 1994	Theis Recovery	
37910	PUMP	A/D	U	8.819E-02	2.50E+02	HLA 1994	Theis Recovery	
37911	PUMP	A/D	U	1.235E-02	3.50E+01	HLA 1994	Theis Recovery	
37912	PUMP	A/D	U	5.997E-02	1.70E+02	HLA 1994	Theis Recovery	
37913	PUMP	A/D	U	1.870E-01	5.30E+02	HLA 1994	Theis Recovery	
37914	PUMP	A/D	U	6.703E-02	1.90E+02	HLA 1994	Theis Recovery	
37915	PUMP	A/D	U	1.058E-01	3.00E+02	HLA 1994	Theis Recovery	
37916	PUMP	A/D	U	1.094E-01	3.10E+02	HLA 1994	Theis Recovery	
37917	PUMP	A/D	U	8.819E-02	2.50E+02	HLA 1994	Theis Recovery	
37918	PUMP	A/D	U	1.305E-01	3.70E+02	HLA 1994	Theis Recovery	
37919	PUMP	A/D	U	6.350E-02	1.80E+02	HLA 1994	Theis Recovery	
37920	PUMP	A/D	U	3.881E-02	1.10E+02	HLA 1994	Theis Recovery	
37921	PUMP	A/D	U	1.129E-02	3.20E+01	HLA 1994	Theis Recovery	
37922	PUMP	A/D	U	2.469E-02	7.00E+01	HLA 1994	Theis Recovery	
37923	PUMP	A/D	U	1.976E-01	5.60E+02	HLA 1994	Theis Recovery	
Offpost Private Wells (See Comments for USGS locations)								Owner, Location (USGS system)
TCHD # (Site Type = TAPW)								
1190C	PUMP	ALL	U	4.692E-01	1.33E+03	USATHAMA 1961	Jacob/Theis	Aden well, T2S-R67W Sec. 9daa

TABLE A-19. RMA Aquifer Tests

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
1189A	PUMP	ALL	U	4.198E-01	1.19E+03	USATHAMA 1961	Jacob/Theis	Dobbs well, T2S-R67W Sec. 9ddb
1380C	PUMP	ALL	U	1.058E+00	3.00E+03	USATHAMA 1961	Jacob/Theis	Marty well, T2S-R67W Sec. 21add
1213B	PUMP	ALL	U	3.669E-01	1.04E+03	USATHAMA 1961	Jacob/Theis	Masunaga well, T2S-R67W Sec. 10dcc
641C	PUMP	ALL	U	9.313E-01	2.64E+03	USATHAMA 1961	Jacob/Theis	Matsumoto well, T2S-R67W Sec. 16ddc
641D	PUMP	ALL	U	9.596E-01	2.72E+03	USATHAMA 1961	Jacob/Theis	Matsumoto well, T2S-R67W Sec. 16ddd2
309B	PUMP	ALL	U	7.691E-01	2.18E+03	USATHAMA 1961	Jacob/Theis	Monson well, T2W-R67W Sec. 15badd
490C	PUMP	ALL	U	4.586E-01	1.30E+03	USATHAMA 1961	Jacob/Theis	Myers well, T2S-R67W Sec. 10bdcd
296D	PUMP	ALL	U	3.669E-01	1.04E+03	USATHAMA 1961	Jacob/Theis	Powers well, T2S-R67W Sec. 15ccd
Unknown	PUMP	ALL	U	4.022E-01	1.14E+03	USATHAMA 1961	Jacob/Theis	Wolpert well, T2S-R67W Sec. 4adb
SAC-17	PUMP	ALL	U	1.660E-01	4.706E+02	May 1982	Jacob	Commerce City Well, 77th and Quebec
SAC-17	PUMP	ALL	U	1.386E-01	3.930E+02	WCC 1991	Neuman	Commerce City Well, reanalyzed using Neuman method
Unknown	PUMP	ALL	U	3.828E-01	1.09E+03	RMA records 1955		Neson Well, T2S-R67W Sec. 22bcc
QUESTIONABLE FLOW SYSTEM								
23218	SLUG	DEN	V	2.400E-06	6.803E-03	ESE 1988a		
23219	SLUG	DEN	Q	2.370E-05	6.718E-02	ESE 1988a		
24032	FH/RH	DEN	Q	2.970E-05	8.419E-02	Ertec 1981		CH
24089	FH/RH	DEN	V	2.560E-03	7.257E+00	Ertec 1981		CH
24137	SLUG	DEN	Q	5.600E-06	1.587E-02	May et al. 1980		
24138	SLUG	DEN	Q	3.340E-05	9.468E-02	May et al. 1980		
24142	SLUG	DEN	Q	6.900E-05	1.956E-01	May et al. 1980		Clayey sand
24145	SLUG	DEN	Q	1.920E-05	5.443E-02	May et al. 1980		jointed clay
24154	PUMP	DEN	Q	3.900E-04	1.106E+00	Black and Veatch 1980		
24154	PUMP	DEN	Q	9.100E-08	2.580E-04	Ertec 1981		Obs. wells 24144 and 24155
24191	SLUG	DEN	V	7.000E-05	1.984E-01	ESE 1988a		
26069	SLUG	DEN	V	7.281E-04	2.064E+00	Bopp and Kolmer 1979	Cooper	
26086	SLUG	DEN	Q	6.766E-04	1.918E+00	Bopp and Kolmer 1979	Cooper	

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
35028	SLUG	DEN	Q	3.710E-05	1.052E-01	Broughton et al. 1979		CH
36078	SLUG	DEN	Q	5.660E-03	1.604E+01	Broughton et al. 1979		OH
36206	SLUG	DEN	Q	1.900E-04	5.386E-01	HLA 1992a		
37372	SLUG	DEN	Q	1.235E-04	3.500E-01	ESE 1988a		Medium grained sandstone
37387	SLUG	DEN	V	2.100E-04	5.953E-01	ESE 1988a		
CONFINED FLOW SYSTEM								
01015	SLUG	DEN	C	1.150E-04	3.260E-01	Broughton et al. 1979		SM
01079	SLUG	DEN	C	3.200E-05	9.071E-02	HLA 1992a		
01103	SLUG	DEN	C	3.400E-05	9.638E-02	HLA 1992a		
01109	SLUG	DEN	C	6.800E-06	1.928E-02	HLA 1992a		
01300	PUMP	DEN	C	4.800E-05	1.361E-01	HLA 1992a		
02004	SLUG	DEN	C	1.780E-03	5.046E+00	Broughton et al. 1979		SM
02064	SLUG	DEN	C	3.300E-06	9.354E-03	HLA 1992a		
02300	PUMP	DEN	C	1.000E-07	2.835E-04	HLA 1992a		Claystone
23161	SLUG	DEN	C	1.420E-05	4.025E-02	May 1980		
23162	SLUG	DEN	C	1.080E-05	3.061E-02	May 1980		
23163	SLUG	DEN	C	7.920E-05	2.245E-01	May 1980		
23164	SLUG	DEN	C	7.900E-07	2.239E-03	May 1980		
23168	SLUG	DEN	C	7.610E-05	2.157E-01	May 1980		
23169	SLUG	DEN	C	3.550E-05	1.006E-01	May 1980		
24131	SLUG	DEN	C	7.890E-05	2.237E-01	May 1980		
24132	SLUG	DEN	C	2.880E-05	8.164E-02	May 1980		
24133	SLUG	DEN	C	1.910E-05	5.414E-02	May 1980		
24134	SLUG	DEN	C	1.150E-05	3.260E-02	May 1980		
24139	SLUG	DEN	C	7.360E-05	2.086E-01	May 1980		
24141	SLUG	DEN	C	8.900E-06	2.523E-02	May 1980		
24143	SLUG	DEN	C	2.080E-05	5.896E-02	May 1980		
24144	SLUG	DEN	C	4.940E-04	1.400E+00	May 1980		
24146	SLUG	DEN	C	1.670E-05	4.734E-02	May 1980		
24147	SLUG	DEN	C	2.210E-04	6.265E-01	May 1980		
25009	PUMP	DEN	C	7.790E-04	2.208E+00	HLA 1999		sandstone
25063	PUMP	DEN	C	7.540E-04	2.137E+00	HLA 1999		sandstone
25064	PUMP	DEN	C	7.600E-04	2.154E+00	HLA 1999		sandstone
25081	SLUG	DEN	C	1.500E-04	4.252E-01	HLA 1999		sandstone
25083	SLUG	DEN	C	4.200E-05	1.191E-01	HLA 1999		sandstone
25085	SLUG	DEN	C	3.500E-04	9.921E-01	HLA 1999		sandstone
26064	SLUG	DEN	C	1.950E-03	5.528E+00	Broughton et al. 1979	Cooper	SM
26067	SLUG	DEN	C	7.238E-04	2.052E+00	Bopp and Kolmer 1979	Cooper	

TABLE A-19. RMA Aquifer Tests

WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
26072	SLUG	DEN	C	1.903E-03	5.394E+00	Bopp and Kolmer 1979		
26075	SLUG	DEN	C	7.232E-04	2.050E+00	Bopp and Kolmer 1979	Cooper	
26080	SLUG	DEN	C	2.020E-05	5.726E-02	Bopp and Kolmer 1979	Cooper	
26134	SLUG	DEN	C	2.200E-03	6.236E+00	WES 1979	Cooper	
26135	SLUG	DEN	C	1.300E-06	3.685E-03	WES 1979	Cooper	Siltstone
26136	SLUG	DEN	C	5.100E-05	1.446E-01	WES 1979		
26137	SLUG	DEN	C	1.900E-07	5.386E-04	WES 1979		Buffer zone
26138	SLUG	DEN	C	2.100E-05	5.953E-02	WES 1979		
26139	SLUG	DEN	C	1.500E-05	4.252E-02	WES 1979		Average of 2 tests
26141	SLUG	DEN	C	1.900E-03	5.386E+00	WES 1979	Cooper	
26142	SLUG	DEN	C	7.600E-06	2.154E-02	WES 1979		
31004	SLUG	DEN	C	3.040E-05	8.617E-02	Broughton et al. 1979		SM
35017	SLUG	DEN	C	1.370E-05	3.883E-02	Broughton et al. 1979	Cooper	SC
35019	SLUG	DEN	C	5.460E-04	1.548E+00	Broughton et al. 1979	Cooper	SM
35021	SLUG	DEN	C	1.710E-04	4.847E-01	Broughton et al. 1979		CH
35039	SLUG	DEN	C	1.289E-04	3.654E-01	Bopp and Kolmer 1979	Cooper	
35041	SLUG	DEN	C	1.297E-04	3.677E-01	Bopp and Kolmer 1979	Cooper	
36059	SLUG	DEN	C	3.120E-05	8.844E-02	Broughton et al. 1979		ML, CH, & SM
36064	SLUG	DEN	C	2.490E-05	7.058E-02	Broughton et al. 1979		SM
36066	SLUG	DEN	C	4.150E-05	1.176E-01	Broughton et al. 1979		OH
36079	SLUG	DEN	C	1.000E-03	2.835E+00	Broughton et al. 1979		CH
36083	SLUG	DEN	C	4.120E-05	1.168E-01	Broughton et al. 1979		OH
36598	SLUG	DEN	C	1.800E-05	5.102E-02	HLA 1992a		Sandstone
36598	PACKER	DEN	C	2.000E-07	5.669E-04	HLA 1992a		45 to 48.3 ft, siltstone, carbonaceous clay
36598	PACKER	DEN	C	2.000E-06	5.669E-03	HLA 1992a		49.5 to 54.5 ft, carbonaceous clay, sandstone
36602	SLUG	DEN	C	8.500E-06	2.409E-02	HLA 1992a		50.5 to 58 ft, claystone
36602	PACKER	DEN	C	2.000E-06	5.669E-03	HLA 1992a		36 to 41 ft, sandy siltstone, fractures
36602	PACKER	DEN	C	2.000E-07	5.669E-04	HLA 1992a		48 to 60 ft, claystone, coal, sandstone lens
Lime Basins Borings (Section 36) Packer Tests								
LB-03	PACKER	DEN		9.300E-07	2.636E-03	Tetra Tech 2007		52 to 60 ft, sandstone and claystone
LB-03	PACKER	DEN		3.900E-07	1.106E-03	Tetra Tech 2007		62 to 70 ft, claystone
LB-05	PACKER	DEN		3.000E-06	8.504E-03	Tetra Tech 2007		47 to 55 ft, sandstone and claystone

TABLE A-19. RMA Aquifer Tests

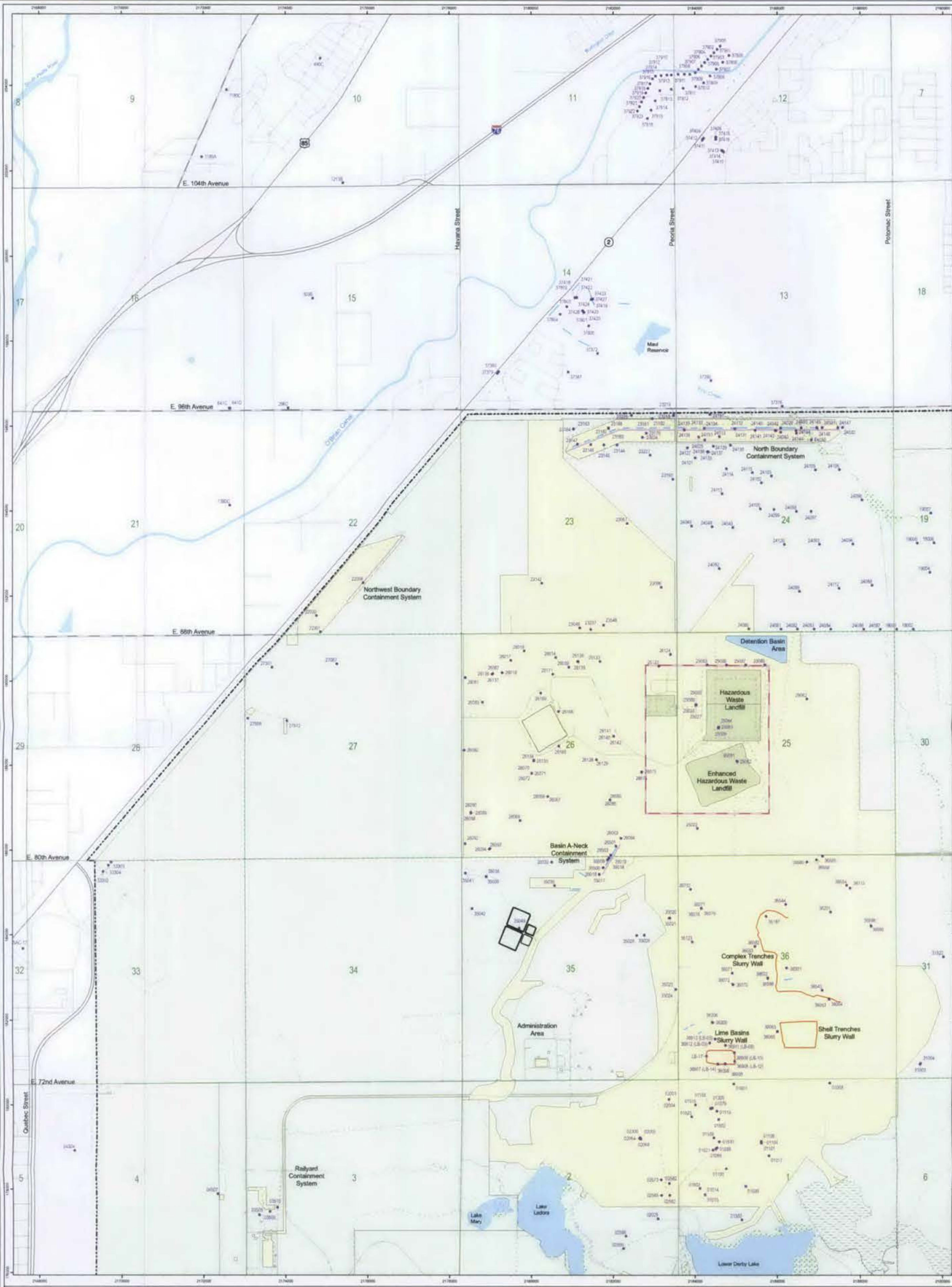
WELLID	TEST TYPE	AQUIFER	FLOW SYSTEM	K, cm/sec	K, ft/day	REFERENCE	ANALYSIS METHOD	COMMENTS Lithology, SSCS, etc.
LB-05	PACKER	DEN		7.600E-07	2.154E-03	Tetra Tech 2007		57 to 65 ft, claystone and sandstone
LB-08	PACKER	DEN		3.100E-07	8.787E-04	Tetra Tech 2007		47 to 55 ft, claystone and sandstone
LB-10	PACKER	DEN		4.000E-07	1.134E-03	Tetra Tech 2007		47 to 55 ft, claystone
LB-12	PACKER	DEN		1.200E-07	3.402E-04	Tetra Tech 2007		47 to 55 ft, claystone
LB-14	PACKER	DEN		5.100E-07	1.446E-03	Tetra Tech 2007		47 to 55 ft, claystone
LB-17	PACKER	DEN		6.100E-07	1.729E-03	Tetra Tech 2007		47 to 55 ft, claystone

TABLE A-20. RMA Aquifer Sediment Organic Carbon Data

WELL	AQUIFER	FLOW SYSTEM	DEPTH (cm)	DEPTH (ft)	MEDIAN GRAIN SIZE (mm)	ORGANIC CARBON (%)	FRACTIONAL ORGANIC CARBON, foc	REFERENCE	FORMATION	LITHOLOGY
22081	A/D	U		47.5		0.0022	0.000022	WCC 1991	Denver	claystone
22082	A/D	U		49		0.0042	0.000042	WCC 1991	Denver	claystone
27088	ALL	U		55		0.0052	0.000052	WCC 1991	alluvium	GW
27090	ALL	U		35.5		0.014	0.00014	WCC 1991	alluvium	SP/GP
27091	A/D	U		37.5		0.001	0.00001	WCC 1991	alluvium	SP/GP
36163	ALL	U		10.5-11.5		0.45	0.0045	ESE 1988b	alluvium	SM
36163	ALL	U		10.5-11.5		0.22	0.0022	ESE 1988b	alluvium	SM
36163	ALL	U		10.5-11.5		0.43	0.0043	ESE 1988b	alluvium	SM
36163	ALL	U		10.5-11.5		0.29	0.0029	ESE 1988b	alluvium	SM
36163	ALL	U		13.5-14.5		0.39	0.0039	ESE 1988b	alluvium	SM
36163	ALL	U		13.5-14.5		0.17	0.0017	ESE 1988b	alluvium	SM
36163	ALL	U		13.5-14.5		0.66	0.0066	ESE 1988b	alluvium	SM
36163	ALL	U		13.5-14.5		0.35	0.0035	ESE 1988b	alluvium	SM
36163	ALL	U		14.5-15.5		0.53	0.0053	ESE 1988b	alluvium	SC
36163	ALL	U		14.5-15.5		0.3	0.003	ESE 1988b	alluvium	SC
36163	ALL	U		14.5-15.5		0.68	0.0068	ESE 1988b	alluvium	SC
36163	ALL	U		14.5-15.5		0.26	0.0026	ESE 1988b	alluvium	SC
36165	ALL	U		3-8.5		0.54	0.0054	ESE 1988b	alluvium	SC
36165	ALL	U		3-8.5		0.59	0.0059	ESE 1988b	alluvium	SC
36165	ALL	U		3-8.5		0.07	0.0007	ESE 1988b	alluvium	SC
36598	DEN	C		44-44.5		0.7	0.007	MKES 1994	Denver	claystone
36598	DEN	C		62.5-63		0.74	0.0074	MKES 1994	Denver	claystone
36602	DEN	C		52.5-53		1.2	0.012	MKES 1994	Denver	claystone
36602	DEN	C		60-60.5		1.7	0.017	MKES 1994	Denver	claystone
37338	A/D	U	97	3.18	0.23	0.1	0.001	ESE 1987	alluvium	
37338	A/D	U	99	3.25	0.002	0.4	0.004	ESE 1987	Denver	
37342	A/D	U	104	3.41	0.3	0.05	0.0005	ESE 1987	alluvium	
37342	A/D	U	105	3.44	0.52	0.01	0.0001	ESE 1987	alluvium	
37342	A/D	U	106	3.48	0.003	0.05	0.0005	ESE 1987	alluvium	
37343	ALL	U	112	3.67	0.39	0.3	0.003	ESE 1987	alluvium	
37343	ALL	U	113	3.71	0.39	0.1	0.001	ESE 1987	alluvium	
37343	ALL	U	114	3.74	0.41	0.01	0.0001	ESE 1987	alluvium	
37343	ALL	U	116	3.81	0.51	0.02	0.0002	ESE 1987	alluvium	
37343	ALL	U	118	3.87	0.0035	0.2	0.002	ESE 1987	Denver	
37343	ALL	U	118	3.87	0.0035	0.25	0.0025	ESE 1987	Denver	
37344	ALL	U	402	13.19	0.01	0.03	0.0003	ESE 1987	alluvium	

TABLE A-20. RMA Aquifer Sediment Organic Carbon Data

WELL	AQUIFER	FLOW SYSTEM	DEPTH (cm)	DEPTH (ft)	MEDIAN GRAIN SIZE (mm)	ORGANIC CARBON (%)	FRACTIONAL ORGANIC CARBON, foc	REFERENCE	FORMATION	LITHOLOGY
37344	ALL	U	403	13.22	0.066	0.03	0.0003	ESE 1987	alluvium	
37344	ALL	U	404	13.25	0.38	0.008	0.00008	ESE 1987	alluvium	
37344	ALL	U	405	13.29	0.81	0.005	0.00005	ESE 1987	alluvium	
37344	ALL	U	406	13.32	0.3	0.006	0.00006	ESE 1987	Denver	
37345	A/D	U	50	1.64	0.88	0.007	0.00007	ESE 1987	alluvium	
37345	A/D	U	51	1.67	1.5	0.003	0.00003	ESE 1987	alluvium	
37345	A/D	U	52	1.71	0.1	0.05	0.0005	ESE 1987	alluvium	
37351	A/D	U	222	7.28	0.37	0.03	0.0003	ESE 1987	alluvium	
37351	A/D	U	223	7.32	0.3	0.4	0.004	ESE 1987	alluvium	
37351	A/D	U	224	7.35	0.32	0.02	0.0002	ESE 1987	alluvium	
37351	A/D	U	225	7.38	0.28	0.03	0.0003	ESE 1987	Denver	
37352	A/D	U	384	12.60	0.25	0.05	0.0005	ESE 1987	alluvium	
37352	A/D	U	386	12.66	1.5	0.002	0.00002	ESE 1987	alluvium	
37352	A/D	U	388	12.73	NA	0.08	0.0008	ESE 1987	Denver	
37353	ALL	U	141	4.63	2.1	0.002	0.00002	ESE 1987	alluvium	
37353	ALL	U	142	4.66	0.23	0.15	0.0015	ESE 1987	alluvium	
37354	ALL	U	171	5.61	3.9	0.002	0.00002	ESE 1987	alluvium	
37354	ALL	U	369	12.11	1.5	0.002	0.00002	ESE 1987	alluvium	
37354	ALL	U	369	12.11	1.5	0.002	0.00002	ESE 1987	alluvium	
37354	ALL	U	373	12.24	2.9	0.004	0.00004	ESE 1987	alluvium	
37354	ALL	U	374	12.27	NA	0.04	0.0004	ESE 1987	Denver	
37358	ALL	U	203	6.66	0.28	0.009	0.00009	ESE 1987	alluvium	
37358	ALL	U	204	6.69	NA	0.08	0.0008	ESE 1987	Denver	
37361	ALL	U	179	5.87	0.46	0.008	0.00008	ESE 1987	alluvium	
37361	ALL	U	180	5.91	2.4	0.002	0.00002	ESE 1987	alluvium	
37361	ALL	U	182	5.97	2.5	0.001	0.00001	ESE 1987	alluvium	
37361	ALL	U	184	6.04	1.9	0.003	0.00003	ESE 1987	alluvium	
37361	ALL	U	185	6.07	2.5	0.2	0.002	ESE 1987	alluvium	



Legend

- RMA National Wildlife Refuge
- Rocky Mountain Arsenal
- Section Lines
- Hazardous Waste Landfill, Enhanced Hazardous Waste Landfill, and Landfill Wastewater Treatment System
- Detention Basin Area
- CAMU Boundary
- Lakes, Ponds, and Rivers
- Wetlands
- Dry Lake Areas
- Ditch or Canal
- Intermittent stream
- Slurry Walls
- Recharge Trenches
- Local Roads
- Secondary Roads
- Primary Roads
- Unimproved Roads
- Aquifer Test Wells

N

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: USGS, DPRA, Inc., Washington Group, RMA Environmental Database, U.S. Army, Shell Chemical

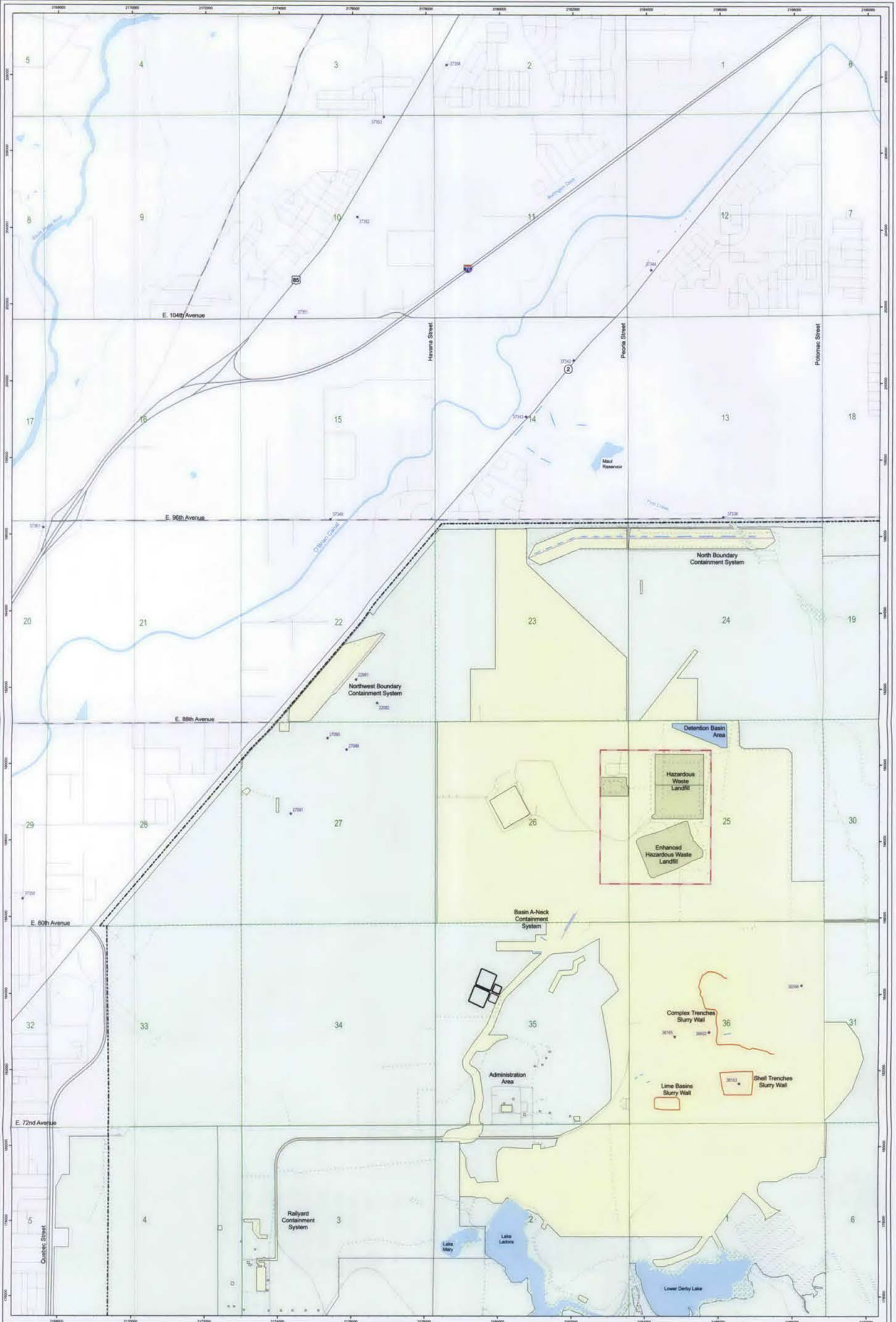
0 1,000 2,000 4,000
Feet

Aquifer Test Wells

Figure A-2

Remediation Venture Office GIS

10/30/2007 DPRA, Inc. Q:\projects\ltmp_06_07\mxds\aquifer_test_wells08.mxd



Legend

- RMA National Wildlife Refuge
- Rocky Mountain Arsenal
- Section Lines
- Hazardous Waste Landfill, Enhanced Hazardous Waste Landfill, and Landfill Wastewater Treatment System
- Detention Basin Area
- CAMU Boundary
- Lakes, Ponds, and Rivers
- Wetlands
- Dry Lake Areas
- Ditch or Canal
- Intermittent stream
- Slurry Walls
- Recharge Trenches
- Local Roads
- Secondary Roads
- Primary Roads
- Unimproved Roads
- Test Wells

NAD27-NGVD29 Datum, US Survey Feet, Colorado North Zone

Sources: USGS, DPRA, Inc., Washington Group, RMA Environmental Database, U.S. Army, Shell Chemical

0 1,000 2,000 4,000

Feet

Aquifer Sediment Organic Carbon Test Wells

Figure A-3

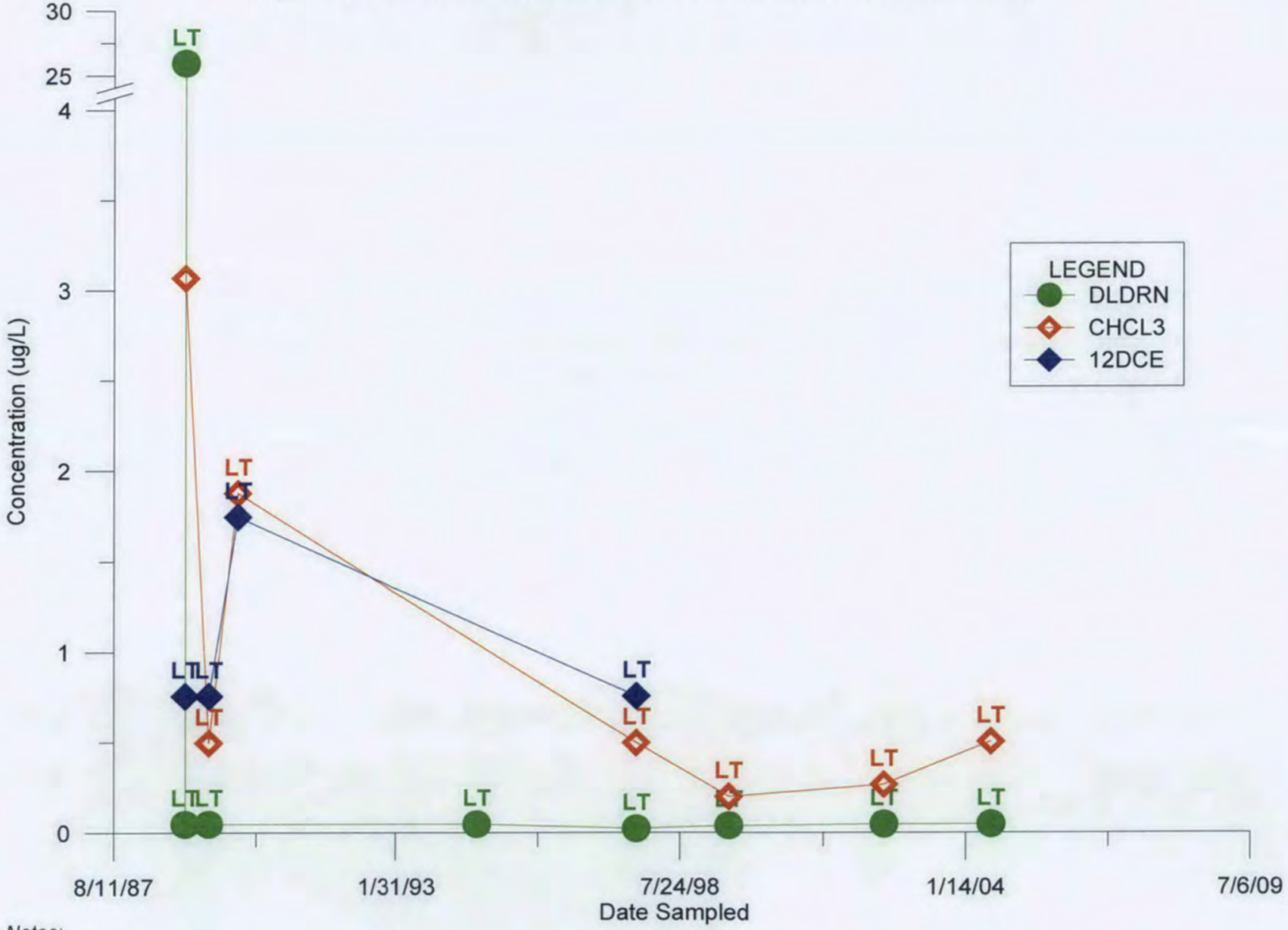
Remediation Venture Office GIS

10/28/2008 DPRA, Inc.

APPENDIX B

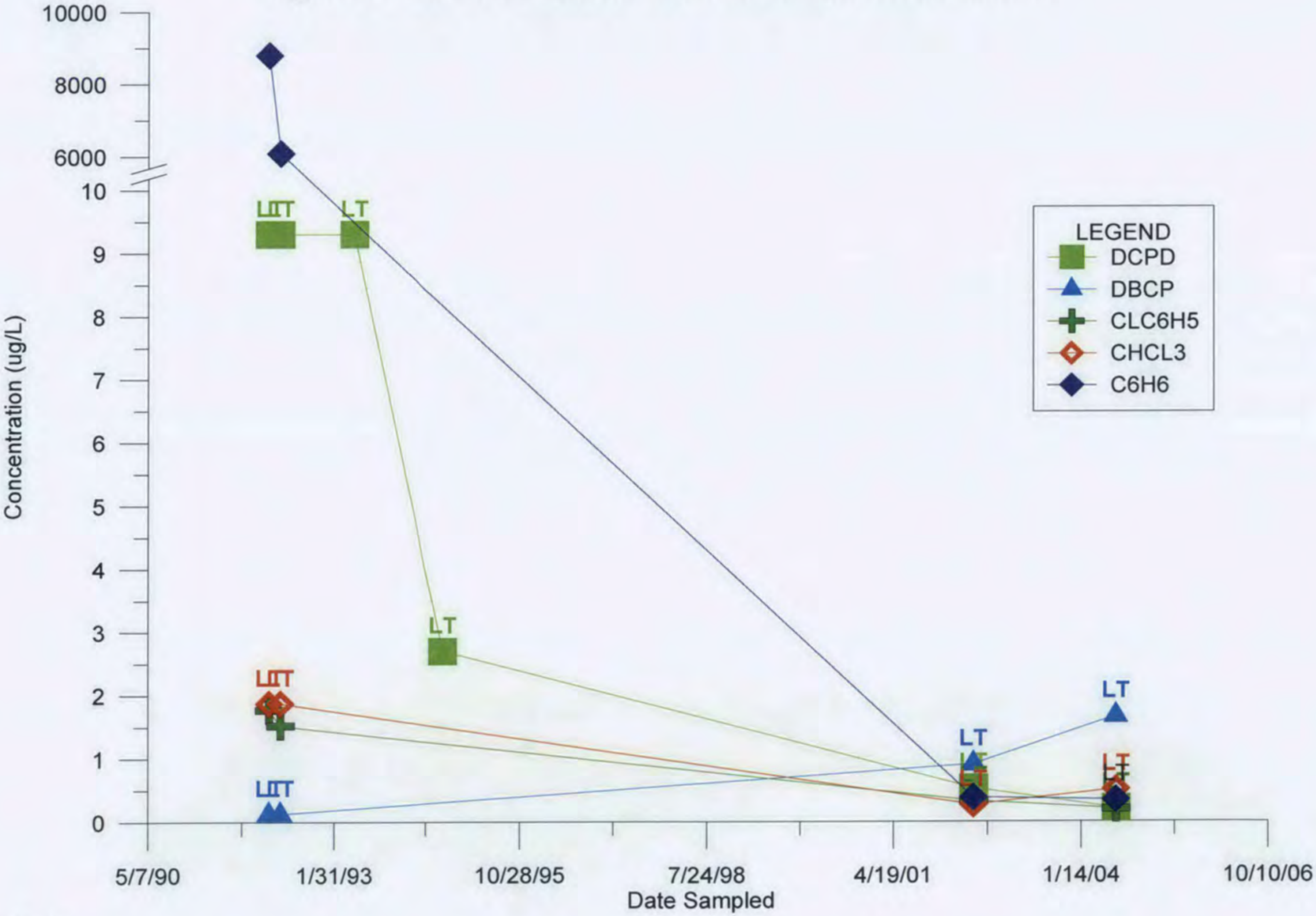
CONCENTRATION TIME-TREND GRAPHS FOR CONFINED FLOW SYSTEM

Figure B-1 Concentration vs. Time Plot of Well 01067



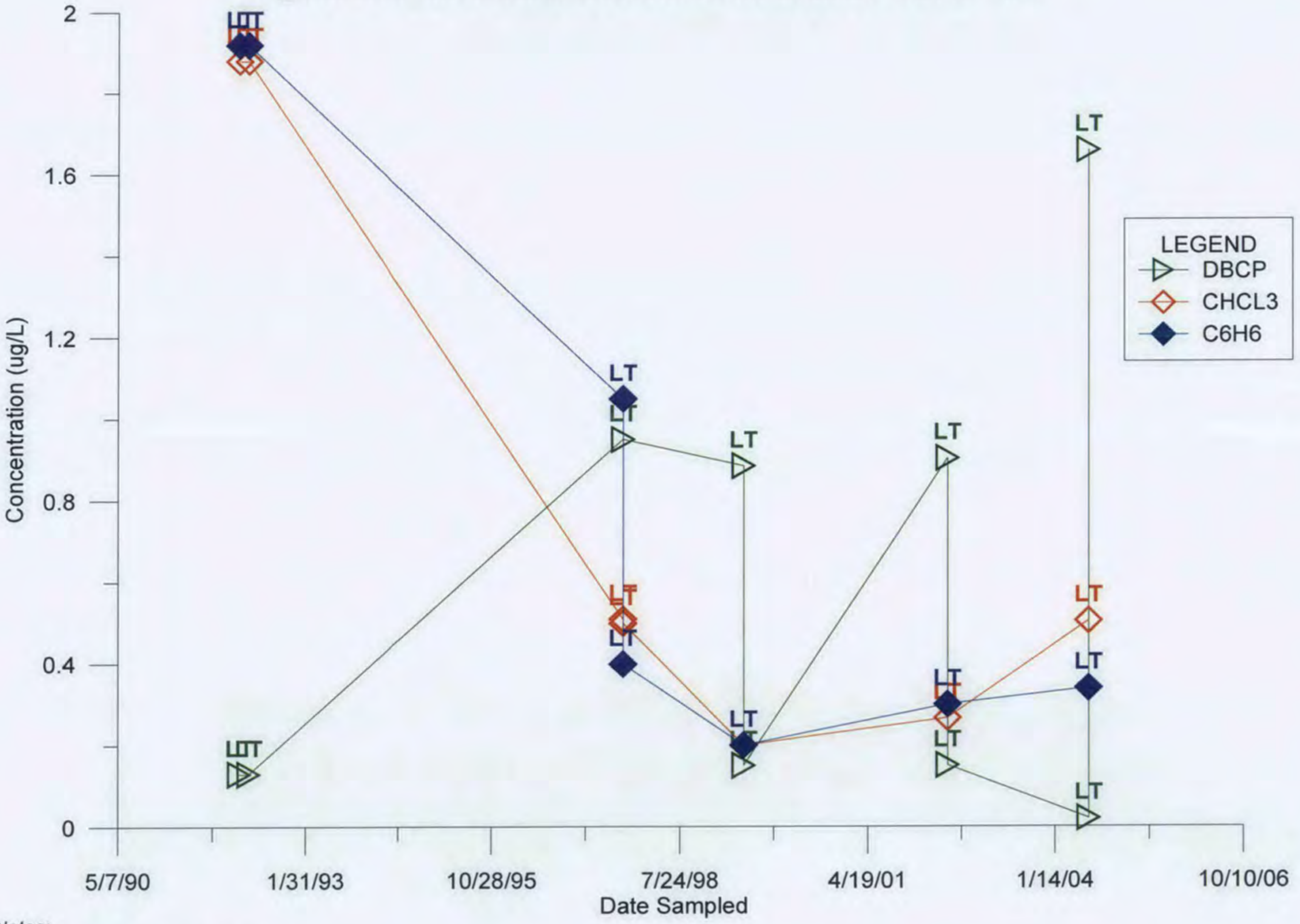
Notes:
LT - Less than detection limit

Figure B-2 Concentration vs. Time Plot of Well 01102



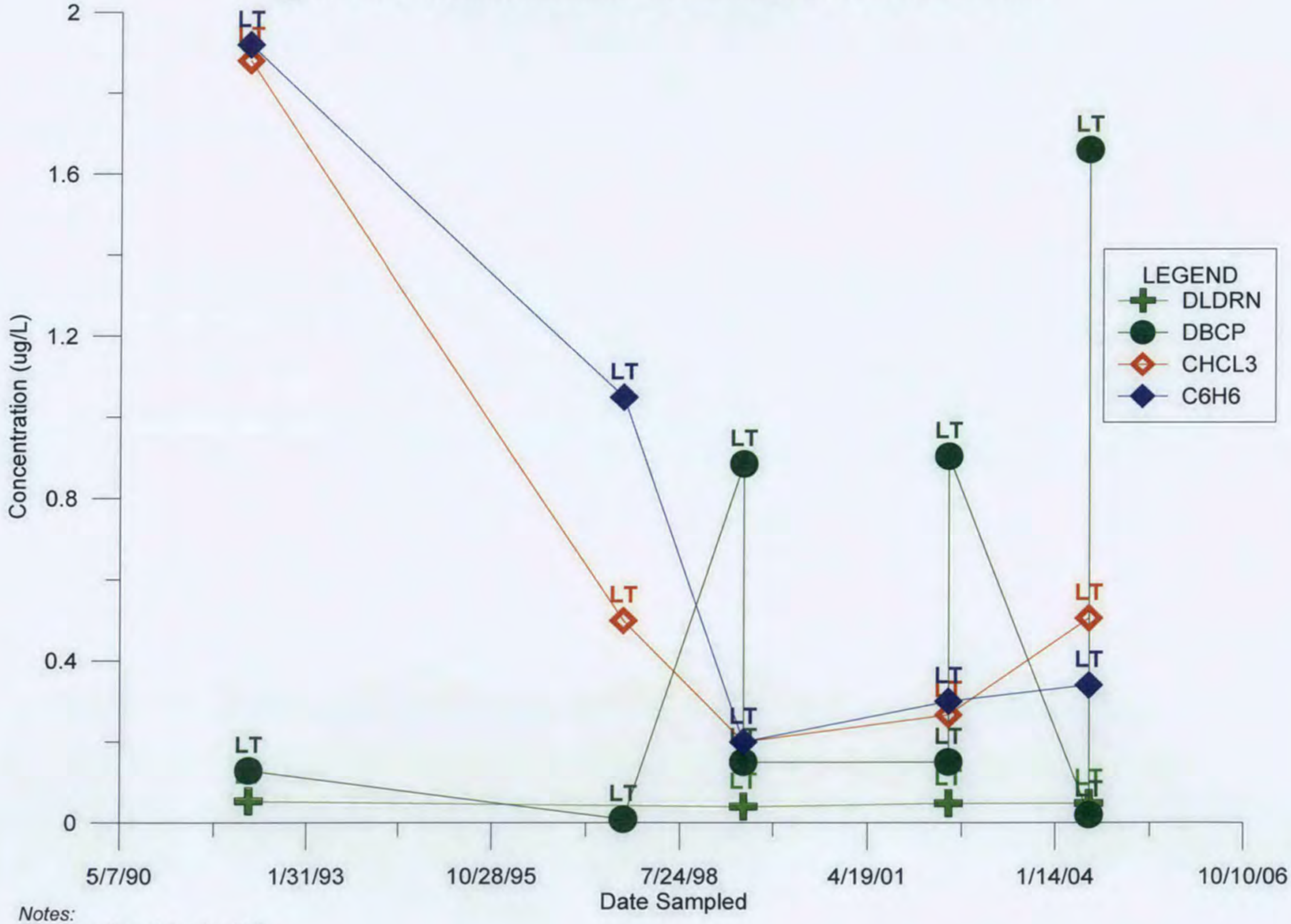
Notes:
LT - Less than detection limit

Figure B-3 Concentration vs. Time Plot of Well 01109



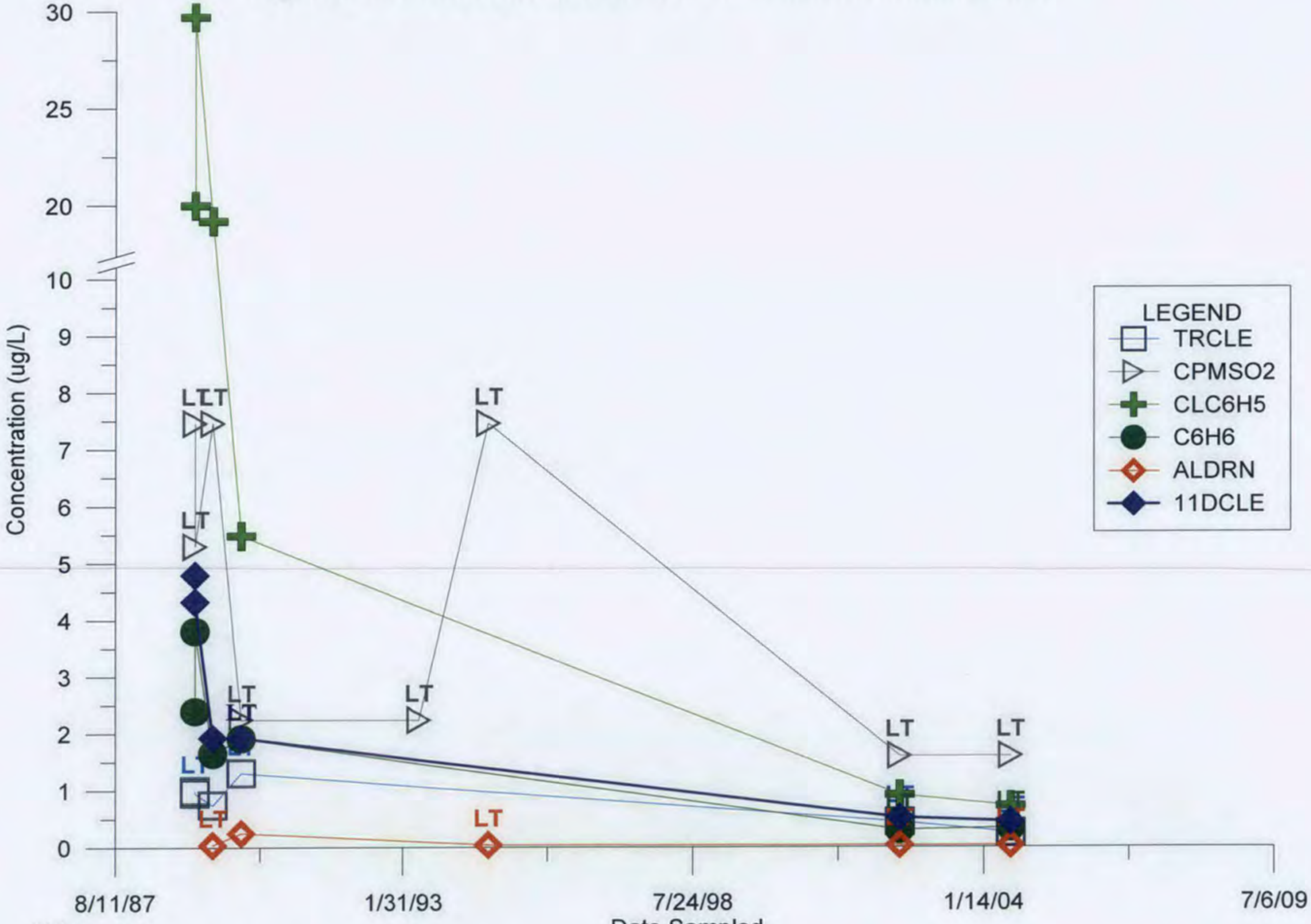
Notes:
LT - Less than detection limit

Figure B-4 Concentration vs. Time Plot of Well 01300



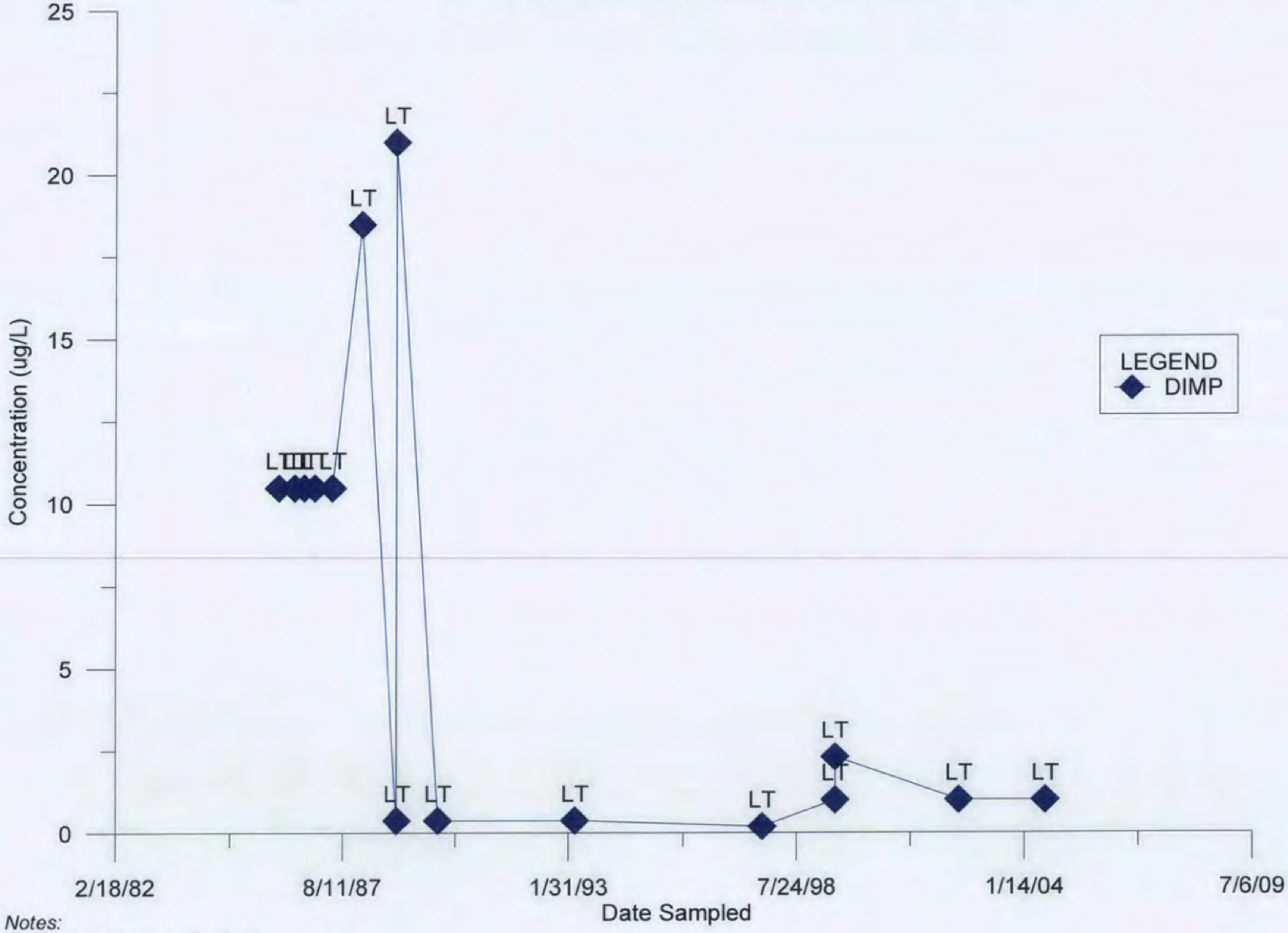
Notes:
LT - Less than detection limit

Figure B-5 Concentration vs. Time Plot of Well 02057



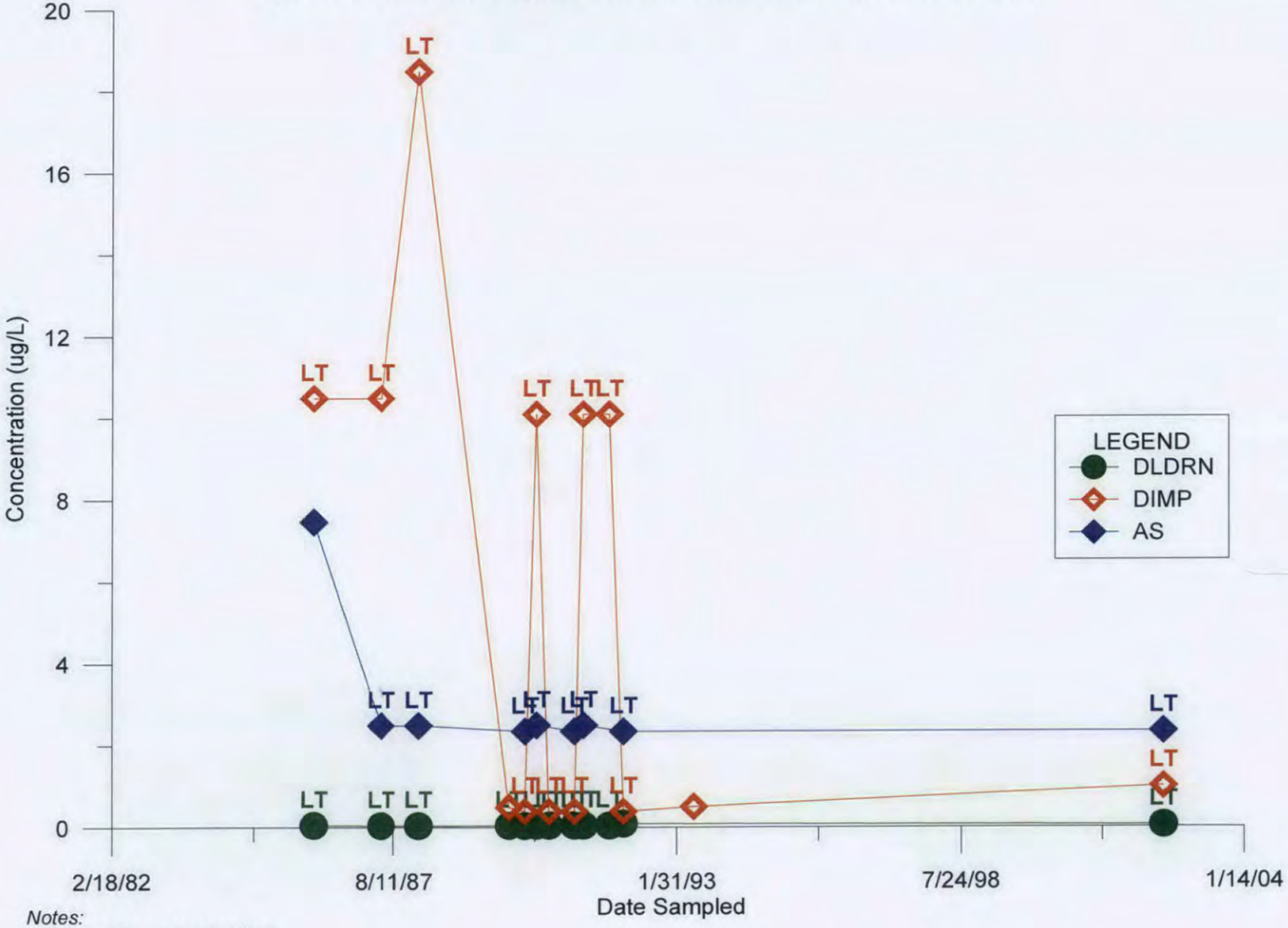
Notes:
LT - Less than detection limit

Figure B-6 Concentration vs. Time Plot of Well 23187



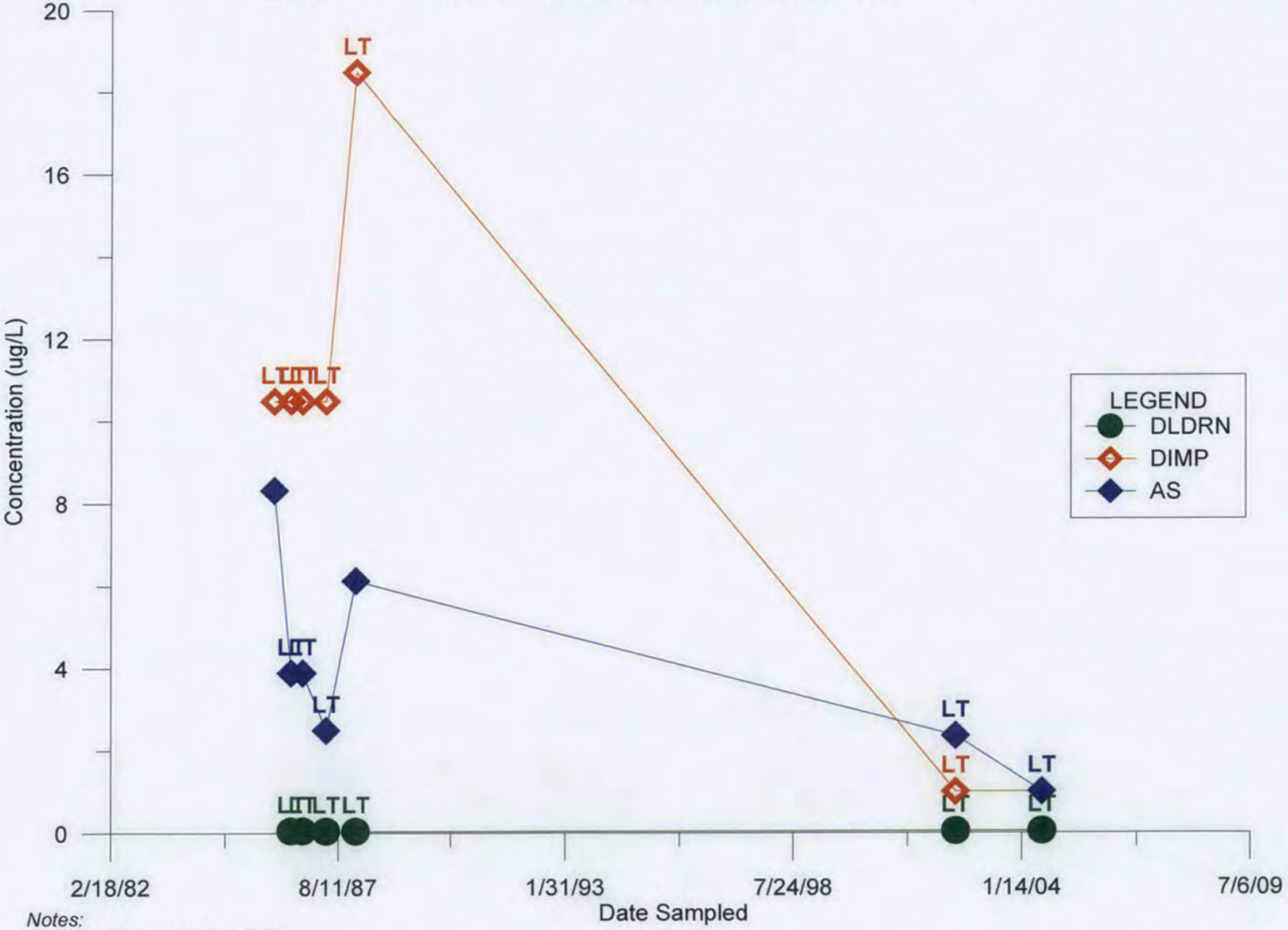
Notes:
LT - Less than detection limit

Figure B-7 Concentration vs. Time Plot of Well 23193



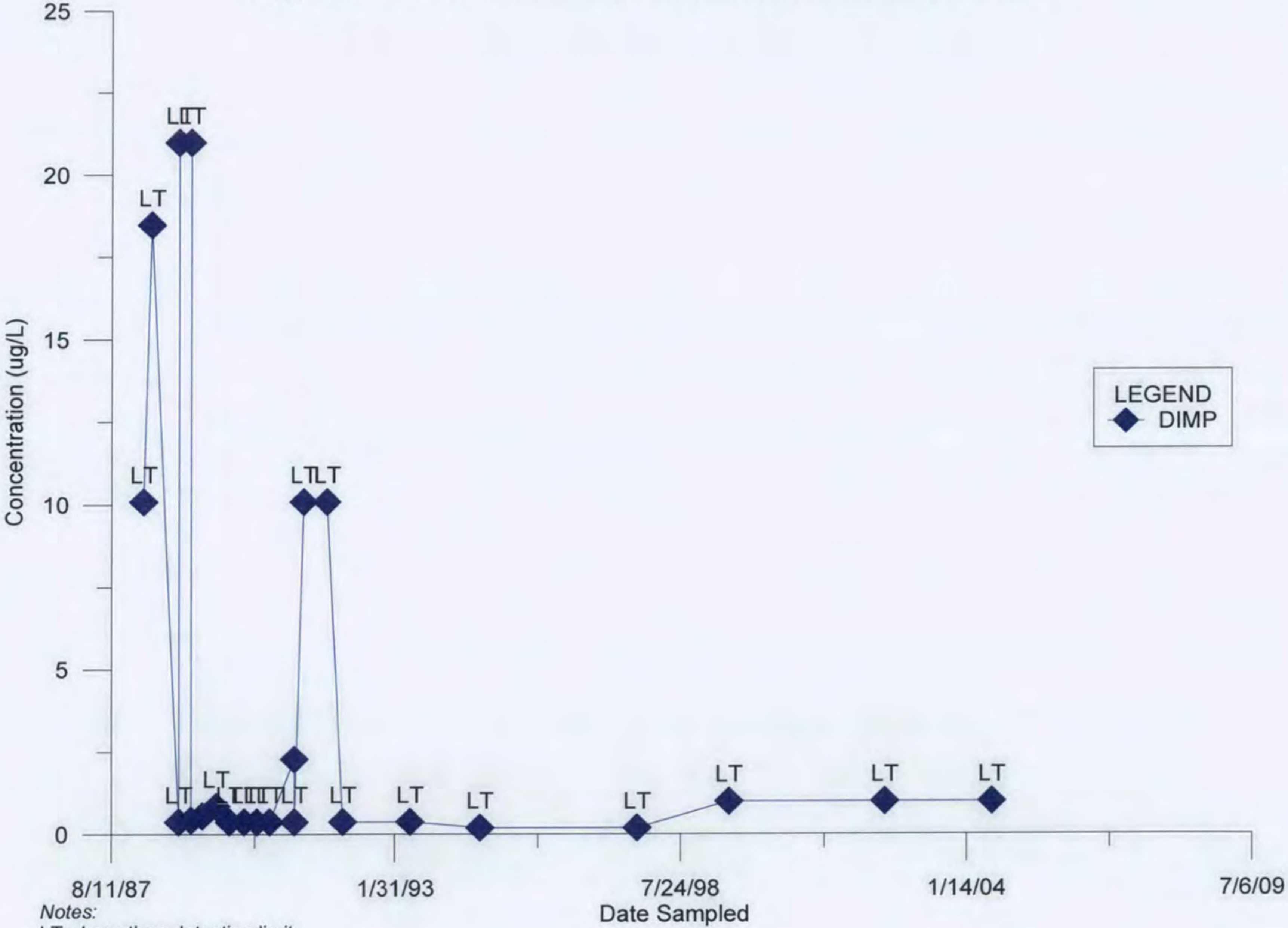
Notes:
LT - Less than detection limit

Figure B-8 Concentration vs. Time Plot of Well 26147



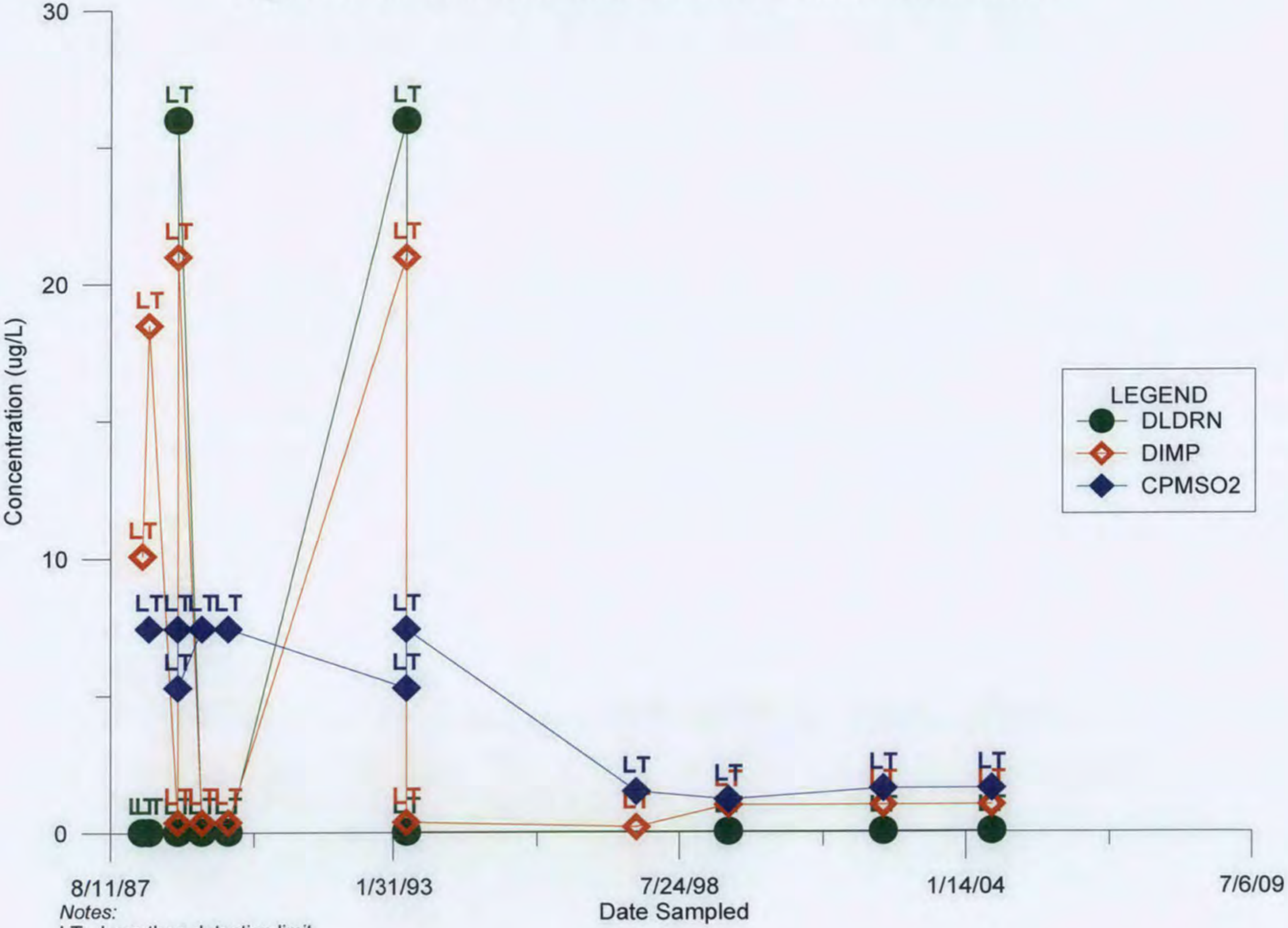
Notes:
LT - Less than detection limit

Figure B-9 Concentration vs. Time Plot of Well 26150



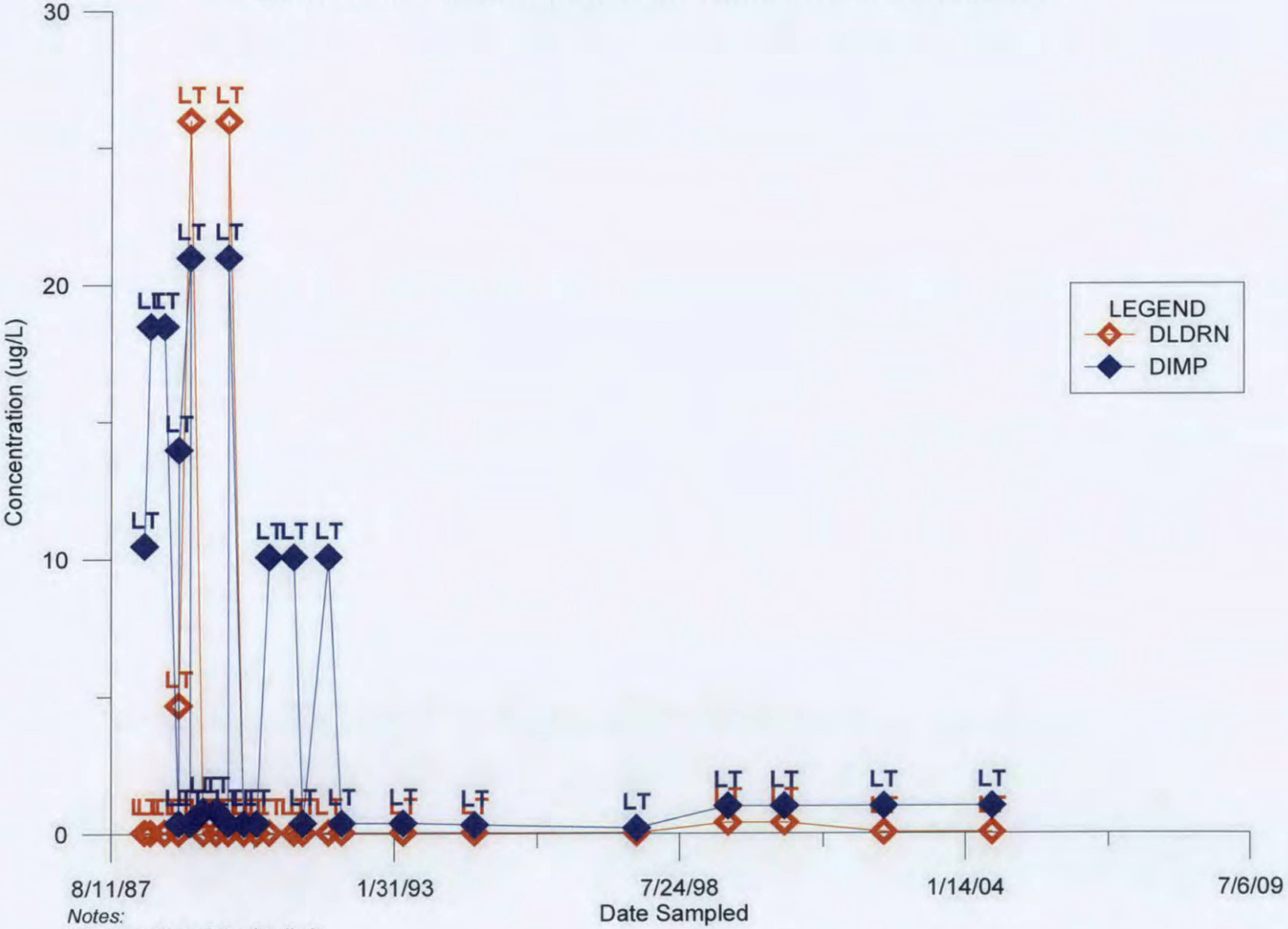
Notes:
LT - Less than detection limit

Figure B-10 Concentration vs. Time Plot of Well 26152

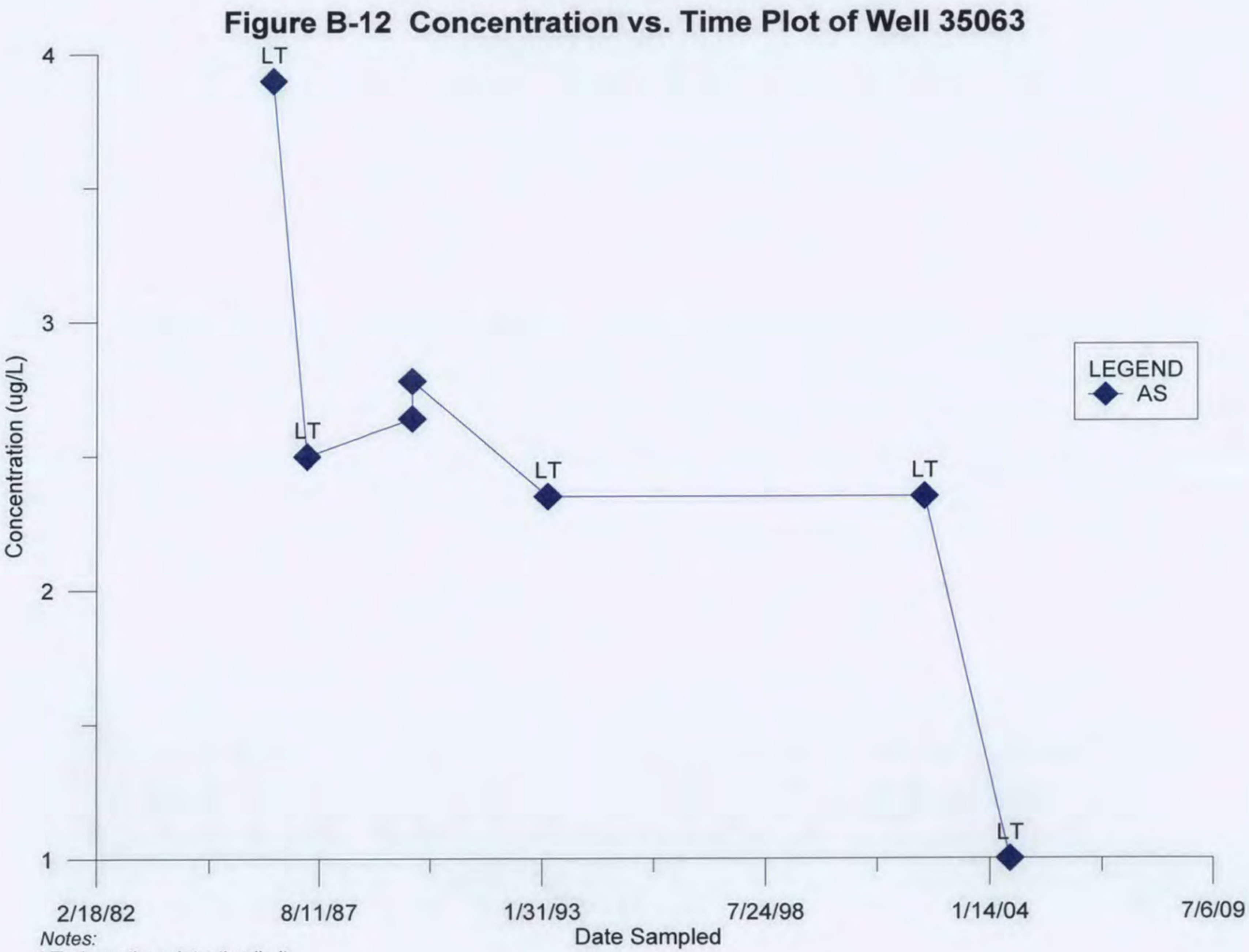


Notes:
LT - Less than detection limit

Figure B-11 Concentration vs. Time Plot of Well 26153

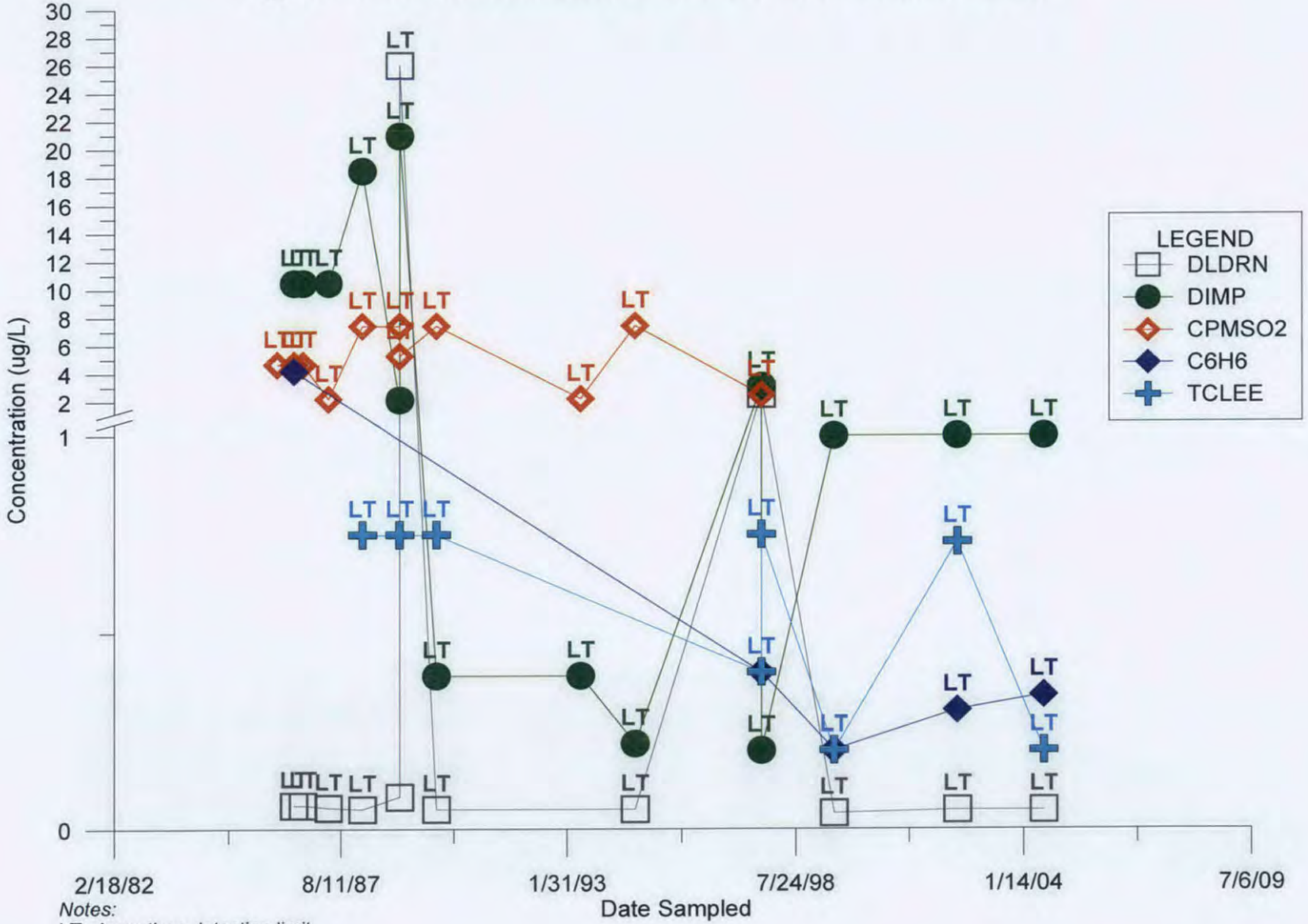


Notes:
LT - Less than detection limit



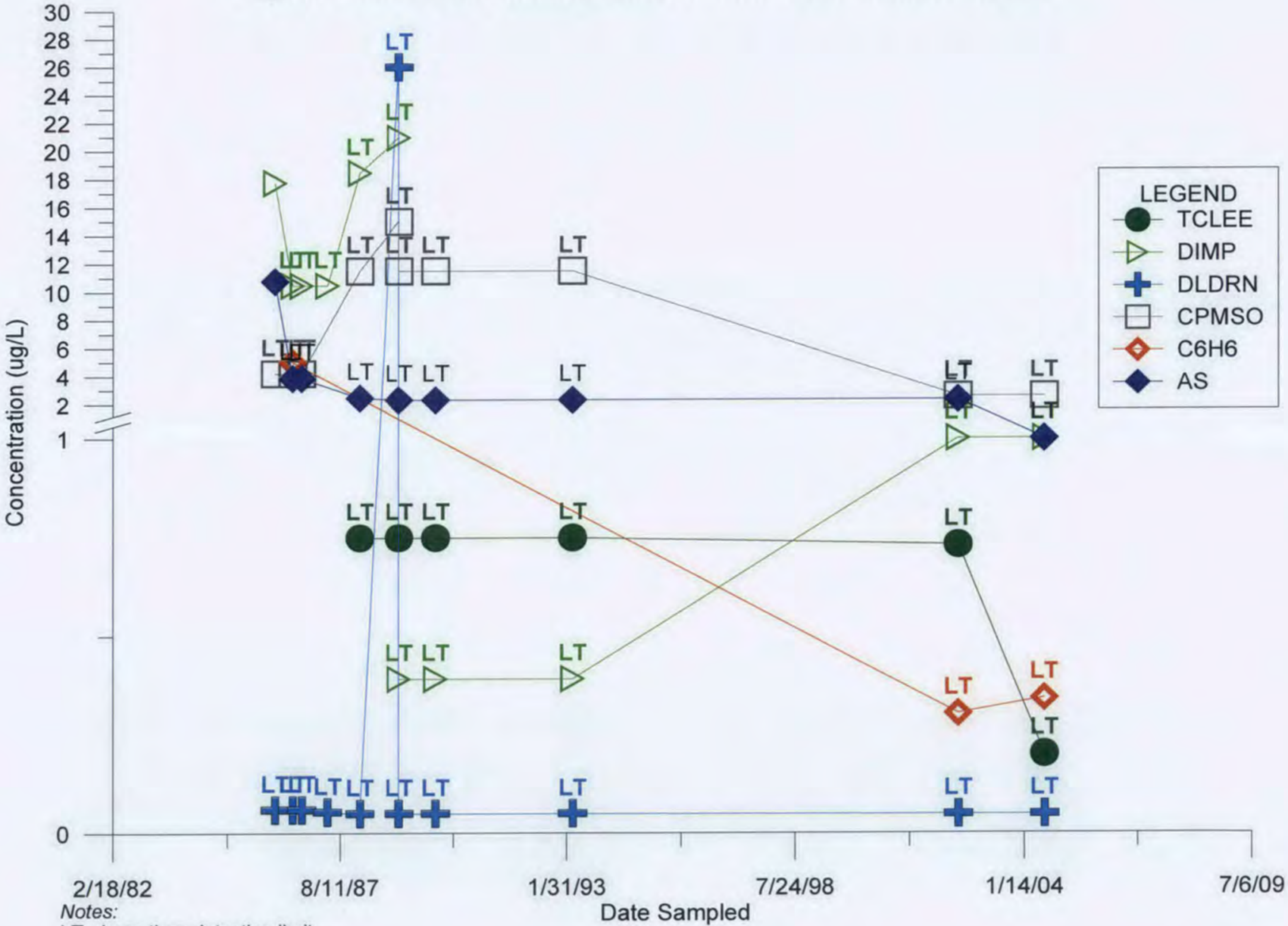
Notes:
LT - Less than detection limit

Figure B-13 Concentration vs. Time Plot of Well 35067



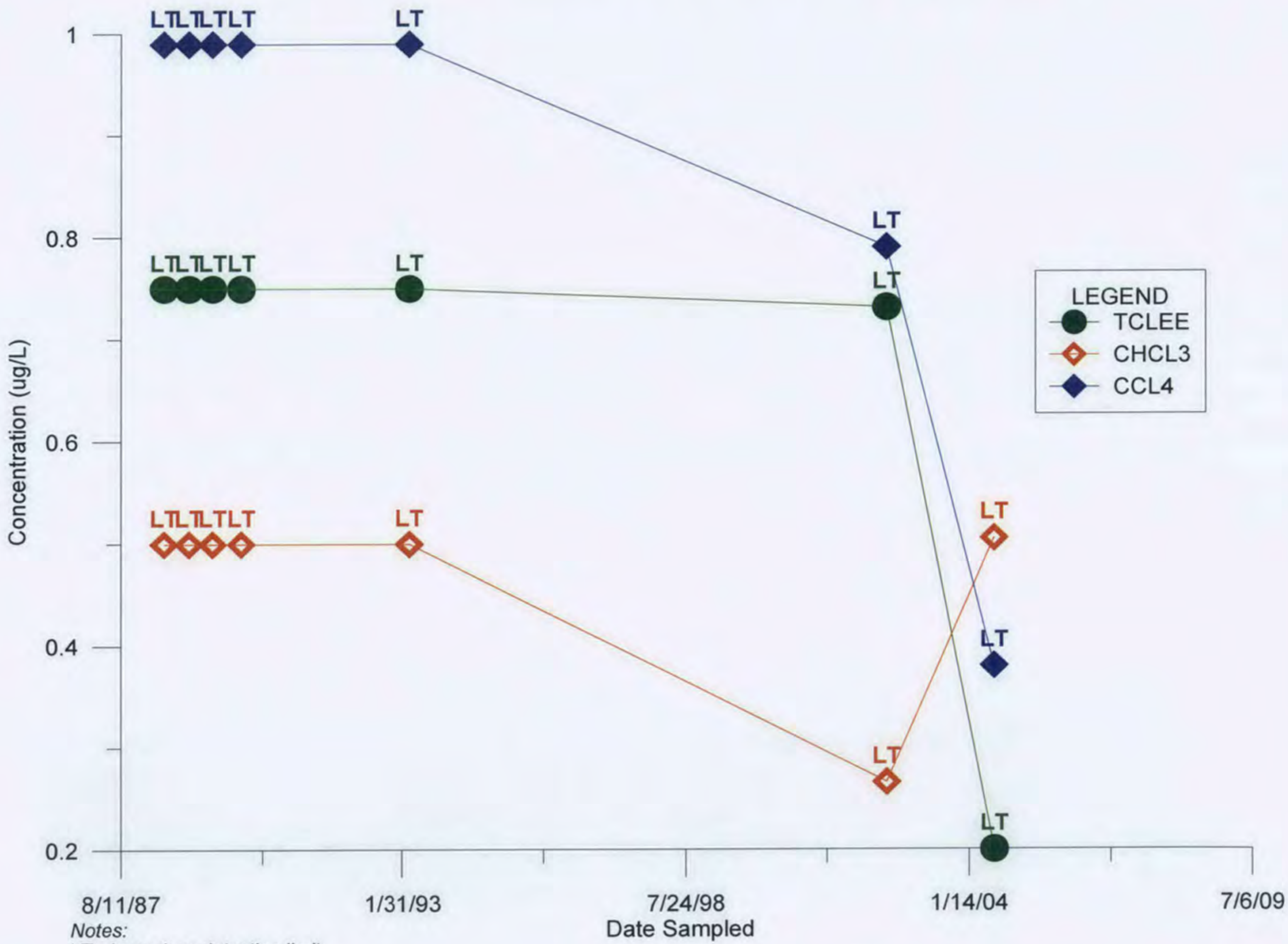
Notes:
LT - Less than detection limit

Figure B-14 Concentration vs. Time Plot of Well 35068



Notes:
LT - Less than detection limit

Figure B-15 Concentration vs. Time Plot of Well 35083



Notes:
LT - Less than detection limit

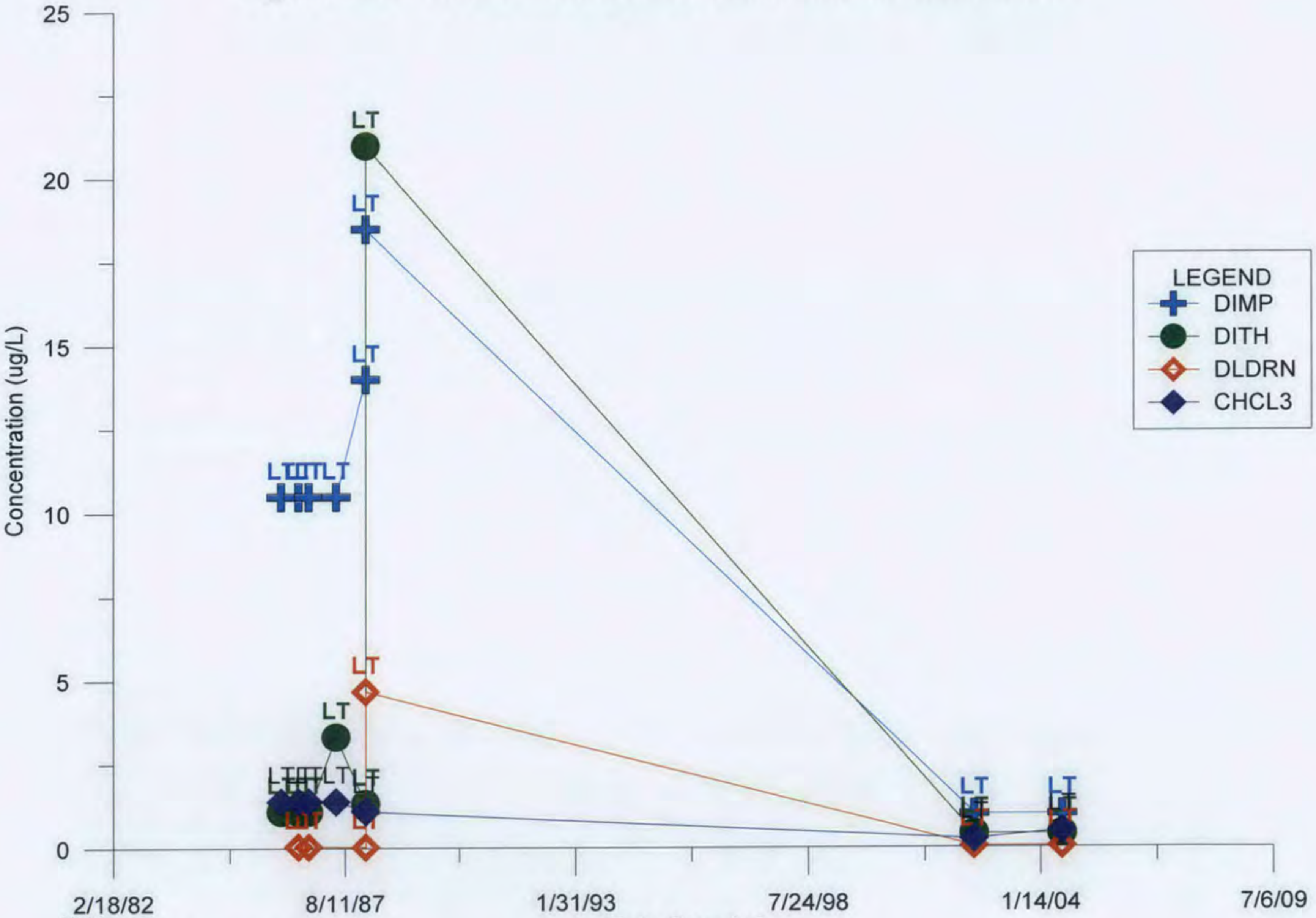
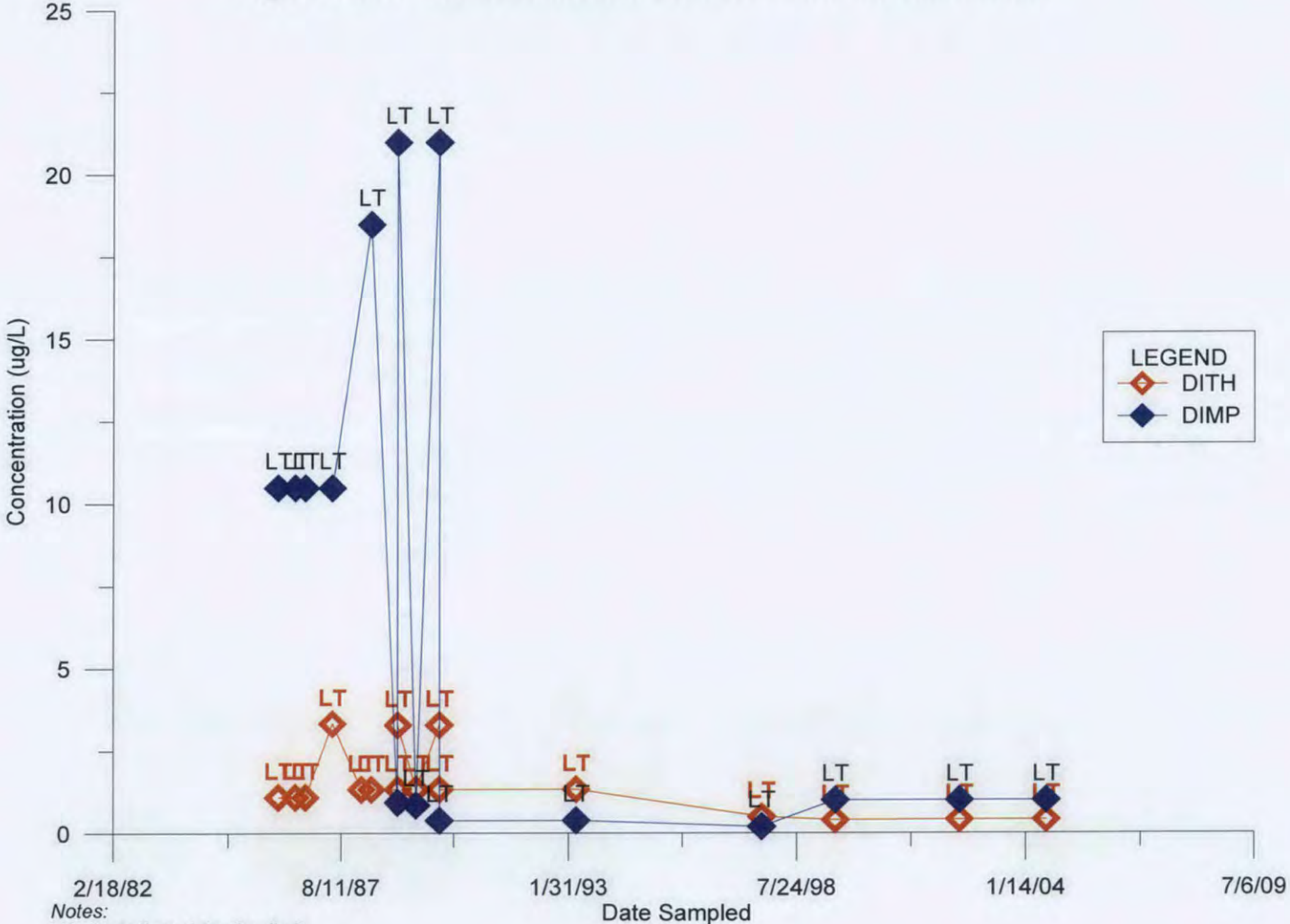


Figure B-16 Concentration vs. Time Plot of Well 36113

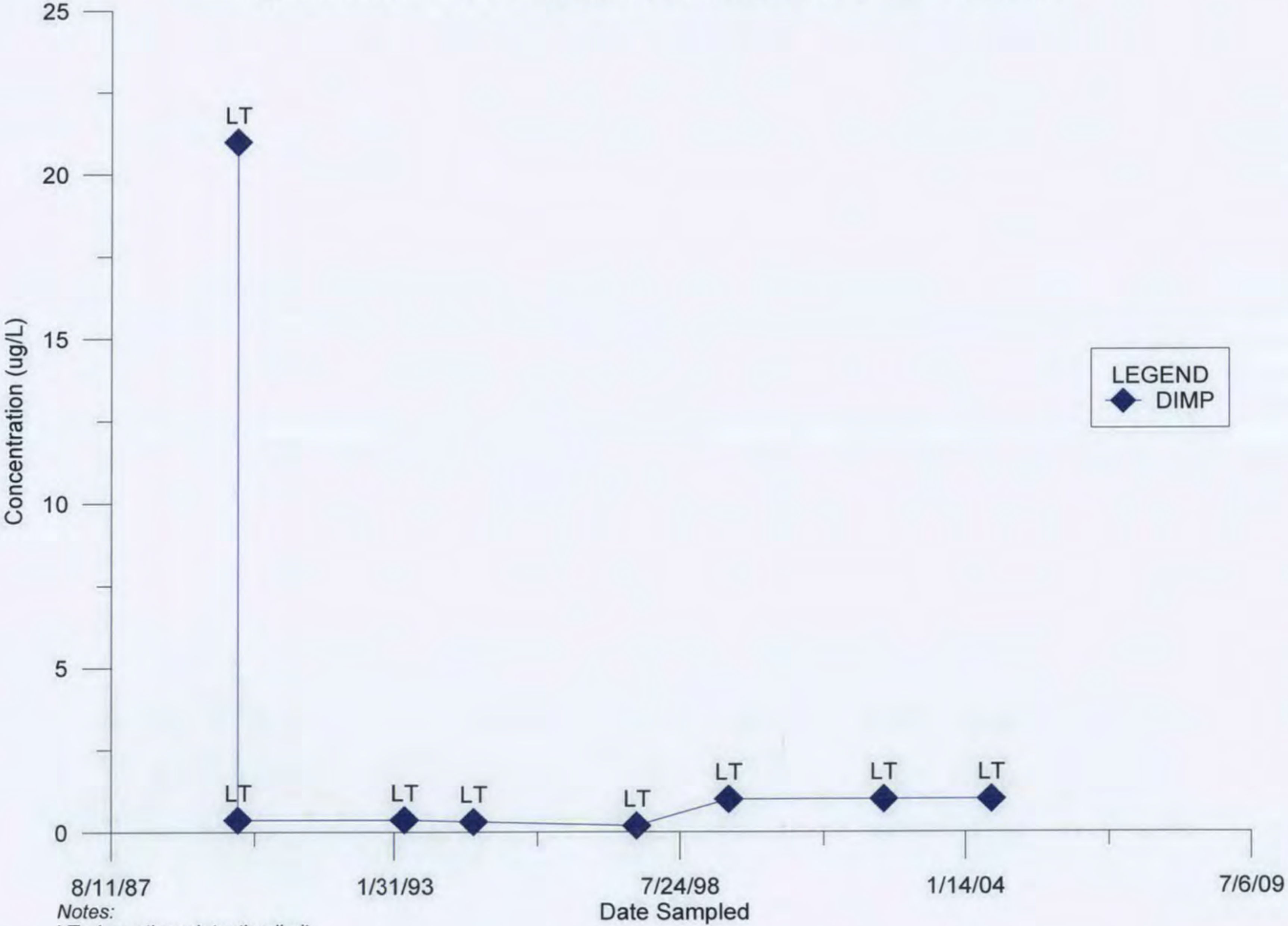
Notes:
LT - Less than detection limit

Figure B-17 Concentration vs. Time Plot of Well 36114



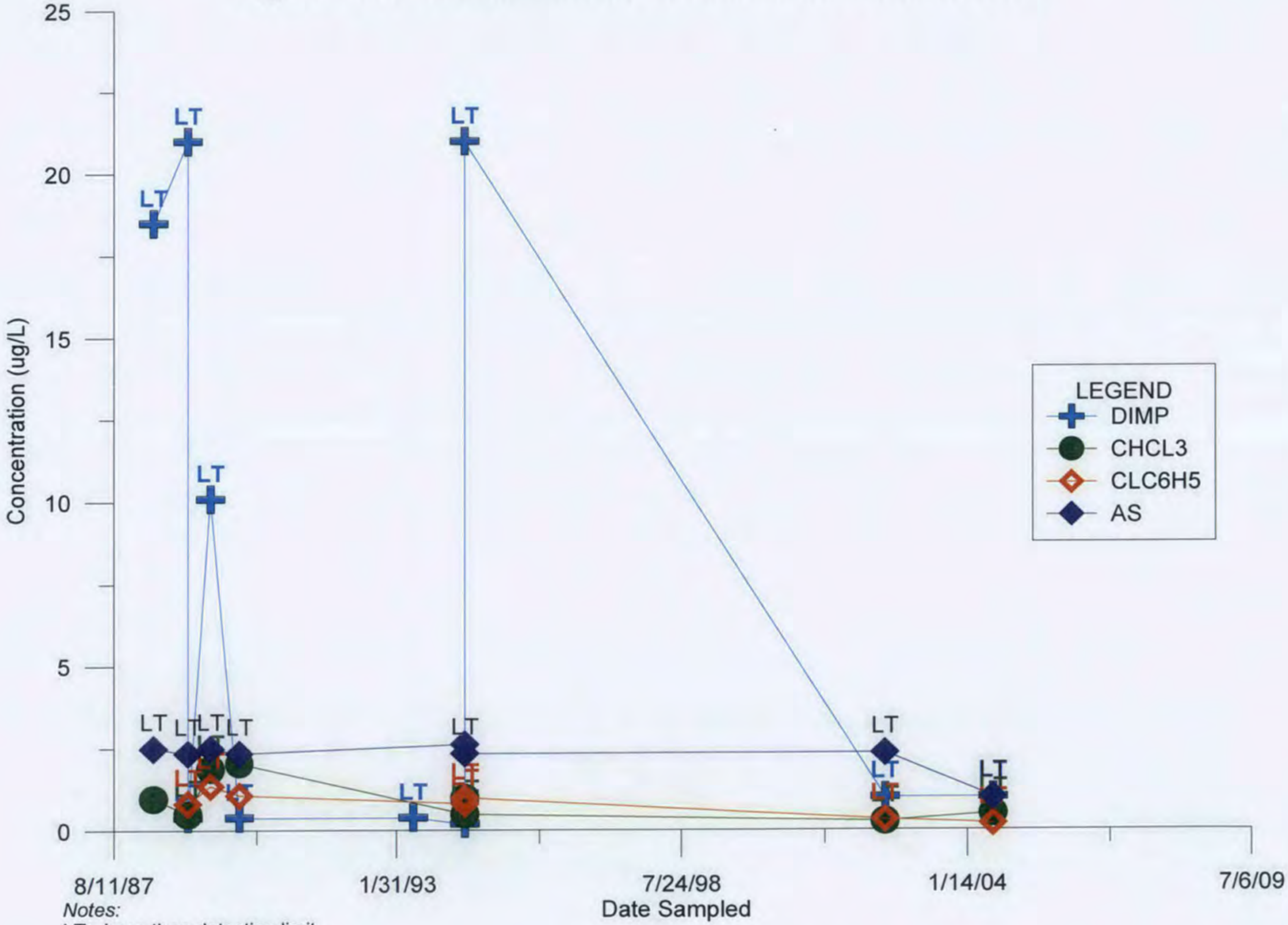
Notes:
LT - Less than detection limit

Figure B-18 Concentration vs. Time Plot of Well 36159



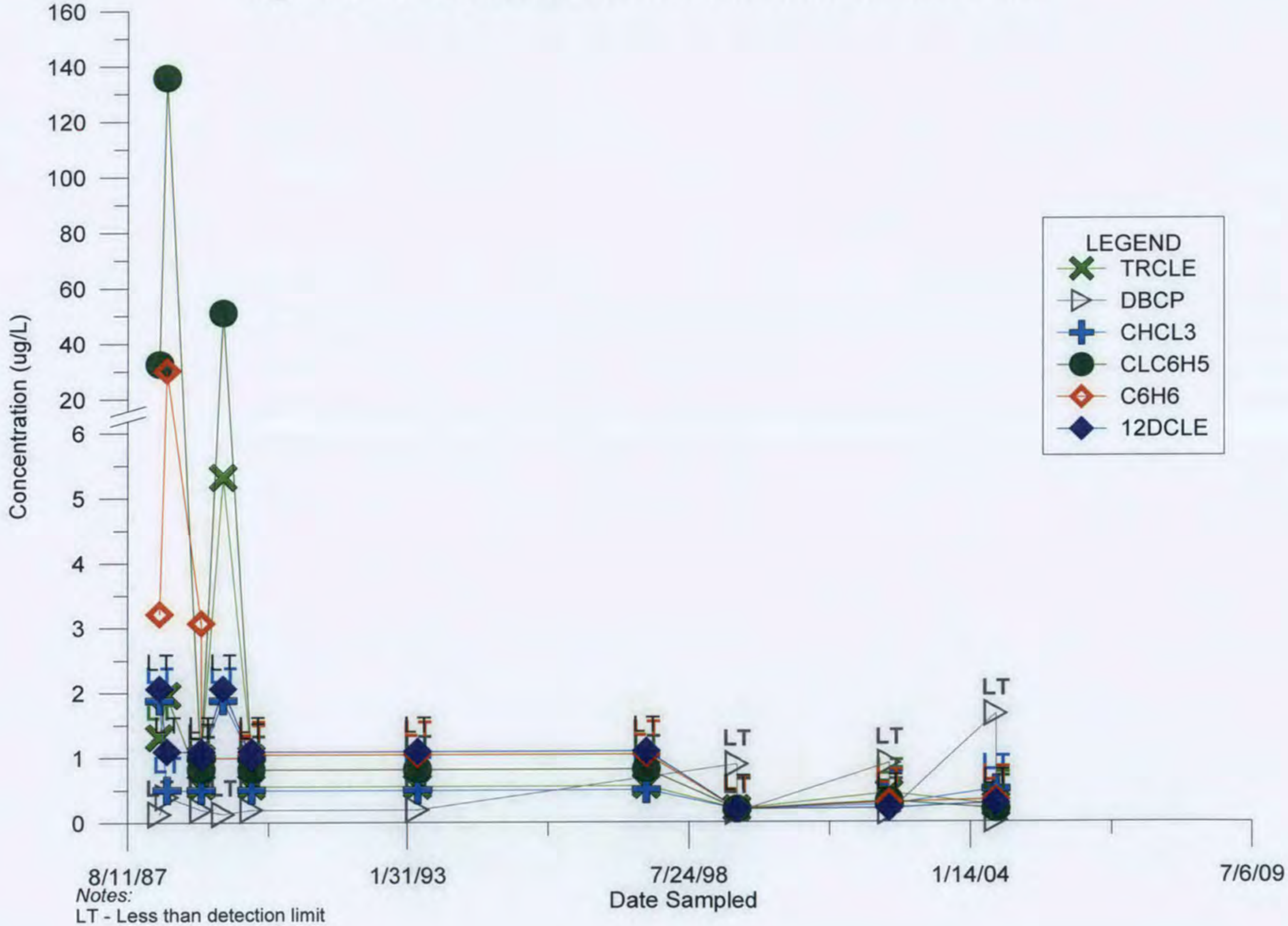
Notes:
LT - Less than detection limit

Figure B-19 Concentration vs. Time Plot of Well 36171



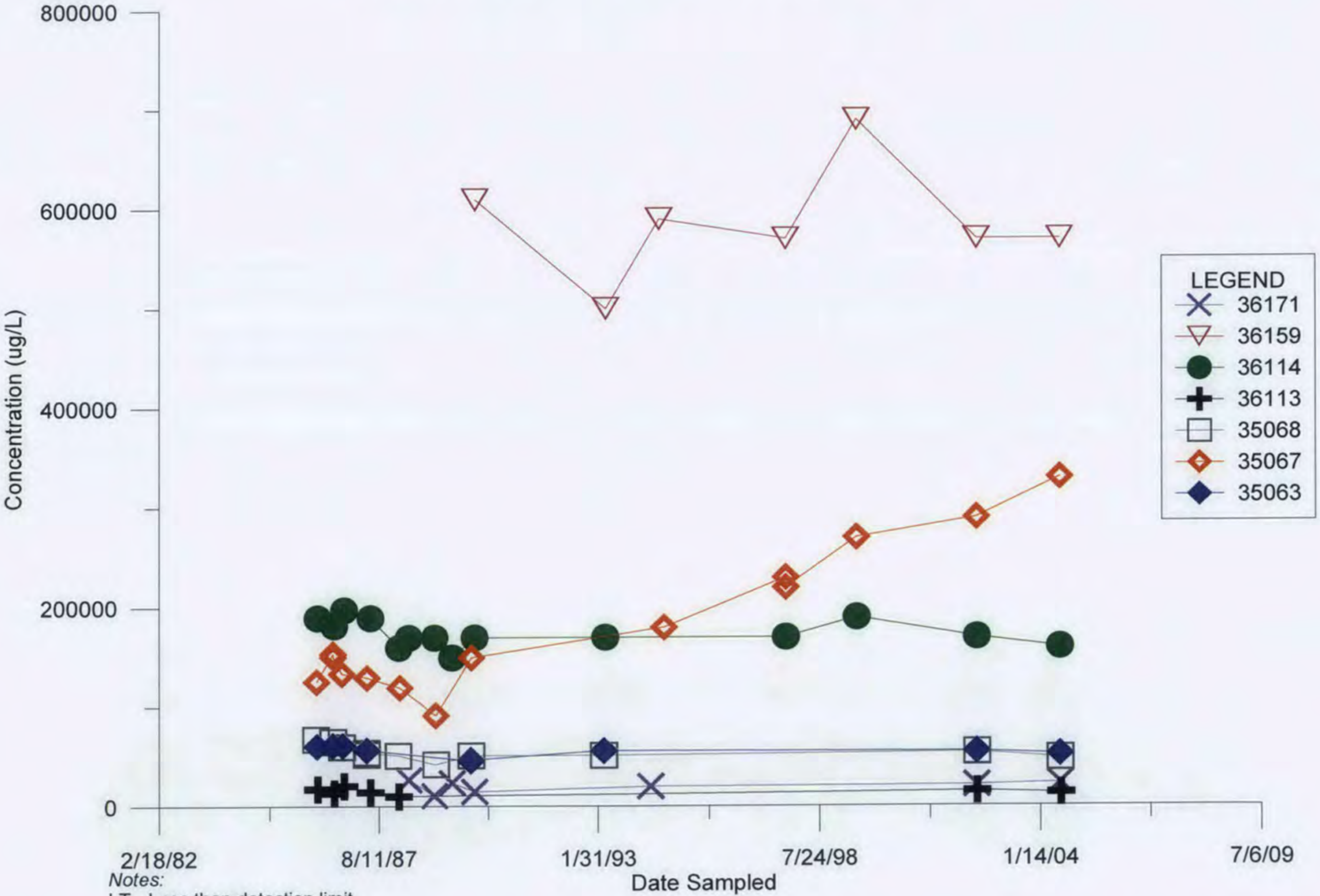
Notes:
LT - Less than detection limit

Figure B-20 Concentration vs. Time Plot of Well 36183



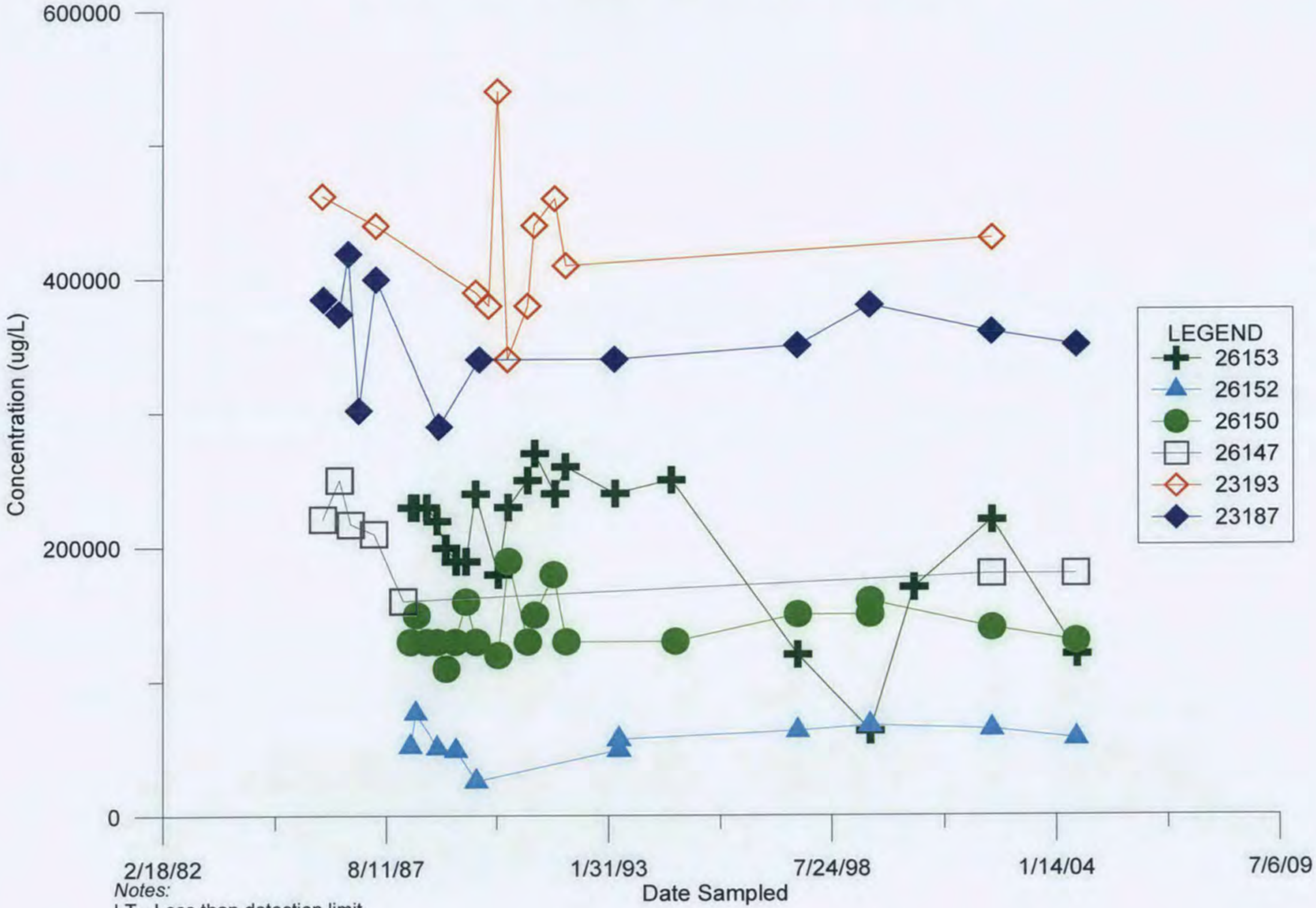
Notes:
LT - Less than detection limit

Figure B-21 Concentration of Chloride vs. Time Plot of Basin A Confined Flow System Wells



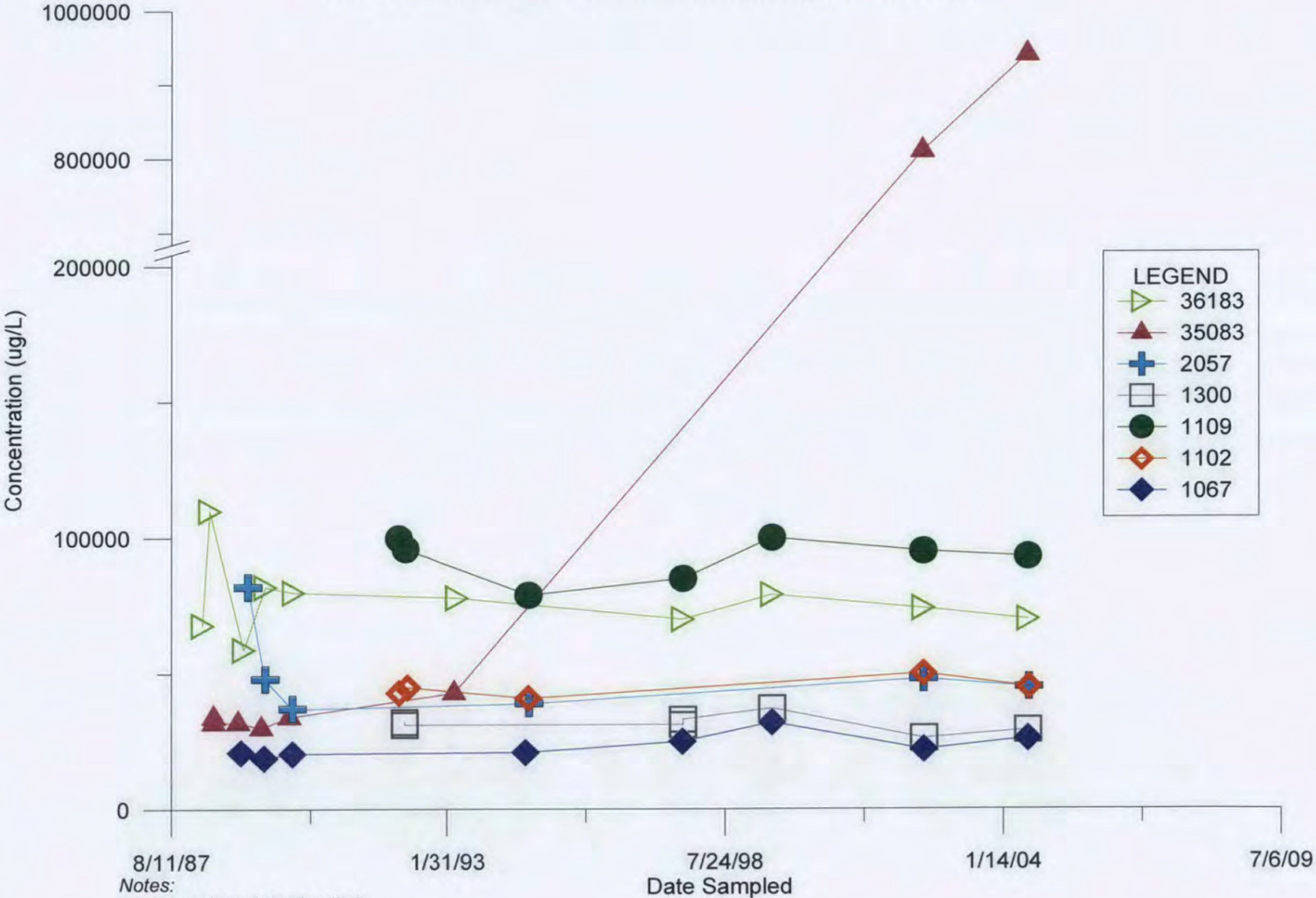
Notes:
LT - Less than detection limit

Figure B-22 Concentration of Chloride vs. Time Plot of Basin F Confined Flow System Wells



Notes:
LT - Less than detection limit

Figure B-23 Concentration of Chloride vs. Time Plot of South Plants Confined Flow System Wells



Notes:
LT - Less than detection limit

APPENDIX C

PRIVATE WELL MONITORING PROGRAM

APPENDIX C

PRIVATE WELL MONITORING PROGRAM

Introduction

The Private Well Monitoring Program is administered by Tri-County Health Department (TCHD) via a Memorandum of Agreement with the Army (PMRMA 1997). Under this program, TCHD samples private wells and surface water sources in the off-post study area. The program is separate and independent from the Army-administered and conducted off-post monitoring program. The primary purpose of private well monitoring is to provide water quality data to address community health concerns related to off-post groundwater contamination. The private well monitoring program will be included in the Off-Post Institutional Control Program.

Data from TCHD's private well monitoring program will be used to help delineate the CSRG Exceedance area. The Offpost OU Remediation Scope and Schedule (RS/S) (HLA 1996) stated that Offpost private wells will be selected for sampling based on the following criteria:

- Available well construction data indicate the well is properly completed within one aquifer
- The well is used for domestic use
- The well is not located near other similarly completed wells that are scheduled to be sampled
- One or more of the following:
    - The well aids in defining the CSRG exceedance area
    - The well has been requested for sampling by the owner
    - The well has indicated detections above the CSRG limit in recent sampling events.

In addition, newly installed private wells within the 1996 DIMP plume footprint are sampled. A selected group of Arapahoe Formation confined flow system (CFS) wells are sampled for well integrity and potential cross contamination from the overlying unconfined aquifer (See Section 2.8.2).

TCHD samples surface water discharges from gravel operations into the South Platte River, which are analyzed for DIMP, and maintains a database with demographic information regarding private wells in the CSRG exceedance area.

TCHD prepares and provides a candidate sampling list based on historical data for RVO, EPA, and CDPHE to review annually. In the past, sampling of up to 50 private wells took place each summer with the permission of the well owners. The list is reviewed by RVO and the other Regulatory Agencies before implementation. Currently, approximately 25 to 35 wells are sampled each year.

As new demographic information and the water quality data become available in the area of interest, they are entered into TCHD and RVO Environmental Databases. The results of the program are provided annually by TCHD to the RVO, EPA, and CDPHE.

The off-post ROD (HLA 1995) included the requirement for sampling and closing CFS wells that exceed CSRGs. The CFS well sampling requirements were amended in the 2000 Five-Year Review Report (FYRR) (RVO 2000) and a 2001 Fact Sheet (RVO 2001). The 1999 LTMP (FWENC 1999) included nine shallow unconfined flow system (UFS) private wells in the off-post CSRG Exceedance network that were to be sampled if possible. As documented in the 2005 FYRR (RVO 2007), the off-post groundwater contaminant concentrations and CSRG exceedance plume areas have decreased significantly since the 1999 LTMP was developed. More private wells were sampled in 2007 and 2009 to confirm these trends and better delineate the CSRG exceedance areas. The additional private-well data collected since 1999 have demonstrated the overall decreasing trends in concentrations such that sampling fewer private wells in the future is appropriate. For example, no private wells had DIMP concentrations above the CSRG in FY2007 and FY2008, and only one private well had a DIMP concentration at the CSRG in FY2009. Additionally, many of the private wells no longer are available for sampling due to a variety of factors, including rapid development of the off-post area, closing of wells, and water rights restrictions.

Arapahoe CFS Wells

Eight Arapahoe CFS wells were identified for continued annual monitoring in the 2000 FYRR and 2001 Fact Sheet. The report recommended that wells 1070B, 343A, 359A, 486C, 588A, 589A, 848A, and 914B should be monitored for DIMP and that wells 1070B and 914B should also be monitored for chloroform. Of these eight wells, six met the criteria established in the 2000 FYRR and 2001 Fact Sheet for discontinuing sampling or they cannot be sampled. The criteria are provided below.

- CFS Well Sampling Criteria
    - Sampling should continue annually until the contaminant concentration falls below analytical reporting limits, or until the well has been sampled at least five times and the mean concentration plus two standard deviations is less than the CSRG.

Wells 343A and 486C are not in use. Only wells 588A and 589A had not met the criteria for discontinuing sampling, but permission was not given for sampling them. The DIMP concentrations were consistently below the CSRG.

In 2004, CFS wells 1171A, 376A, 544A, 545A, 548A, 848A, and 986B were added to TCHD's CFS sampling program. Wells 544A, 545A, 548A, and 848A met the criteria for discontinuing monitoring during the 2000 - 2005 FYR period. Table C-1 is an evaluation of the DIMP and chloroform data applying the above CFS well sampling criteria for the wells specified in the 2000 FYRR and wells subsequently added to TCHD'CFS well monitoring program. Wells 359A, 376A, 914B, 986B, 1070B, and 1171A met the criteria during the 2005 - 2010 FYR period. Thus, all the CFS wells specified in the 2001 Fact Sheet, and the wells added to TCHD's monitoring program in 2004 have met the criteria and the annual CFS monitoring may be discontinued. TCHD may still sample CFS wells at their discretion or if requested by the well owner, or if permission is granted to sample wells 588A or 589A. As stated previously, the private well monitoring program will be included in the Off-Post Institutional Control Program.

References

FWENC (Foster Wheeler Environmental Corporation)

1999 (Dec.) *Rocky Mountain Arsenal Long-Term Monitoring Plan for Groundwater.* Final.

HLA (Harding Lawson Associates)

1995 (Dec. 19) *Rocky Mountain Arsenal Offpost Operable Unit, Final Record of Decision.*

1996 (Sep. 25) *Remediation Scope and Schedule for the Offpost Operable Unit, Rocky Mountain Arsenal, Commerce City, Colorado.*

PMRMA (Program Manager for Rocky Mountain Arsenal)

1997 (Aug. 13) Memorandum *of Agreement Between Tri-County Health Department and Program Manager for Rocky Mountain Arsenal.*

RVO (Remediation Venture Office)

2000 *2000 Five-Year Review Report*, Final.

2001 (Mar. 25) *Letter to EPA confirming finalization of the Documentation of Non-Significant or Minor Off-post ROD Change at RMA of the CFS Well Evaluation Criteria*

2007 *2005 Five-Year Review Report*, Final.

Table C-1. Offpost Private CFS Well Data Evaluation

		Sample				
Well	Analyte	Date	Boolean	Value	Units	
DIMP						
1070B	DIMP	1999-05-25		7.36	UGL	
1070B	DIMP	1999-06-24		6.59	UGL	
1070B	DIMP	2000-06-14		4.91	UGL	
1070B	DIMP	2001-07-10		3.53	UGL	
1070B	DIMP	2002-07-02		3.54	UGL	
1070B	DIMP	2003-06-09		2.7	UGL	
1070B	DIMP	2003-07-30		2.88	UGL	
1070B	DIMP	2004-07-07		1.86	UGL	
1070B	DIMP	2005-06-24		2.43	UGL	
1070B	DIMP	2006-06-12		2.25	UGL	
1070B	DIMP	2007-06-20		2.48	UGL	
1070B	DIMP	2008-06-18		2.16	UGL	
1070B	DIMP	2009-06-11		1.82	UGL	
			Average	3.42		
			STD	1.79		
			Avg. + 2 STD	7.0		
1171A	DIMP	1990-10-30		1.8	UGL	
1171A	DIMP	1993-12-10		6.5	UGL	
1171A	DIMP	1994-07-18		5.6	UGL	
1171A	DIMP	1994-10-05		5.86	UGL	
1171A	DIMP	1995-01-23		5.43	UGL	
1171A	DIMP	1995-05-04		4.86	UGL	
1171A	DIMP	1995-07-25		7.07	UGL	
1171A	DIMP	1996-01-26		5.08	UGL	
1171A	DIMP	1997-09-18		4.53	UGL	
1171A	DIMP	1998-05-18		4.44	UGL	
1171A	DIMP	1999-07-29		3.41	UGL	
1171A	DIMP	2000-07-18		3.65	UGL	
1171A	DIMP	2001-09-24		2.53	UGL	
1171A	DIMP	2002-09-10	LT	0.35	UGL	
1171A	DIMP	2004-07-13		1.14	UGL	
1171A	DIMP	2005-06-16		1.56	UGL	
1171A	DIMP	2006-06-15		1.47	UGL	
1171A	DIMP	2007-06-18		0.932	UGL	
1171A	DIMP	2009-06-10		0.735	UGL	
			Average	3.52		
			STD	2.15		
			Avg. + 2 STD	7.8		

Table C-1. Offpost Private CFS Well Data Evaluation

		Sample				
Well	Analyte	Date	Boolean	Value	Units	
343A	DIMP	1993-09-30		0.411	UGL	
343A	DIMP	1995-08-02	LT	0.92	UGL	
343A	DIMP	1996-01-22	LT	0.35	UGL	
343A	DIMP	1998-05-20		0.48	UGL	
			Average	0.54		
			STD	0.26		
			Avg. + 2 STD	1.06		
359A	DIMP	1991-11-19		3.25	UGL	
359A	DIMP	1994-07-19	LT	1.78	UGL	
359A	DIMP	1995-01-24		3.4	UGL	
359A	DIMP	1995-07-31		6.49	UGL	
359A	DIMP	1996-01-25		4.8	UGL	
359A	DIMP	1998-05-19		4.77	UGL	
359A	DIMP	1998-09-29		3.12	UGL	
359A	DIMP	1999-07-29		5.68	UGL	
359A	DIMP	2000-06-28		4.02	UGL	
359A	DIMP	2001-06-06		4.24	UGL	
359A	DIMP	2002-07-09		3.69	UGL	
359A	DIMP	2003-07-14		1.01	UGL	
359A	DIMP	2004-06-29		2.72	UGL	
359A	DIMP	2005-08-25		4.96	UGL	
359A	DIMP	2006-07-05		4.1	UGL	
359A	DIMP	2007-06-14		4.04	UGL	
359A	DIMP	2008-06-11		2.58	UGL	
359A	DIMP	2009-06-16		3.77	UGL	
			Average	3.8		
			STD	1.33		
			Avg. + 2 STD	6.45		
376A	DIMP	1992-02-06	LT	0.392	UGL	
	DIMP	1996-03-27	LT	0.35	UGL	
	DIMP	1998-09-18	LT	0.35	UGL	
	DIMP	2003-06-24	LT	0.35	UGL	
	DIMP	2004-06-15	LT	0.35	UGL	
	DIMP	2005-06-17	LT	0.4	UGL	
	DIMP	2006-06-15	LT	0.4	UGL	
	DIMP	2007-06-18	LT	0.4	UGL	
	DIMP	2009-06-09	LT	0.5	UGL	
486C	DIMP	1998-03-10		0.624	UGL	
544A	DIMP	1992-01-28	LT	0.392	UGL	
	DIMP	1994-10-07	LT	0.6	UGL	
	DIMP	2002-07-10	LT	0.35	UGL	
	DIMP	2004-08-18	LT	0.35	UGL	
545A	DIMP	1991-01-31	LT	0.392	UGL	
	DIMP	1995-07-28	LT	0.92	UGL	
	DIMP	1997-05-12	LT	0.35	UGL	

Table C-1. Offpost Private CFS Well Data Evaluation

Well	Analyte	Sample Date	Boolean	Value	Units	
	DIMP	1998-05-20	LT	0.35	UGL	
	DIMP	2004-06-15	LT	0.35	UGL	
548A	DIMP	1992-07-16	LT	0.392	UGL	
	DIMP	1993-11-17	LT	0.2	UGL	
	DIMP	1997-05-12	LT	0.35	UGL	
	DIMP	1998-05-21	LT	0.35	UGL	
	DIMP	2002-07-09	LT	0.35	UGL	
	DIMP	2004-07-14	LT	0.35	UGL	
588A	DIMP	1991-10-15		8.44	UGL	
588A	DIMP	1993-11-18		5.5	UGL	
588A	DIMP	1994-09-22		5.01	UGL	
588A	DIMP	1994-09-22		4.81	UGL	
588A	DIMP	1995-05-04		4.33	UGL	
588A	DIMP	1995-08-01	LT	0.92	UGL	
588A	DIMP	1996-02-14		3.33	UGL	
			Average	4.62		
			STD	2.27		
			Avg. + 2 STD	9.17		
589A	DIMP	1992-01-28		3.49	UGL	
589A	DIMP	1993-11-16		9.9	UGL	
589A	DIMP	1994-07-22		4.71	UGL	
589A	DIMP	1994-10-06		5.01	UGL	
589A	DIMP	1995-01-26		3.87	UGL	
589A	DIMP	1995-05-02		4.69	UGL	
589A	DIMP	1995-07-25		5.22	UGL	
589A	DIMP	1995-10-05		4.6	UGL	
589A	DIMP	1996-01-26		2.13	UGL	
589A	DIMP	1998-05-18		4.69	UGL	
589A	DIMP	1999-07-29		1.91	UGL	
			Average	4.57		
			STD	2.09		
			Avg. + 2 STD	8.75		
848A	DIMP	1996-06-11		0.906	UGL	
848A	DIMP	1996-09-09		0.974	UGL	
848A	DIMP	1998-05-21		1.28	UGL	
848A	DIMP	1999-05-26		1.32	UGL	
848A	DIMP	2000-06-29		1.74	UGL	
848A	DIMP	2001-06-13	LT	0.35	UGL	
848A	DIMP	2001-08-03		1.11	UGL	
848A	DIMP	2002-07-16		0.708	UGL	
848A	DIMP	2003-06-10	LT	0.35	UGL	
848A	DIMP	2004-06-30	LT	0.35	UGL	
			Average	0.91		
			STD	0.47		
			Avg. + 2 STD	1.86		

Table C-1. Offpost Private CFS Well Data Evaluation

		Sample				
Well	Analyte	Date	Boolean	Value	Units	
914B	DIMP	1999-05-26		1.02	UGL	
914B	DIMP	1999-06-24		1.07	UGL	
914B	DIMP	2000-05-25		1.75	UGL	
914B	DIMP	2001-07-10		3.6	UGL	
914B	DIMP	2002-07-16		3.11	UGL	
914B	DIMP	2003-06-16		2.51	UGL	
914B	DIMP	2004-07-06		2.67	UGL	
914B	DIMP	2005-06-15	LT	0.4	UGL	
914B	DIMP	2006-06-12		1.6	UGL	
914B	DIMP	2007-06-20		0.888	UGL	
914B	DIMP	2008-07-02		1.78	UGL	
914B	DIMP	2008-07-02	LT	0.5	UGL	
			Average	1.74		
			STD	1.04		
			Avg. + 2 STD	3.82		
986B	DIMP	1991-10-16	LT	0.392	UGL	
986B	DIMP	1993-06-17	LT	0.392	UGL	
986B	DIMP	1994-10-04	LT	0.6	UGL	
986B	DIMP	1996-02-13	LT	0.35	UGL	
986B	DIMP	1998-06-02	LT	0.35	UGL	
986B	DIMP	1998-09-24	LT	0.35	UGL	
986B	DIMP	2002-07-18	LT	0.35	UGL	
986B	DIMP	2004-06-17	LT	0.35	UGL	
986B	DIMP	2005-06-14	LT	0.4	UGL	
986B	DIMP	2006-06-13	LT	0.4	UGL	
986B	DIMP	2007-06-04	LT	0.4	UGL	
986B	DIMP	2009-05-18	LT	0.5	UGL	
Chloroform						
1070B	CHCL3	1999-06-24		8.86	UGL	
1070B	CHCL3	2000-06-14		0.209	UGL	
1070B	CHCL3	2001-07-10		0.447	UGL	
1070B	CHCL3	2003-07-30	LT	0.2	UGL	
914B	CHCL3	1999-06-24		1.09	UGL	
914B	CHCL3	2001-07-10	LT	0.2	UGL	

Table C-1. Offpost Private CFS Well Data Evaluation

Well	Analyte	Sample Date	Boolean	Value	Units	
Notes:						
STD = Standard Deviation						
LT = Less Than						
UGL = Micrograms per liter						
DIMP = Diisopropylmethyl phosphonate						
CHCL3 = Chloroform						