ROCKY MOUNTAIN ARSENAL

Final
Fifth Five-Year Review Report
for the
Rocky Mountain Arsenal
Commerce City
Adams County, Colorado

September 2021

Revision 0

U.S. Department of the Army

Approved by: **Date:**

21 September 2021

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Project Manager
Rocky Mountain Arsenal

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Final
Fifth Five-Year Review Report
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Commerce City
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Review Period: April 1, 2015 – March 31, 2020

Revision 0

September 22, 2021

U.S. Department of the Army

Prepared by:

Navarro Research and Engineering, Inc.

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ACRONYMS

μg/L	Micrograms per Liter
AFFF	Aqueous Film-Forming Foams
ALR	Action Leakage Rate
ARAR	Applicable or Relevant and Appropriate Requirement
Army	U.S. Army
ASR	Annual Summary Report
BANS	Basin A Neck System
BMP	Biomonitoring Program
BRES	Bedrock Ridge Extraction System
CAMU	Corrective Action Management Unit
CBSG	Colorado Basic Standard for Groundwater
CCR	Construction Completion Report
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFS	Confined Flow System
COC	Contaminant of Concern
CPMSO	4-Chlorophenylmethyl Sulfoxide
CPMSO2	4-Chlorophenylmethyl Sulfone
CSRG	Containment System Remediation Goal
cy	Cubic Yard
DBCP	Dibromochloropropane
1,1-DCLE	1,1-Dichloroethylene
12DCLE	1,2-Dichloroethane
DCN	Design Change Notice
DCPD	Dicyclopentadiene
DDE	2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDD	2,2-bis(p-chlorophenyl)-1,1-dichloroethane
DDT	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP	Diisopropylmethyl phosphonate
DNAPL	Dense Non-Aqueous Phase Liquid
ELF	Enhanced Hazardous Waste Landfill
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference(s)
FCS	First Creek Pathway System
FFA	Federal Facility Agreement
FS	Feasibility Study

ft	Foot/Feet
FY	Fiscal Year
FYR	Five-Year Review
FYRR	Five-Year Review Report for Rocky Mountain Arsenal
FYSR	Five-Year Summary Report for Groundwater and Surface Water
gpad	Gallons Per Acre Per Day
gpm	Gallon Per Minute
HHE	Human Health Exceedance
H:V	Horizontal to Vertical Ratio
HWL	Hazardous Waste Landfill
IC	Institutional Control
ICS	Integrated Cover System
IRA	Interim Response Action
kg	Kilogram
lbs	Pounds
LCS	Leachate Collection System
LDS	Leak Detection System
LNAPL	Light Non-Aqueous Phase Liquid
LS/LF	Leachate Storage/Loadout Facility
LTCP	Long-Term Care Plan
LTMP	Long-Term Monitoring Plan for Groundwater and Surface Water
LUC	Land Use Control
MCL	Maximum Contaminant Level
MCR	Monitoring Completion Report
mg/L	Milligrams Per Liter
mg/kg-day	Milligrams Per Kilogram Per Day
mm/year	Millimeters Per Year
MPS/ICS	Motor Pool System/Irondale Containment System
MRL	Method Reporting Limit
NBCS	North Boundary Containment System
NDMA	n-Nitrosodimethylamine
NDPA	n-Nitrosodi-n-propylamine
NOAEC	No Observed Adverse Effect Concentration
NODp	Notice of Partial Deletion
NOIDp	Notice of Intent for Partial Deletion
NRAP	Non-Routine Action Plan
NPL	National Priorities List
NPS	Northern Pathway System

NWBCS	Northwest Boundary Containment System
O&F	Operational and Functional
O&M	Operations and Maintenance
OCN	Operations and Maintenance Change Notice
OCPs	Organochlorine pesticides
OGITS	Off-Post Groundwater Intercept and Treatment System
OMC	Operations and Maintenance Contractor
OU	Operable Unit
PCB	Polychlorinated Biphenyl
PCE/TCLEE	Tetrachloroethylene
PCGMP	Post-Closure Groundwater Monitoring Plan
PFAS	Per- and Polyfluoroalkyl Substances
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctanesulfonic Acid
PQL	Practical Quantitation Limit
PT	Principal Threat
PUD	Planned Unit Development
PWT	Pacific Western Technologies, Inc.
RAO	Remedial Action Objective(s)
RCRA	Resource Conservation and Recovery Act
Refuge	Rocky Mountain Arsenal National Wildlife Refuge
Refuge Act	Rocky Mountain Arsenal National Wildlife Refuge Act
RfD	Reference dose for chronic oral exposure
RI	Remedial Investigation
RMA	Rocky Mountain Arsenal
RMANWR	Rocky Mountain Arsenal National Wildlife Refuge
ROD	Record of Decision
RVO	Remediation Venture Office
RYCS	Railyard Containment System
SAP	Sampling and Analysis Plan
SAR	Study Area Report
SARA	Superfund Amendments and Reauthorization Act of 1986
SCMMS	Soil Cover Moisture Monitoring System
SDT	Shell Disposal Trenches
SEO	State Engineer's Office
SFo	Oral cancer slope factor
Shell	Shell Oil Company
SOP	Standard Operating Procedure
SWAQMP	Site-Wide Air Quality Monitoring Program

TBC	To-Be-Considered Criterion
TCE/TRCLE	Trichloroethylene
TCHD	Tri-County Health Department
TCLEA	1,1,2,2-Tetrachloroethane
UFS	Unconfined Flow System
UPL	Upper Prediction Limit
USFWS	U.S. Fish and Wildlife Service
VOC	Volatile Organic Compound
WP	Wastepile

EXECUTIVE SUMMARY

This is the fifth Five-Year Review for the Rocky Mountain Arsenal (RMA) Superfund Site, which includes the RMA site and its associated area of affected groundwater contamination located in Adams County, Colorado. The purpose of the Five-Year Review is to evaluate the implementation and performance of the remedies in place to determine if the remedies are protective of human health and the environment.

Section 121(c) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), together with the implementing regulation in the National Oil and Hazardous Substance Pollution Contingency Plan, requires that remedial actions resulting in any hazardous substances, pollutants, or contamination remaining at a site above concentrations that allow for unlimited use and unrestricted exposure be reviewed no less than every five years to ensure protection of human health and the environment. This requirement applies to the cleanup being conducted at RMA. The United States Army (Army) conducted this Five-Year Review in accordance with these requirements and Section 36 of the Federal Facility Agreement (FFA) (EPA 1989), and this Five-Year Review Report (FYRR) presents a summary of this review.

The RMA includes two Operable Units (OUs) designated as On-Post OU (OU3) and Off-Post OU (OU4). The On-Post OU encompasses the entire RMA property and includes soil, structures and groundwater contamination within the approximately 26.5 square miles of RMA. The Off-Post OU includes soil and groundwater contamination north and northwest of RMA.

The U.S. 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 the release of contamination. Approximately 70 chemicals were the focus of the Remedial Investigation (RI) for the On-Post OU (Ebasco 1989, 1992). Of these, the principal contaminants are organochlorine pesticides, heavy metals, agent-degradation products and manufacturing by-products, and chlorinated and aromatic solvents.

The RI and subsequent investigations identified chemicals at more than 180 sites contaminating soil, ditches, stream and lakebed sediments, natural depressions and manmade basins, sewers, groundwater, surface water, biota, and structures. Unexploded ordnance was 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 Record of Decision (ROD) (Foster Wheeler 1996). The overall remedy required by the 1996 ROD for the On-Post OU includes the following:

- Intercept and treat contaminated groundwater.
- Construct a Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act-compliant Hazardous Waste Landfill (HWL) on-post.
- Demolish structures with no designated future use and dispose of the debris in either the new on-post HWL or the Basin A consolidation area, depending upon the degree of contamination.
- Remediate contaminated soil at RMA primarily through containment in the on-post HWL or under caps/covers or through treatment depending upon the type and degree of contamination. 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 future wildlife refuge.
- Implement institutional controls which restrict land use and prohibit use of the property for residential or agricultural purposes, use of the groundwater or surface water as a source of potable water, consumption of fish or game taken at RMA, and provide access restrictions to capped or covered areas.

Groundwater contamination migrated off post prior to the implementation of groundwater pump-and-treat systems, resulting in the need for the Off-Post OU, which addresses groundwater contamination north and northwest of RMA. The risk assessment performed for the Off-Post OU indicated that only human exposure via contaminated groundwater needed to be addressed. As a result, an Off-Post ROD was prepared and approved on December 19, 1995 (HLA 1995). The Off-Post ROD identified the following remedial components for off-post groundwater:

- Continue operation (and improvement, if necessary) of the Off-Post Groundwater Intercept and Treatment System (OGITS)
- Continue operation (and improvement, if necessary) of the North Boundary Containment System (NBCS) and Northwest Boundary Containment System (NWBCS)
- Conduct long-term groundwater and surface water monitoring
- Provide alternative water supplies for domestic well owners in areas of the Off-Post OU with contaminated groundwater and implementation of institutional controls intended to prevent future use of contaminated groundwater

Current and future land use for the On-Post OU has been restricted because the provisions in the Federal Facility Agreement (EPA 1989) and the On-Post ROD restrict certain land uses. Surrounded by development, the On-Post OU also provides a refuge for an abundant diversity of flora and fauna. For this reason, the majority of the site was designated a future National Wildlife Refuge in the Rocky Mountain Arsenal National Wildlife Refuge Act (Refuge Act) of 1992 (Public Law 102-402 1992).

As components of the remedy have been completed, administrative jurisdiction has been transferred to the U.S. Fish and Wildlife Service (USFWS) or other parties purchasing the land, except for the property and facilities continuing to be used for response actions. The portions of the On-Post OU transferred to other parties are subject to land use restrictions identified in the

FFA and ROD prohibiting residential development, use of groundwater 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; however, Institutional Controls (ICs) identified in the Off-Post ROD have been implemented to reduce the potential for exposure to groundwater exceeding remediation goals. In addition, the ROD requires a deed restriction that prohibits drilling new alluvial wells and use of deeper groundwater underlying the Shell Property (off-post) for potable purposes until such groundwater no longer contains contamination in exceedance of groundwater remediation goals established in the ROD.

Approximately, 93 percent of RMA surface media has been deleted from the National Priorities List (NPL) and almost 15,000 acres have been transferred to the USFWS since the Rocky Mountain Arsenal National Wildlife Refuge was established on April 21, 2004. Partial deletions have included groundwater in the eastern and southern perimeter areas of the RMA. However, groundwater underlying the central and northwestern portions of the site has not met remediation goals and remains on the NPL.

Five-Year Review (FYR) of the On-Post OU and the Off-Post OU remedial actions is required by statute. The Army has elected to perform RMA’s review on a site-wide basis and as such this review includes both the On-Post OU and Off-Post OU. Additional operable units were defined by EPA for purposes of completing IRAs. Although review of IRAs is not included in the FYR, a listing of the RMA projects and associated EPA-identified and tracked OUs is provided in Appendix C. The schedule for conducting this FYR is based on the completion date of the previous FYR, which was September 26, 2016.

Protectiveness Statements

The protectiveness of the remedial actions in both the On-Post and Off-Post OUs in terms of human health and the environment is discussed below. All controls are in place to adequately minimize risks.

On-Post Operable Unit

The remedy for the On-Post OU currently protects human health and the environment because remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks. Placement of contaminated soils and debris in the HWL, Enhanced Landfill (ELF), and Basin A has been completed with engineered cap/cover systems in place. These sites have specific groundwater monitoring and ongoing cover Operation & Maintenance (O&M) programs that monitor remedy effectiveness. Fences and signs are maintained around these areas and institutional controls prohibiting intrusive activities are in place to prevent exposure. Groundwater contamination is being treated to remediation goals at the RMA boundary (NWBCS and NBCS) as well as on post at the Railyard Containment System (through FY16) and at the Basin A Neck System, and operation and maintenance plans are in place to ensure long-term protection. The long-term and operational groundwater and surface water monitoring programs effectively monitor contaminant migration pathways on post and ensure effective operation of the treatment systems as well as track off-post contamination trends. Monitoring programs were completed for emerging contaminants. Treatment system containment system remediation goals (CSRGs) and long-term monitoring requirements were revised for 1,4-dioxane and n-Nitrosodi-n-propylamine (NDPA) to maintain protectiveness. Monitoring for perfluorooctanoic acid (PFOA)/perfluorooctanesulfonic acid (PFOS) indicates that RMA is not a significant source and no drinking water sources are impacted. The long-term biomonitoring program was completed during the FYR period and review of the tissue and soil sample results demonstrate the remedy is protective of wildlife. Completion of the Monitoring Completion Report is pending. Risks to human health and the environment are also minimized through implementation of land use controls (LUCs) restricting land and groundwater use to prevent exposures. The Land Use Control Plan (Navarro 2013) requirements were effectively implemented and monitoring of LUCs to ensure protectiveness continued during this FYR period. To be protective in the long-term, further evaluation of potential bypass at the NWBCS Northeast Extension needs to be completed and system adjustments made as necessary, and the Prairie Gateway Planned Unit Development (PUD) needs to be revised to resolve conflicts with the existing land use restrictions.

Off-Post Operable Unit

The remedy for the Off-Post OU currently protects human health and the environment because remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks in these areas. Groundwater contamination is being treated to Off-Post ROD remediation goals at the RMA boundary as well as at the OGITS. Chloride and sulfate concentrations are attenuating toward their CSRGs. Groundwater monitoring plans and system operation and maintenance plans are in place to ensure long-term protection. The required institutional control, notifying well permit owners of potential groundwater contamination, remains effective in its implementation. To be protective in the long-term, monitoring adjustments are needed for the off-post monitoring network, particularly downgradient of the NWBCS, to maintain adequate coverage for monitoring contaminant plumes. The NPS needs to be upgraded to address the existing dieldrin plume and revised easement. Contamination present in private well 359D needs to be further evaluated.

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site Name: Rocky Mountain Arsenal (RMA)		
EPA ID: CO5210020769		
Region: 8	**State:** CO	**City/County:** Commerce City/Adams County

SITE STATUS	
NPL Status: Final	
Multiple OUs? Yes	**Has the site achieved construction completion?** No

REVIEW STATUS
Lead agency: Other Federal Agency **If "Other Federal Agency" was selected above, enter Agency name:** U.S. Army
Author name (Federal or State Project Manager): Donald MacKelvey
Author affiliation: U.S. Army
Reporting period: April 1, 2015 – March 31, 2020 **Review period:** March 30, 2020 – April 30, 2021
Date of site inspection: June 23 through June 25, 2020
Type of review: Statutory
Review number: 5
Triggering action date: September 26, 2016
Due date *(five years after triggering action date)*: September 26, 2021

Issues/Recommendations

OU(s) without Issues/Recommendations Identified in the Five-Year Review:
Not applicable.

Issues and Recommendations Identified in the Five-Year Review:

OU(s): On Post (3)	Issue Category: Remedy Performance			
	Issue: Dieldrin is present above the practical quantitation limit in the Northwest Boundary Containment System Northeast Extension downgradient performance wells. System bypass could be a contributing factor for these exceedances.			
	Recommendation: Additional evaluation of system performance and potential flow north of the slurry wall to identify potential system modifications necessary to maintain plume capture.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	June 30, 2023

OU(s): On Post (3)	Issue Category: Remedy Performance			
	Issue: Uses identified in the Prairie Gateway PUD are inconsistent with the land use restrictions.			
	Recommendation: Continue coordination with Commerce City to ensure appropriate changes are made to the Prairie Gateway PUD to resolve apparent conflicts with the LUCs.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	September 30, 2024

Issues and Recommendations Identified in the Five-Year Review (Continued):

OU(s):Off Post (4)	**Issue Category: Monitoring**			
	Issue: Dieldrin is present above the practical quantitation limit in the off-post area downgradient of the Northwest Boundary Containment System. A permanent monitoring network has not been identified.			
	Recommendation: Review the off-post monitoring network to determine locations suitable for long-term monitoring of the dieldrin plume downgradient of the Northwest Boundary Containment System.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	March 31, 2022

OU(s): Off Post (4)	**Issue Category**: **Institutional Controls**			
	Issue: Diisopropylmethyl phosphonate (DIMP) concentrations exceed the Colorado Basic Standard for Groundwater in private drinking water well 359D.			
	Recommendation: Additional evaluation of well 359D and other private wells in the area to determine the most appropriate action for providing an alternate water source.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	December 31, 2021

OU(s): Off-Post (4)	**Issue Category: Monitoring**			
	Issue: Dieldrin was identified above the practical quantitation limit in the gap between modified Northern Pathway System extraction wells 37817 and 37818. The lease is expiring for the area where original system wells capture this portion of the plume.			
	Recommendation: Construct system upgrades for extraction and recharge to address dieldrin plume in the gap area. Finalize lease for modified Northern Pathway System location.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	June 1, 2022

Issues and Recommendations Identified in the Five-Year Review (Continued):

OU(s): Off-Post (4)	Issue Category: Monitoring			
	Issue: Off-post monitoring wells have been damaged or are unsafe to sample due to road construction or increased traffic.			
	Recommendation: Review off-post monitoring network to ensure adequate coverage for monitoring off-post contaminant plumes and identify appropriate safe locations for replacement wells.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	Federal Facility	EPA/State	December 31, 2021

Protectiveness Statement(s)

Operable Unit: On-Post (3)	*Protectiveness Determination:* Short-term Protective	*Addendum Due Date (if applicable):*

Protectiveness Statement:
The remedy for the On-Post Operating Unit currently protects human health and the environment because remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks. Placement of contaminated soils and debris in the Hazardous Waste Landfill, Enhanced Hazardous Waste Landfill, and Basin A has been completed with engineered cap/cover systems in place. These sites have specific groundwater monitoring and ongoing cover operations and maintenance programs that monitor remedy effectiveness. Fences and signs are maintained around these areas and institutional controls prohibiting intrusive activities are in place to prevent exposure. Groundwater contamination is being treated to remediation goals at the Rocky Mountain Arsenal boundary (Northwest Boundary Containment System and North Boundary Containment System) as well as on post at the Railyard Containment System (through Fiscal Year 2016) and at the Basin A Neck System, and operation and maintenance plans are in place to ensure long-term protection. The long-term and operational groundwater and surface water monitoring programs effectively monitor contaminant migration pathways on post and ensure effective operation of the treatment systems as well as track off-post contamination trends. Monitoring programs were completed for emerging contaminants. Treatment system CSRGs and long-term monitoring requirements were revised for 1,4-dioxane and NDPA to maintain protectiveness. Monitoring for PFOA/PFOS indicates that RMA is not a significant source and no drinking water sources are impacted. The long-term biomonitoring program was completed during the five-year review period and review of the tissue and soil sample results demonstrate the remedy is protective of wildlife. Completion of the Monitoring Completion Report is pending. Risks to human health and the environment are also minimized through implementation of land use controls restricting land and groundwater use to prevent exposures. The Land Use Control Plan requirements were effectively implemented and monitoring of land use controls to ensure protectiveness continued during this five-year review period. To be protective in the long-term, further evaluation of potential bypass at the Northwest Boundary Containment System Northeast Extension needs to be completed and system adjustments made as necessary, and the Prairie Gateway Planned Unit Development needs to be revised to resolve conflicts with the existing land use restrictions.

Operable Unit: Off-Post (4)	*Protectiveness Determination:* Short-term Protective	*Addendum Due Date (if applicable):* Click here to enter date.

Protectiveness Statement:
The remedy for the Off-Post Operating Unit currently protects human health and the environment because remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks in these areas. Groundwater contamination is being treated to Off-Post Record of Decision remediation goals at the Rocky Mountain Arsenal boundary as well as at the Off-Post Groundwater Intercept and Treatment System. Chloride and sulfate concentrations are attenuating toward their Containment System Remediation Goals. Groundwater monitoring plans and system operation and maintenance plans are in place to ensure long-term protection. The required institutional control, notifying well permit owners of potential groundwater contamination, remains effective in its implementation. To be protective in the long-term, monitoring adjustments are needed for the off-post monitoring network, particularly downgradient of the Northwest Boundary Containment System, to maintain adequate coverage for monitoring contaminant plumes. The Northern Pathway System needs to be upgraded to address the existing dieldrin plume and revised easement. Contamination present in private well 359D needs to be further evaluated.

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1.0 INTRODUCTION

This Five-Year Review (FYR) was performed for the Rocky Mountain Arsenal (RMA) Superfund Site, which includes the RMA site and its associated area of affected groundwater contamination located in Adams County, Colorado. The purpose of the Five-Year Review is to determine whether the remedy at the RMA is protective of human health and the environment. This Five-Year Review Report (FYRR) provides a detailed discussion of the conclusions reached, issues identified, and recommendations made to address them.

Section 121(c) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), together with the implementing regulation in the National Oil and Hazardous Substance Pollution Contingency Plan, requires that remedial actions resulting in any hazardous substances, pollutants, or contamination remaining at a site above concentrations that allow for unlimited use and unrestricted exposure be reviewed no less than every five years to ensure protection of human health and the environment. This requirement applies to the cleanup being conducted at RMA, shown on Figure 1.0-1. The United States Army (Army) conducted this Five-Year Review in accordance with these requirements and Section 36 of the RMA Federal Facility Agreement (EPA 1989).

This is the fifth Five-Year Review completed at RMA and primarily includes information generated between April 1, 2015, through March 31, 2020, referred to in this report as the FYR period. Environmental monitoring and analytical data results from October 1, 2014, through September 30, 2019, were reviewed and evaluated in this FYR. All projects are discussed based upon their status as of March 31, 2020. Where data and information relevant to preparation of the FYRR, or necessary for responses to Regulatory Agency comments, became available after the deadlines noted above, it was evaluated for inclusion. In some cases, subsequent data and reports were included if the information was important to the assessment based on best professional judgment.

Five-Year Review (FYR) of the On-Post OU and the Off-Post OU remedial actions is required by statute. The Army has elected to perform RMA's review on a site-wide basis and as such this review includes both the On-Post OU and Off-Post OU. Additional operable units were defined by EPA for purposes of completing IRAs. Although review of IRAs is not included in the FYR, a listing of the RMA projects and associated EPA-identified and tracked OUs is provided in Appendix C. The triggering date for this review is the date of signature of the previous FYR, which was September 26, 2016.

The general structure of this report was based on EPA FYR guidance (EPA 2001) and supplemental guidance as appropriate. To enable the reader to better understand this report, the outline is provided below:

> **Section 1, Introduction**—Provides the legal basis and the objectives for the review as well as a description of the report structure.
>
> **Section 2, Site Chronology**—Provides a chronology of significant ROD-related events.

Section 3, Background—Provides historical information on RMA, including a description of past operations, a list of Contaminants of Concern (COCs), and information on current and future land use.

Section 4, Remedial Actions— Provides a summary of the remedial actions conducted at the site including the Remedial Action Objectives (RAOs), the selected remedy, the ROD standards, and the ROD goals. In order to streamline the presentation of information, this section is first organized to be consistent with the selected remedy in the On-Post and Off-Post RODs.

As such, the implementation projects are first grouped into one of three ROD categories (groundwater, soil, structures) or "other" for miscellaneous remedy components.

Consistent with EPA FYR guidance, within the three medium groups or "other," the projects are further grouped into projects under construction, operational projects, and completed projects. This second structure facilitates organization of the assessments in Section 7.0.

Section 5, Progress since 2015 Five-Year Review— Provides the protectiveness statements and lists the status of recommendations and follow-up actions from the 2015 FYRR and whether they achieved the intended purpose.

Section 6, Five-Year Review Process—Provides a list of participants in the FYR process as well as the approach taken in performing this review. This section also presents data collected in the groundwater, surface water, biota, and air monitoring programs, and a section summarizing remedy costs.

Section 7, Assessment—Uses information provided in Section 6.0 as well as additional information gathered in the review process to answer the three key questions identified below.

> **Sections 7.1**—Question 1 - "Is the remedy functioning as intended by the decision documents?"
>
> **Section 7.2**—Question 2 - "Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives used at the time of the remedy selection still valid?" This includes a review of risk assessment assumptions; an update to all Applicable or Relevant and Appropriate Requirements (ARARs) and TBCs; and a discussion of the impact of these changes.
>
> **Section 7.3**—Question 3 - "Has any other new information come to light that could call into question the protectiveness of the remedy?"
>
> **Section 7.4**—Provides a Technical Assessment Summary.
>
> Consistent with EPA FYR guidance, the projects are regrouped in Section 7.0 into projects under construction, operational projects, and completed projects to facilitate the assessment process.

Section 8, Issues—Provides a succinct statement of the issues identified that might affect remedy protectiveness.

Section 9, Recommendations and Follow-up Actions—Details follow-up actions necessary to address the issues identified in Section 8.0.

Section 10, Protectiveness Statements—Provides protectiveness statements under the current FYR for both the On-Post and Off-Post OUs.

Section 11, Next Five-Year Review—Details when the next FYR is scheduled to take place.

Section 12, References.

The summary of the community interviews is presented in Appendix A of this report. Public comments received and responses to public comments are presented in Appendix B. Appendix C lists the Operable Units associated with the RMA Site. The FYR site inspection and interview checklists are presented in Appendix D and responses to Regulatory Agency comments are presented in Appendix E.

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2.0 SITE CHRONOLOGY

Table 2.0-1 lists the chronology of significant ROD-related events. Additional sources of information regarding the schedules of specific remedial project start and completion dates and CCR dates include the Remediation Design and Implementation Schedule (RDIS) (PMRMA 2010), the Remedial Action Summary Report (TtEC 2011e), and the CCRs listed in the references.

Table 2.0-1 also includes actions related to listing and deletion from the National Priorities List. To date, five partial deletions occurred as discussed below. Combined, these five deletions have reduced the surface media area remaining on the NPL On-Post OU to approximately 1.7 square miles.

- **Western Tier Parcel** - The Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 (Refuge Act) stipulated that approximately 815 acres (subsequently more accurately defined as 917 acres) referred to as the Western Tier Parcel be transferred to Commerce City for fair market value. In October 1998, a Notice of Intent for Partial Deletion (NOIDp) was published by EPA in the Federal Register to delete surface media and groundwater. The deletion was subsequently postponed to allow for additional soil sampling and site evaluation. These additional efforts resulted in the publication of a second NOIDp in September 2002. After public comment, the Notice of Partial Deletion (NODp) was published in January 2003. The ultimate sale of the property to Commerce City occurred in June 2004.
- **Selected Perimeter Area and Surface Deletion Area** - The Refuge Act also requires that upon certification by EPA that all response actions at RMA have been completed (i.e., NPL deletions have been made), the Army will transfer administrative jurisdiction over the property to the U.S. Fish and Wildlife Service (USFWS). The NOIDps for the Selected Perimeter Area and Surface Deletion Area were published in the Federal Register in July 2003 for a total of approximately 5,000 acres. The Selected Perimeter Area included surface media, structures, and groundwater, while the Surface Deletion Area included surface media only. The corresponding NODps were published in the Federal Register in January 2004. Most of the Selected Perimeter Area and Surface Deletion Area were transferred to the USFWS on March 2, 2004, and the USFWS officially established the Rocky Mountain Arsenal National Wildlife Refuge (Refuge) in April 2004.

  The Refuge Act also specifies that 100-foot (ft)-wide strips inside the RMA boundary on the northwestern, northern, and southern sides be transferred to local governments, at no cost, to allow improvement of public roads. The approximately 11 miles of 100-ft-wide strips amount to approximately 126 acres. This property was included in the Selected Perimeter Area deletion described above. Following that deletion, the property was transferred to Commerce City, City and County of Denver, and Colorado Department of Transportation in September 2004.
- **Internal Parcel** - The Internal Parcel deletion included surface media and groundwater in areas east of E Street (with the exception of a small area of contaminated groundwater located in the northwestern corner of Section 6) and surface media only for areas west of

E Street. The NOIDp for the Internal Parcel at RMA was published in April 2006. Following public comment, the NODp for approximately 7,400 acres (11.5 square miles) was published in the Federal Register at the end of July 2006. Most of the property was transferred to the USFWS in September 2006 to further expand the extent of the Refuge.

- **Central and Eastern Area** - This partial deletion included approximately 2,500 acres (3.9 square miles) of surface media in the central and eastern areas of the RMA. No groundwater was included in this partial deletion. The NOIDp was published in June 2010, and, following public comment, the NODp was published in the Federal Register on September 13, 2010. This property was then transferred to the USFWS on September 30, 2010.
- **Off-Post OU Partial Deletion** - One partial deletion has been completed for the Off-Post OU. The deletion included all surface media in the Off-Post OU, including the Shell Oil Company (Shell) Property. Groundwater in the off-post area has not met remediation goals and remains on the NPL. A NOIDp was issued in June 2010, and the NODp was published September 13, 2010, along with the Central and Eastern Area deletion described above. Some of the Shell Property was deeded to Commerce City following Ready for Reuse Determination (EPA 2009).

Table 2.0-1. Chronology of ROD-Related Events

Date*	Event
1942	Establishment of RMA.
Late 1950s	Off-Post groundwater contamination first suspected.
1974	Army establishes the RMA Contamination Control Program.
Apr. 1975	Colorado Department of Health issues a Cease-and-Desist Cleanup and Monitoring Order to RMA in connection with the alleged pollution of groundwater and surface water north of RMA.
1977	Army installs pilot groundwater containment system at the north boundary.
1978–1984	Army and Shell install three boundary groundwater containment systems.
1984	Site proposed for addition to the NPL.
1984	Army completes a Preliminary Assessment and Site Inspection that identifies 179 potentially contaminated sites.
1985	First interim response action completed.
Aug. 1987	RMA added to the NPL.
Feb. 1989	FFA signed.
Jan. 1992	RI completed.
Dec. 1992	Development and Screening of Alternatives completed.
Oct. 1995	Detailed Analysis of Alternatives completed.
Dec. 1995	Record of Decision signed for Off-Post OU.
Jun. 1996	Record of Decision signed for On-Post OU.
May 1999	Technical Justification Report for volume modification of Toxic Storage Yards Soil Remediation project.
Oct. 2000	RMA first FYRR issued.

Table 2.0-1. Chronology of ROD-Related Events

Date*	Event
Nov. 2000	ESD issued on Chemical Sewer Remediation—Section 35 and Section 26.
Nov. 2000	ESD issued on South Plants Balance of Areas and Central Processing Area Soil Remediation project.
Nov. 2001	ESD issued on change in endrin standard for treatment systems (NBCS, NWBCS, BANS, and OGITS).
Feb. 2002	ESD issued on Secondary Basins Soil Remediation project.
Jan. 2003	Deleted approximately 940 acres on the western side of RMA from the NPL.
Apr. 2003	On-Post ROD Amendment for Hex Pit Remediation.
Apr. 2003	ESD issued on Section 36 Balance of Areas Soil Remediation project.
Dec. 2003	Removed Chemical Weapons Convention Treaty monument.
Jan. 2004	Deleted approximately 5,053 acres mostly on the southern and eastern sides of RMA from the NPL.
Apr. 2004	Rocky Mountain Arsenal National Wildlife Refuge officially established.
Jul. 2004	ESD issued on Burial Trenches Soil Remediation project.
Sep. 2004	ESD issued on North Plants Structure Demolition and Removal project.
May 2005	ESD issued on Existing (Sanitary) Landfills Soil Remediation project.
Oct. 2005	On-Post ROD Amendment for the Section 36 Lime Basins and Basin F Principal Threat Soil projects.
Mar. 2006	ESD issued on groundwater remediation and revegetation requirements.
May 2006	ESD issued on Section 36 Bedrock Ridge Groundwater Plume Extraction System.
June 2006	ESD issued on Shell Disposal Trenches project.
July 2006	Deleted approximately 7,396 acres of the on-post OU from the NPL.
Nov. 2007	RMA second FYRR issued.
Apr. 2008	Minor change to On-Post ROD for soil covers.
June 2008	ESD issued on Miscellaneous Southern Tier Soil Remediation project and Section 35 Soil Remediation project (Sand Creek Lateral and Other Ditches Remediation).
Sept. 2008	ESD issued on Off-Site Waste Disposal and cost increases for On-Site Disposal Facility projects.
Nov. 2008	ESD issued on Munitions (Testing) Soil Remediation project.
Jan. 2009	ESD issued on North Plants Soil Remediation project.
Jan. 2009	ESD issued on Basin F/Basin F Exterior Remediation project, Part 2, and Chemical Sewer Remediation project.
Apr. 2009	ESD issued on Basin F Wastepile Remediation project.
Oct. 2009	ESD issued on Section 36 Balance of Areas Soil Remediation project.
Sept. 2010	Deleted approximately 2,500 acres of the on-post OU from the NPL. Deleted all surface media in the off-post OU.
Feb. 2011	ESD issued on Basin F/Basin F Exterior Remediation project.
Sept. 2011	RMA third FYRR issued.
Sept. 2011	Remedial Action Summary Report issued

Table 2.0-1. Chronology of ROD-Related Events

Date*	Event
Jan. 2012	ESD issued on Lime Basins DNAPL Remediation project.
May 2012	Minor change for the Off-Post Groundwater Intercept and Treatment, Northern Pathway System relocation.
Sept. 2012	ESD issued on Groundwater Remediation Requirements.
Sept. 2016	RMA fourth FYRR issued.
May 2017	Minor change to On-Post ROD for BANS adding TCLEA CSRG.
Apr. 2020	Minor change to On-Post and Off-Post RODs adding 1,4-Dioxane and n-Nitrosodi-n-propylamine (NDPA) CSRGs.

Notes:*Dates noted are EPA approval dates.

ESD = Explanation of Significant Differences NBCS = North Boundary Containment System
NWBCS = Northwest Boundary Containment System BANS = Basin A Neck System
OGITS = Off-Post Groundwater Intercept and Treatment System NPL = National Priorities List
OU = Operable Unit RI = Remedial Investigation DNAPL = Dense Non- Aqueous Phase Liquid

3.0 BACKGROUND

3.1 PHYSICAL CHARACTERISTICS

The RMA site is comprised of two OUs. The On-Post OU originally consisted of all of RMA and occupied approximately 26.6 square miles in southern Adams County, approximately 10 miles northeast of downtown Denver. As of the end of the FYR period, five partial deletions have occurred that reduce the On-Post OU surface media area remaining on the NPL to approximately 1.7 square miles (see Section 2.0). Groundwater underlying the central and northwestern portions of the site has not met remediation goals and remains on the NPL. The Off-Post OU encompasses groundwater north and northwest of RMA that exceeds Containment System Remediation Goals (CSRGs), as well as property where the Off-Post Groundwater Intercept and Treatment System (OGITS) is located. The Off-Post OU surface media has been deleted from the NPL; however, groundwater in the off-post area has not met remediation goals and remains on the NPL. The Off-Post and On-Post OUs are depicted on Figure 3.0-1.

3.2 LAND AND RESOURCE USE

The 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, the principal lessee, manufactured primarily pesticides at RMA from 1952 to 1982. Common industrial and waste disposal practices during these years resulted in the release of contamination.

Because the area is ecologically unique, current and future land use for the On-Post OU has been restricted pursuant to land use restrictions established by the FFA (EPA 1989). Surrounded by development, the RMA provides a refuge for an abundant diversity of flora and fauna. For this reason, the majority of the site was designated as a future National Wildlife Refuge by the Refuge Act of 1992. As components of the remedy have been completed and the land deleted from the NPL, administrative jurisdiction has been transferred to the USFWS or other parties purchasing the land, except for the property and facilities continuing to be used for response actions (e.g., landfills and groundwater treatment systems).

Refuge property must be managed in accordance with the FFA, On-Post ROD, and Refuge Act. The land transferred or sold to other non-USFWS parties continues to be subject to restrictions prohibiting residential and industrial use, use of water on the site as a source of potable water, hunting and fishing for consumptive use, and agricultural use in accordance with the On-Post ROD, the Refuge Act, and the FFA. Current and future land use of the Off-Post OU has not been restricted; however, Institutional Controls (ICs) identified in the Off-Post ROD have been implemented to reduce the potential for exposure to groundwater exceeding remediation goals. In addition, the Off-Post ROD requires a deed restriction that prohibits drilling new alluvial wells and use of deeper groundwater underlying the Shell Property for potable purposes until such groundwater no longer contains contamination in exceedance of groundwater remediation goals established in the Off-Post ROD.

3.3 HISTORY OF CONTAMINATION

RMA was used as a manufacturing facility for the production and dismantling of chemical and incendiary munitions. Industrial and agricultural chemicals, primarily pesticides, also were manufactured at RMA by several lessees, most notably Shell Oil Company. Wastes from the manufacturing facilities were initially discharged into Basin A, an unlined basin in Section 36. Overflow was directed into other unlined basins (Basins B, C, D, and E). After November 1956, the chemical sewers discharged all liquid wastes into Basin F (which was asphalt lined to prevent leakage) and the use of unlined basins was discontinued. Basin F remained in use until 1982. Solid wastes were disposed primarily in Section 36, although other on-post disposal sites also were used. Some of the basins, pits, burn sites, sewers, and structures (buildings, pipes, and tanks) became sources of soil and groundwater contamination as a result of spills, leaks, or other releases.

Contamination migrated off post primarily by shallow groundwater prior to the implementation of groundwater pump-and-treatment systems. Off-post surface soil was contaminated by the deposition of airborne contaminants, non-RMA-related agricultural application of pesticides, and irrigation practices.

3.4 INITIAL RESPONSE

In 1974, chemicals associated with RMA operations were found in groundwater north of the site. As a result, the Army established the Contamination Control Program to evaluate the nature and extent of contamination and to develop response actions to control contaminant migration for sites that posed potential immediate risks to human health and the environment. Initial responses included construction of groundwater treatment systems at the RMA boundaries to capture and treat contaminated groundwater and minimize the off-post discharge of RMA contaminants. The North Boundary Containment System, Irondale Containment System and Northwest Boundary Containment System were constructed between 1978 and 1983. Other early actions included closing of the on-post deep disposal well, applying fugitive dust emission controls for basins, disposing of 76,000 drums of waste salts, removing portions of the chemical sewer system, upgrading the sanitary sewer system, and enhancing liquid evaporation from Basin F.

The RMA site was proposed for addition to the NPL in 1984 and the listing was finalized in August 1987. Interim response actions were determined to be necessary to mitigate the impact of contamination at several sites prior to selection of a final remedy to stop the spread of or eliminate contamination and to begin the actual remediation. Most of these actions were completed before the RODs were issued, although some are ongoing (e.g., groundwater treatment systems) and have been incorporated into the RODs. In January 1992, the Remedial Investigation was completed. The Feasibility Study was completed in October 1995 and the Proposed Plan, identifying the preferred remedy, was submitted for public comment on October 16, 1995.

3.5 BASIS FOR TAKING ACTION

One hundred eighty-one sites with varying degrees of contamination, ranging from areas of several hundred acres with multiple contaminant detections at concentrations up to a few parts per hundred to isolated detections of single analytes at a few parts per billion, were delineated during the Remedial Investigation. Contamination was detected on-post in soil, ditches, stream and lakebed sediments, sewers, groundwater, surface water, biota, structures, and, to a much lesser extent, air. These contaminated areas included approximately 3,000 acres of soil, 15 groundwater plumes, and 798 structures. The principal contaminants are organochlorine pesticides, heavy metals, agent-degradation products and manufacturing by-products, and chlorinated and aromatic solvents. Unexploded ordnance was identified at several locations. Contamination was detected off-post in groundwater, surface water, surface soil, and sediments. The specific COCs that were identified for on-post soil and off-post environmental media are listed in Table 3.0-1. The individual CCRs may be referenced for a list of COCs on a project-specific basis.

Risk assessments were conducted for on-post soil and off-post groundwater for which COCs were identified. The baseline risk assessment did not evaluate exposure pathways related to on-post groundwater and surface water, fish and game consumption, or agricultural uses due to existing land use restrictions, so COC concentrations in those media were not developed.

The risk assessment performed for the On-Post OU indicated that soil is the primary medium through which humans would be exposed to contamination on post (Ebasco 1990, 1994). This is because other exposure pathways are limited through land-use restrictions and/or limitations specified in the On-Post ROD (FWENC 1996) and the Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 (Public Law 1992). The risk assessment performed for the Off-Post OU indicated that the only exposure pathway of concern was human exposure to contaminated groundwater (HLA 1992).

Table 3.0-1. Contaminants of Concern

On-Post OU Soil COCs (On-Post ROD, Table 6.1-1)	Off-Post OU Soil COCs (Off-Post ROD, Table 6.4)	Off-Post OU Sediment COCs (Off-Post ROD, Table 6.3)	Off-Post OU Groundwater COCs (Off-Post ROD, Table 6.1)	Off-Post OU Surface Water COCs (Off-Post ROD, Table 6.2)
Aldrin	Aldrin	Aldrin	Aldrin	Arsenic
Arsenic	Chlordane	DBCP	Arsenic	Chlordane
Benzene	Dieldrin	Dieldrin	Atrazine	Chloride
Cadmium	Endrin	Endrin	Benzene	DCPD
Carbon Tetrachloride	DDE	DDE	Carbon tetrachloride	DDE
Chlordane	DDT	DDT	Chlordane	DDT
Chloroacetic Acid			Chloride	Dieldrin
Chlorobenzene			Chlorobenzene	DIMP
Chloroform			Chloroform	Fluoride
Chromium			CPMSO	Sulfate
DBCP			CPMSO2	
DCPD			DBCP	
DDE			1,2-Dichloroethane	
DDT			DCPD	

Table 3.0-1. Contaminants of Concern

On-Post OU Soil COCs (On-Post ROD, Table 6.1-1)	Off-Post OU Soil COCs (Off-Post ROD, Table 6.4)	Off-Post OU Sediment COCs (Off-Post ROD, Table 6.3)	Off-Post OU Groundwater COCs (Off-Post ROD, Table 6.1)	Off-Post OU Surface Water COCs (Off-Post ROD, Table 6.2)
1,2-Dichloroethane			DDE	
1,1-Dichloroethylene			DDT	
Dieldrin			Dichlorobenzene	
Endrin			DIMP	
HCCPD			Dieldrin	
Isodrin			Dithiane	
Lead			1,4-Dioxane	
Mercury			Endrin	
Methylene Chloride			Ethylbenzene	
1,1,2,2-Tetrachloroethane			Fluoride	
Tetrachloroethylene			HCCPD	
Toluene			Isodrin	
Trichloroethylene			Malathion	
			Manganese	
			NDPA	
			Oxathiane	
			Sulfate	
			Tetrachloroethylene	
			Toluene	
			Trichloroethylene	
			Xylene	

Note: Emerging contaminants 1,4-dioxane and NDPA were added to the Off-Post OU groundwater COCs in 2020.

4.0 REMEDIAL ACTIONS

This section describes the remedy selected in the On-post and Off-post RODs, and the status of each component of the remedy. The On-Post ROD specified that the remedy address four essential parts: groundwater, structures, soil, and "other". The On-Post remedy components are summarized in Table 4.0-1. Table 4.0-2 summarizes the remedy components of the Off-Post ROD. The ROD Requirements listed in Tables 4.0-1 and 4.0-2 represent modifications to the RODs through Explanation of Significant Difference (ESD) or ROD Amendment. The four parts and their components were reconfigured into a design/construction-oriented approach as detailed in the Remediation Design and Implementation Schedule, Appendix B.

Table 4.0-1. Summary of On-Post Remedy Requirements

Remedy Component	On-Post ROD Requirement
Groundwater	
Site-wide Groundwater Monitoring and Surface Water Monitoring	Continue to conduct groundwater and surface water monitoring programs at RMA. A network of monitoring wells will be sampled to evaluate the effectiveness of the remedy. A select number of deep wells will also be sampled to monitor any contamination in the confined aquifer. Surface water will be monitored and managed in a manner consistent with the selected remedy.
Confined Flow System Monitoring	Confined aquifer wells are monitored in the South Plants, Basin A, and Basin F areas.
Confined Flow System Well Closure	Close and seal monitoring wells installed in the confined aquifer that may represent pathways for migration from the unconfined aquifer.
Northwest Boundary Containment System (NWBCS)	Continue operation of boundary system until shut-off criteria are met (also part of Off-Post ROD). [a]
North Boundary Containment System (NBCS) and n-Nitrosodimethylamine (NDMA)	Continue operation of boundary system until shut-off criteria are met (also part of Off-Post ROD). [a] Monitoring and assessment of NDMA contamination (using a 20 part per trillion method detection limit) will be performed in support of design refinement/design characterization to achieve remediation goals specified for the boundary groundwater treatment systems (also part of Off-Post ROD).
Irondale Containment System	Continue operation of boundary system until shut-off criteria are met. [a]
Motor Pool Containment System	Continue operation of existing IRA systems until shut-off criteria are met. [a]
Railyard Containment System (RYCS)	Continue operation of existing IRA systems until shut-off criteria are met. [a]
Basin A Neck System (BANS)	Continue operation of existing IRAs until shut-off criteria are met. [a]
Section 36 Bedrock Ridge Extraction System (BRES)	Install extraction system and treat extracted groundwater at Basin A Neck System. [a]

Table 4.0-1. Summary of On-Post Remedy Requirements

Remedy Component	On-Post ROD Requirement
Section 36 Lime Basins Dense Non-Aqueous Phase Liquid (DNAPL) Remediation Project	Continue removal of recoverable quantities of DNAPL and monitor to evaluate potential impacts on the Lime Basins slurry wall. DNAPL is collected and transported off site for treatment. This project consists of the Lime Basins Slurry Wall Dewatering System and its accompanying facilities, and additional DNAPL project-specific monitoring wells. [a]
North Plants Light Non-Aqueous Phase Liquid (LNAPL) Recovery	A pilot study on removal of LNAPL was initiated in 2009 with the purpose to determine the extent to which removal of LNAPL is practicable using a passive skimming system. This system consists of LNAPL recovery wells and monitoring wells. Remedy requirements to be determined following pilot study. [a]
North of Basin F Well	Continue operation of existing IRAs until shut-off criteria are met.
South Lakes Plume Monitoring	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. [a]
Groundwater Mass Removal System	Perform additional source treatment in targeted areas. Extract contaminated groundwater from the South Tank Farm Plume and the South Plants North Plume in the vicinity of the Lime Basins. Treat extracted groundwater at the CERCLA Wastewater Treatment Facility and recharge treated groundwater in the vicinity of the extraction well fields. [a]
Chloride and Sulfate	Chloride and sulfate are expected to attenuate naturally to the CSRGs.
Structures	
Agent History	All No Future Use structures will be demolished[1] and disposed of in on-post Hazardous Waste Landfill (HWL).
Significant Contamination History	All No Future Use structures will be demolished and disposed of in on-post HWL.
Other Contamination History	All No Future Use structures will be demolished and used as grade fill in Basin A, which will subsequently be covered as part of the soil remediation.
Asbestos-Containing Material (ACM) and Polychlorinated Biphenyl (PCB)	Structural assessments will be performed, and ACM and PCB contaminated materials will be removed and disposed of in the on-post HWL.
Process Related Equipment	Process-related equipment not remediated as part of the Chemical Process-Related Activities IRA will be disposed in the on-post HWL.
Soil	
On-Post Hazardous Waste Landfill	Construction of a Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA) - compliant hazardous waste landfill on post. [a]

Table 4.0-1. Summary of On-Post Remedy Requirements

Remedy Component	On-Post ROD Requirement
Enhanced Hazardous Waste Landfill (ELF)	Construct a triple-lined RCRA- and TSCA-compliant hazardous waste landfill on post. [a]
Former Basin F	Excavate soil that exceeded the principal threat (PT) soil exceedance criteria and dispose in triple-lined cell. [a]
Basin F Wastepile	Excavate wastepile soil that exceeded the PT soil exceedance criteria and liner materials and dispose in triple-lined landfill. [a,3] Backfill with on-post borrow material and stockpiled overburden.
Basin F/Basin F Exterior	Construct a RCRA-equivalent cover including biota barrier over the entire former basin and the remaining chemical sewer. [a]
Basin A Consolidation and Remediation	Consolidation of soil posing a potential risk to biota and structural debris from other sites. Construction of a RCRA-Equivalent cover including biota barrier over the soil that exceeded the PT soil exceedance criteria, the Human Health Soil Exceedance Criteria (HH SEC), and soil posing a potential risk to biota. [a]
Sanitary/Process Water Sewers	Plug sanitary sewer manholes to prohibit access and eliminate the manholes as a potential migration pathway for contaminated groundwater. Post aboveground warning signs every 1,000 ft along the sewer lines to indicate their location underground.
Chemical Sewers	Plug chemical sewer voids within South Plants Central Processing Area (CPA) and Complex (Army) Disposal Trenches area. The plugged sewers are contained beneath the RCRA-equivalent cover in their respective site. For areas outside the South Plants CPA and Complex (Army) Disposal Trenches cover areas, excavate and landfill sewer lines and soil that exceeded the PT soil exceedance criteria and the HH SEC.[1] Backfill with on-post borrow material.
Complex (Army) Disposal Trenches Slurry Wall	Install slurry wall into competent bedrock around the disposal trenches. Dewatering within the slurry wall to ensure containment.[2]
Complex (Army) Disposal Trenches	Construct a RCRA-equivalent cover including biota barrier over the entire site. [a]
Shell Disposal Trenches Slurry Wall	Install slurry wall into competent bedrock around the disposal trenches. Dewatering within the slurry wall to ensure containment.
Shell Disposal Trenches	Modify the existing soil cover to be a RCRA-equivalent cover including a biota barrier. Construct a 2-ft-thick soil cover over impacted soil areas adjacent to the Shell Disposal Trenches.[a]
Toxic Storage Yards	Excavate and landfill soil that exceeded the HH SEC. [a, 2] Backfill with on-post borrow material.
Existing (Sanitary) Landfills	Excavate and landfill soil that exceeded the HH SEC. Excavate landfill debris and biota risk soil and consolidate

Table 4.0-1. Summary of On-Post Remedy Requirements

Remedy Component	On-Post ROD Requirement
	beneath Basin A cover. Backfill with on-post borrow material.[a]
Lake Sediments	Excavate and landfill soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. Backfill with on-post borrow material.
Buried Sediments	Excavate and landfill soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. Backfill with on-post borrow material. [a]
Burial Trenches	Locate unexploded ordnance (UXO) using geophysical survey; remove and detonate. Remove and landfill munitions debris. Excavate and landfill soil that exceeded the HH SEC. Perform agent screening during excavation of ESA-2c. [a, 1, 2] Backfill with on-post borrow material.
Munitions Testing	Locate UXO using geophysical survey; remove and detonate. Remove and landfill munitions debris. [a,2]
Sand Creek Lateral	Excavate and landfill soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. Backfill with on-post borrow material. [a]
Surficial Soil	Excavate and landfill soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. Excavate and landfill soil from the pistol and rifle ranges and consolidate beneath Basin A cover. Backfill the HHE exceedance area with on-post borrow material. [a]
Ditches and Drainage Areas	Excavate and landfill soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. Backfill with on-post borrow material. [a]
Buried M-1 Pits	Excavate the soil that exceeded the PT soil exceedance criteria and the HH SEC, stabilize, and landfill.[1,3] Perform treatability testing to determine the mixture of stabilization agents, verify the effectiveness of the treatment process, and establish operating parameters for the design of the full-scale operation. Backfill with on-post borrow material.
Hex Pit	Excavate and landfill the soil that exceeded the PT soil exceedance criteria and the HH SEC. [a,3]
South Plants Central Processing Area	Excavate the soil that exceeded the PT soil exceedance criteria and the HH SEC to a depth of 5 ft and landfill.[1] Foundations within human health soil areas are removed to a depth of 5 ft. Construct a RCRA-Equivalent cover including biota barrier over the remaining PT and HHE soil and soil posing a potential risk to biota. Soil posing a potential risk to biota from other portions of South Plants may be used as backfill and/or gradefill prior to placement of the soil cover. [a]
South Plants Ditches	Excavate and landfill the soil that exceeded the PT soil exceedance criteria and the HH SEC; consolidate soil posing risk to biota under the South Plants Balance of Areas soil cover. Backfill with on-post borrow material. [a]
South Plants Balance of Areas	Locate UXO using geophysical survey; remove and detonate. Excavate and landfill chemical sewer lines, soil

Table 4.0-1. Summary of On-Post Remedy Requirements

Remedy Component	On-Post ROD Requirement
	that exceeded the PT soil exceedance criteria and the HHSEC, and PCB soil.[1,2] Remove and landfill munitions debris. Excavate biota risk soil and consolidate under the South Plants Central Processing Area cover or use as backfill for excavated areas. Construct a 3-ft-thick soil cover over the former HHE areas. Sample former biota risk soil areas to verify contaminant of concern concentrations do not exceed site evaluation criteria. Backfill former biota risk soil areas with minimum 1-ft-thick, clean soil from on-post borrow areas. [a]
Section 36 Balance of Areas	Locate UXO using geophysical survey; remove and detonate. Remove and landfill munitions debris. Excavate and landfill chemical sewer lines and soil that exceeded the HH SEC. Backfill with on-post borrow material. Excavate biota risk soil and consolidate beneath Basin A cover. [a,1,2]
Secondary Basins	Excavate and landfill the soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. Backfill with on-post borrow material. [a]
North Plants Soil	Excavate and landfill chemical sewer lines and soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. [a,2] Backfill with on-post borrow material.
Section 35 Soil	Excavate and landfill soil that exceeded the HH SEC. Excavate biota risk soil and consolidate beneath Basin A cover. Backfill with on-post borrow material. [a]
Section 36 Lime Basins	Construct a RCRA-Equivalent cover including biota barrier over the former basins. Install slurry wall into competent bedrock around the disposal basins. Dewatering within the slurry wall to ensure containment. [a,1]
PCB Contaminated Soil	Excavate and disposal of PCB-contaminated soil with concentrations of 250 parts per million (ppm) or greater in the on-post HWL. Soils identified with concentrations ranging from 50-250 ppm will be covered with 3 ft of soil.
Contingent Soil Volume	Excavate and landfill up to 150,000 bank cubic yards of additional volume to be identified based on visual field observations. Confirmatory samples may be used to identify the contingent soil volume requiring excavation. An additional 14 samples from North Plants, Toxic Storage Yards, Lake Sediments, Sand Creek Lateral, and Burial Trenches and up to 1,000 additional confirmatory samples may be used to identify the contingent soil volume requiring excavation.
Other	
CERCLA Wastewater Treatment Plant	Continue operation of the CWTP to support the remediation activities.
RCRA-Equivalent Cover Demonstration Project	Demonstrate cap performance equivalent to a RCRA landfill cap according to an EPA- and state-approved demonstration

Table 4.0-1. Summary of On-Post Remedy Requirements

Remedy Component	On-Post ROD Requirement
	that will include comparative analysis and field demonstration.
Site Wide Biota Monitoring	Continued monitoring, as part of design refinement, for areas that may pose a potential risk to biota. [a] Water levels in Lake Ladora, Lake Mary, and Lower Derby Lake will be maintained to support aquatic ecosystems. The biological health of the ecosystems will continue to be monitored. Aquatic sediments are left in place and the area is monitored to ensure that the sediments continue to pose no unacceptable risk to aquatic biota. Continue to fund USFWS to conduct on-post wildlife monitoring programs.
Site Wide Air Monitoring	Continue to conduct air, groundwater, and surface water monitoring programs at RMA.
Medical Monitoring	The Army and Shell will fund Agency for Toxic Substances and Disease Registry to conduct an RMA Medical Monitoring Program in coordination with CDPHE. The program's nature and scope will include baseline health assessments and be determined by the on-post monitoring of remedial activities to identify exposure pathways, if any, to any off-post community.
Geophysical Screening	Areas outside the central portions of RMA that are suspected to have potential UXO presence are screened and cleared.
UXO Disposal	Any UXO encountered during remediation will be excavated and transported off post for detonation (unless the UXO is unstable and must be detonated on post) or other demilitarization process.
Permanent Revegetation/Irrigation	Remedy components for all sites include reconditioning the surface soil and revegetating areas disturbed during remediation with locally adapted perennial vegetation. The disturbed areas will be revegetated consistent with a USFWS refuge management plan. [a]
Drummed Waste Handling	Stored, drummed waste identified in the waste management element of the CERCLA Hazardous Waste IRA may be disposed in the on-post hazardous waste landfill in accordance with the Corrective Action Management Unit (CAMU) Designation Document.
South Adams County Water Supply and DIMP	Provision of $48.8 million held in trust to provide for the acquisition and delivery of 4,000 acre-feet of potable water to South Adams County Water and Sanitation District and the extension of the water-distribution lines from an appropriate water supply distribution system to all existing well owners within the DIMP plume footprint north of RMA as defined by the detection limit for DIMP of 0.392 parts per billion (ppb).

Table 4.0-1. Summary of On-Post Remedy Requirements

Remedy Component	On-Post ROD Requirement
	In compliance with National Environmental Policy Act, PMRMA will separately evaluate the potential impacts to the environment of both the acquisition of a water supply for South Adams County Water and Sanitation District and for extension of water-distribution lines. In the future, owners of any domestic wells, new or existing, found to have DIMP concentrations of 8 ppb (or other relevant CBSG at the time) or greater will be connected to a water-distribution system or provided a deep well or other permanent solution.
On-Post Water Supply	A sufficient on-post water supply will be maintained to support remedial actions (revegetation, habitat enhancement, maintenance of lake levels). A risk evaluation will be performed prior to any future non-potable use to ensure that such use is protective of human health and the environment,
Trust Fund	Form a Trust Fund group and provide a good-faith best effort to establish a Trust Fund for the operation and maintenance of the Remedy.
CERCLA Five-year Reviews	In accordance with CERCLA, a site review will be conducted at least every five years until groundwater containment system remediation goals are achieved to assure that human health and the environment are protected during and after remediation. The site review will use monitoring program data to assess whether additional remedial action would be warranted

[a] ROD Requirement represents modifications made to the On- and Off-Post RODs through ESD or ROD Amendment.

[1]Agent monitoring during structure demolition or soil excavation and treatment of any debris or soil containing agent by caustic solution washing.

[2]Munitions screening prior to excavation, off-post detonation of any munitions encountered, and landfill munitions debris/soil above toxic characteristic leaching procedure (TCLP).

[3] Excavation is conducted using vapor-and odor-suppression measures as necessary.

Table 4.0-2. Summary of Off-Post Remedy Requirements

Remedy Component	Off-Post ROD Requirement
Groundwater	
Off-Post Groundwater Intercept and Treatment System (OGITS)	Continue operation of the OGITS until shut-off criteria are met. The OGITS consists of the First Creek pathway System (FCS) and the Northern Pathway System (NPS).[a]
Northwest Boundary Containment System	Continue operation of boundary system until shut-off criteria are met (also part of On-Post ROD). [a]
North Boundary System Containment System and NDMA	Continue operation of boundary system until shut-off criteria are met (also part of On-Post ROD). [a] Monitoring and assessment of NDMA contamination (using a 20 part per trillion method detection limit) will be performed in support of design refinement/design

Table 4.0-2. Summary of Off-Post Remedy Requirements

Remedy Component	Off-Post ROD Requirement
	characterization to achieve remediation goals specified for the boundary groundwater treatment systems (also part of On-Post ROD).
Off-Post Well Closure	Abandon groundwater wells completed in one or more aquifers below the alluvial aquifer that may represent pathways for migration between aquifers.
Site–Wide Groundwater Monitoring and Surface Water Monitoring	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 (included with on-post site-wide monitoring).
South Adams County Water Supply and DIMP	Exposure control/provision of alternated water supply. As part of the On-Post ROD, provide for the acquisition and delivery of 4,000 acre-feet of potable water to South Adams County Water and Sanitation District and the extension of the water-distribution lines from an appropriate water supply distribution system to all existing well owners within the DIMP plume footprint north of RMA as defined by the detection limit for DIMP of 0.392 ppb. In the future, owners of any domestic wells, new or existing, found to have DIMP concentrations of 8 ppb (or other relevant CBSG at the time) or greater will be connected to a water-distribution system or provided a deep well or other permanent solution.
Land Use Controls	Land use controls (LUCs) to prevent the future use of groundwater exceeding remediation goals.
Soil	
Off-Post Surficial Soil	Revegetate (tilling and seeding) approximately 160 acres located in the southeast portion of Section 14 and the southwest portion of Section 13.
Remediation Scope and Schedule	The Army will present the scope of the ongoing groundwater monitoring programs in an Implementation Plan to be submitted within 90 days following issuance of the Off-Post ROD. A schedule for compliance with the containment system remediation goals will be included in the Implementation Plan.
CERLCA Five-year Reviews	In accordance with CERCLA, a site review will be conducted at least every five years until groundwater containment system remediation goals are achieved to assure that human health and the environment are protected during and after remediation. The site review will use monitoring program data to assess whether additional remedial action would be warranted.

[a] ROD Requirement represents modifications made to the On- and Off-Post RODs through ESD or ROD Amendment.

Table 4.0-3 (Tables Tab) provides a detailed list of the On-Post and Off-Post ROD projects/topics and IRAs and references the sections of this FYRR where each project/topic is discussed. The number in parentheses at the end of each section heading (e.g., #17) corresponds to the number used to identify the projects in Table 4.0-3. The table indicates the status of each project/topic as of March 31, 2020, and actual or projected CCR or Monitoring Completion Report (MCR) completion dates for each project. Projects classified as "Operating" do not include projected CCR completion dates. More detailed information on the schedule for completed projects, as well as a more comprehensive description, can be found in the Remediation Design and Implementation Schedule for On-Post ROD projects (PMRMA 2010), Off-Post Remediation Scope and Schedule for Off-Post ROD projects (HLA 1996), CCRs, and the IRA Summary Reports.

Consistent with EPA FYR guidance, the status of each project in Table 4.0-3 is defined by one of the following:

- **Under construction**—Defined as actions where physical construction has been initiated but is not yet complete as of March 31, 2020.
  - For soil cover projects, under construction includes projects where cover construction is complete and interim O&M activities are occurring. However, because O&M activities are the only project activities occurring during the FYR period, these projects are considered substantially complete for purposes of protectiveness determination.
- **Operating**—Defined as projects where remedial actions are ongoing but cleanup levels have not yet been achieved.
  - For projects that include installation of a dewatering system, operating is defined for the project when the dewatering system is installed and functioning; however, dewatering goals have not yet been achieved.
- **Completed**—Defined as actions where construction is complete and cleanup levels or objectives have been achieved.
  - For groundwater projects, post-shut-off monitoring may occur after project completion.

In addition, where relevant, IRAs that were incorporated into the final remedy are included on Table 4.0-3 with an indication of the corresponding ROD-identified project.

Sections 4.1 through 4.3 describe specific components of the selected remedy for the On-Post and Off-Post OUs for groundwater, soil and other components. The remedy for structures has been completed and is not discussed in detail in this report. Each section identifies events that occurred during the FYR period. Events include one-time events that would require Regulatory Agency notification and potential FYR issues that were resolved during the FYR period.

4.1 GROUNDWATER REMEDY SELECTION AND IMPLEMENTATION

The On-Post ROD specified the following RAOs for 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.*

The selected remedy for on-post groundwater includes:

- *Continued operation of the three RMA boundary groundwater containment and treatment systems, the North Boundary Containment System (NBCS), the Northwest Boundary Containment System (NWBCS), and Irondale Containment System, which treat groundwater to attain ARARs and health-based remediation goals. These systems and the on-post groundwater IRA systems (Basin A Neck, North of Basin F, Motor Pool, and Rail Yard) will continue to operate until shut-off criteria specified in Section 9.1 of the On-Post ROD are met. ARARs for chloride and sulfate at the NBCS will be achieved through natural attenuation as described in "Development of Chloride and Sulfate Remediation Goals for the North Boundary Containment System at the Rocky Mountain Arsenal" (MKE 1996). Assessment of the chloride and sulfate concentrations will occur during the 5-year site reviews.*
- *Installation of a new extraction system to intercept and contain a contaminated groundwater plume in the northeast corner of Section 36 that will be treated at the Basin A Neck IRA system.*
- *Water levels in Lake Ladora, Lake Mary, and Lower Derby Lake will be maintained to support aquatic ecosystems. The biological health of the ecosystems will continue to be monitored.*
- *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 Colorado Basic Standards for Groundwater (CBSGs) in groundwater at the point of discharge. Groundwater monitoring will be used to demonstrate compliance.*
- *Monitoring and assessment of n-nitrosodimethylamine contamination in support of potential design refinement/design characterization to achieve remediation goals specified for boundary groundwater treatment systems.*

Other specific components of the selected remedy for on-post groundwater are provided below in the context of the project discussions.

The Off-Post ROD (HLA 1995) did not provide specific RAOs but did establish remediation goals in the form of CSRGs. The CSRGs were established based on chemical-specific ARARs or health-based criteria when an ARAR was not present.

The selected remedy identified the following remedial components for off-post groundwater:

- *Operation (and improvement if necessary) of the OGITS*
- *Continued operation (and improvement, if necessary) of the NBCS and NWBCS*
- *Long term groundwater and surface water monitoring*
- *Provision of alternative water supplies and implementation of institutional controls intended to prevent future use of contaminated groundwater.*

The on-post and off-post groundwater remedies for RMA are summarized as discussed in Sections 4.1.1.1 through 4.1.1.3. The site-wide groundwater and surface water monitoring programs associated with the RMA remedy are addressed in Sections 6.3.3 and 6.3.4 as part of the data review.

4.1.1 Operating Groundwater Remedies

The data used for this FYR were collected pursuant to the 2010 Long-Term Monitoring Plan (LTMP) for Groundwater and Surface Water, as amended (TtEC and URS 2010), the Rocky Mountain Arsenal Sampling Quality Assurance Project Plan (SQAPP) (Navarro 2015c, Navarro 2019y), and the Sampling and Analysis Plans (SAPs) issued as part of the Post-Closure Plans developed in accordance with RCRA requirements.

The main objectives of the monitoring programs are to evaluate the effectiveness of the remedies; to verify the effectiveness of existing on-post and off-post groundwater extraction, containment, and treatment systems; to satisfy CERCLA requirements for waste left in place; and to provide data for FYRs. The main component of the remedy related to groundwater is continued operation of the groundwater extraction and treatment systems. Locations of the treatment systems are shown on Figure 3.0-1.

The following on-post and off-post groundwater extraction and treatment systems were evaluated against compliance requirements and performance criteria:

- Northwest Boundary Containment System (NWBCS)
- North Boundary Containment System (NBCS)
- Railyard Containment System (RYCS)
- Basin A Neck System (BANS)
- Bedrock Ridge Extraction System (BRES)
- Off-Post Groundwater Intercept and Treatment System (OGITS)
  OGITS consists of two separate extraction systems, the First Creek Pathway System (FCS) and the Northern Pathway System (NPS).

CSRGs were established for each containment/treatment system on the basis of 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 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. Compliance is maintained when the four-quarter moving average in the treatment plant effluent is below the corresponding CSRG for each analyte.

For several contaminants where the chemical-specific ARAR was below the method reporting limit, the ROD identified Practical Quantitation Limits (PQLs) as applicable criteria to serve as the remediation goals. The PQL represents the lowest calculated level of analyte concentration that can be reliably achieved within specified limits of precision and accuracy during routine analysis for environmental samples. Currently, PQLs serve as the CSRGs for aldrin, dieldrin and NDMA.

The 2010 LTMP (TtEC and URS 2010) performance criteria for each of these systems are presented in their respective subsections in this report. The 2010 LTMP performance criteria incorporated and revised the criteria presented in the Off-Post Remediation Scope and Schedule and 1999 LTMP (Foster Wheeler 1999). The LTMP provides the framework for reporting evaluations of groundwater treatment systems. The LTMP also has specific consultation triggers and notification requirements for each remedy component. Table 4.1-1 provides a summary of regulatory agency notifications and summary of actions taken during the five-year review period.

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
FY14 Trigger Events and Agency Notifications			
9/29/2014	Trigger Event – Shell Trenches water levels exceed dewatering goal.	After meeting the Shell Trenches dewatering goal in July and October 2013, water levels rose above the target elevation at one of the six compliance boreholes. Shell Trenches water levels exceeded the dewatering goal at one of the six performance boreholes for third consecutive quarter, September 2014 (Note, previous notifications were made on 3/21/2014 and 7/7/2014). Water levels remained above the dewatering goal through FY15.	LTMP-NRAP-2016-001 was approved on 7/21/2016. Corrective Action – A cost-benefit evaluation for potential dewatering options was conducted in 2018. A new monitoring well was installed inside the southeast corner of the slurry wall. Refer to OCN-LTMP-2019-010. An investigation was completed to locate a burial trench and identify the trench bottom elevation. The newly identified trench bottom was incorporated into the LTMP. Refer to OCN-LTMP-2020-005.
9/29/2014	Trigger Event – Complex Army Disposal Trenches (CADT) water levels exceed dewatering goal.	The target dewatering goals were required to be achieved September 9, 2014, after the five-year period required to establish vegetation. The dewatering goal has been met in one of the two compliance wells (i.e., well 36216). However, the design goal of water levels below the target elevation of 5,227 feet in well 36217 has not been met. Meeting the dewatering goal in 36217 is projected to take between 11 and 25 years.	LTMP-NRAP-2016-002 was approved on 7/21/2016. Corrective Action – A cost-benefit evaluation for installing dewatering wells in the CADT to supplement the existing dewatering trench was conducted in 2016. to the LTMP was revised to incorporate the alternate performance goal. Refer to OCN-LTMP-2019-009.

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
9/29/2014	Trigger Event – Lime Basins water levels exceed dewatering goal.	The target dewatering goals were required to be achieved September 9, 2014, after the five-year period required to establish vegetation. The dewatering goals include water elevations below the waste inside the slurry wall enclosure, and an inward hydraulic gradient across the slurry wall in all performance well pairs.	LTMP-NRAP-2016-003 was approved on 8/25/2016. Corrective Action – Progress toward meeting the goals is being made. A corrective action was taken in FY15 to improve the system performance, which involved changing the dewatering well and treatment operations from batch mode to more continuous operation. As of 2016, water levels have fallen below the waste. The inward hydraulic gradient is anticipated to be achieved in April 2021. An interim date of November 2018 was accepted by the parties for tracking progress toward meeting the 2021 goal. Refer to OCN-LTMP-2016-001.
FY15 Trigger Events and Agency Notifications			
11/13/2014	Trigger Event – Individual effluent sample above Containment System Remediation Goals (CSRG) at Northwest Boundary (NWBCS).	The dieldrin concentration in the plant effluent sample was 0.024 µg/L, which exceeds the current practical quantitation limit (PQL) of 0.013 µg/L.	Corrective Action – Changes in NWBCS treatment operation included more frequent pulsing of higher amounts of regenerated carbon and use of virgin carbon in all three adsorbers.
9/2/2015		The dieldrin concentration in the plant effluent sample was 0.0146 µg/L, which exceeds the current PQL of 0.013 µg/L.	Corrective Action – Plant operational sampling continued on a biweekly schedule to monitor plant performance until effluent concentrations were stabilized below the PQL. The NWBCS waste sump was cleaned out.
12/3/2014	Trigger Event – Concentrations of inorganic COCs in surface water samples exceeded the aquatic life standards.	Surface water samples collected in May 2013 at SW25101 and SW26002 showed concentrations above the calculated aquatic life standards. Additional samples collected in FY15 also exceed aquatic life standards.	Corrective Action – Short-Term Surface Water Sampling and Analysis Plan, Addendum 1 approved by Regulatory Agencies on August 2, 2016. Follow-up samples collected at SW26002 (Basin E Pond) in FY17 exceeded aquatic standards, but samples collected in FY18 did not. Former Basin E surface soils were evaluated in FY19. Metals in the Basin E surface water were determined to be from naturally occurring metals in soils (Navarro 2019b).

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
12/31/2014	Trigger Event – NWBCS, Northeast Extension – Loss of primary performance criteria – downgradient concentrations increasing.	Dieldrin concentration in downgradient performance well 22512 exceeded the PQL of 0.013 for four consecutive quarters and is increasing.	Corrective Action – Operational changes at the plant included more frequent pulsing of higher amounts of regenerated carbon and use of virgin carbon in all three adsorbers. Army completed evaluation of NWBCS recharge well flow rates and specific capacities to optimize flow. Preliminary evaluation of recharge system indicated that specific capacity of most recharge wells had declined and, redevelopment was needed. Redevelopment of the recharge wells was completed in FY17. Decision Document DD-36 finalized in May 2019 and monitoring well 22084 was installed at the Northeast Extension July 16, 2019. Evaluation is ongoing and may include modifying recharge volumes and/or locations to help maintain system containment. Installing a new extraction well to intercept the Northeast Extension flow was proposed to eliminate potential off-post migration of dieldrin. Evaluation is ongoing.
10/19/2015 Similar to event in FY15 (12/31/2014)	Trigger Event – NWBCS – Loss of secondary performance criterion – downgradient concentration trend increasing while primary criteria are met.	Dieldrin concentrations in NWBCS and downgradient performance wells exceeded the PQL in June 2015 (Note, previous notification had been made in May 2014). The dieldrin concentrations above the PQL at NWBCS likely are caused by a combination of higher water levels, concentrations near or at the PQL in the NWBCS effluent, and a small amount of contaminated flow from the Northeast Extension area. Identified as an issue in Section 8.0.	
4/2/2015	Trigger Event – Basin A Neck System (BANS) – Loss of primary performance criterion – downgradient concentrations increasing.	Concentrations of 1,2-dichloroethane, CPMSO2, dieldrin, and dithiane increased to above their respective CSRGs in downgradient performance well 26505. Concentrations of CPMSO2 and dieldrin increased to above their respective CSRGs in downgradient performance well 35525. Increased concentrations are likely attributed to a reduction in the area with a reverse hydraulic gradient due to overall increased water levels in the area.	Corrective Action – Extraction pumping rates were increased to improve the extent and magnitude of reverse hydraulic gradient. Reverse gradient improved as a result of the increased extraction and concentrations of contaminants in the downgradient wells decreased to below CSRGs.
8/27/2015	Trigger Event – Missed water level data collection from two damaged off-post wells (37348 and 37429).	Wells were damaged during highway improvements off post.	Corrective Action – Commerce City Public Works Project Manager informed the Army that the subcontractor will be held responsible for replacement of the wells and requested information regarding locations for replacement wells.

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
			Wells were replaced in November 2016. Refer to OCN-LTMP-2017-003.
9/17/2015	Trigger Event – Inability to collect performance monitoring data at NWBCS well 22075.	During quarterly water level monitoring activities for the NWBCS, well 22075 was identified as plugged. Efforts to clear the obstruction in well failed.	Corrective Action – Well 22005 will be used as an interim well until 22075 is replaced. Refer to OCN-LTMP-2017-001. The well was replaced in September 2017.
FY15 Operational Change Notices – None issued in FY15			
FY16 Trigger Events and Notifications			
3/16/2016	NWBCS, Original System, show potential loss of primary performance criterion – possible loss of plume-edge capture.	The dieldrin concentration in cross-gradient performance well 27010 was slightly above the PQL during the first quarter of FY16. This well may not be within the capture zone of the NWBCS and contamination in the vicinity of the well could migrate off post at concentrations above the remediation goal.	Corrective Action – Actions taken to bring the NWBCS treatment plant effluent into more consistent compliance with the dieldrin PQL appear to have been successful, and the December 2015 effluent compliance sample was below the PQL. Increasing the sampling frequency of well 27010 to quarterly is the proposed action to address all the potential causes because the dieldrin concentrations are expected to decrease. If the lower effluent concentrations and the reversal in the water level trend do not cause dieldrin concentrations to decrease to below the PQL in well 27010, subsequent actions such as increasing the flow rates in the Southwest Extension recharge wells and/or Original System dewatering wells will be considered. <u>Current Status</u>: The dieldrin concentration in well 27010 decreased to below the PQL in subsequent quarters; however, the concentration increased to above the PQL again in the first quarter of FY17. As a result, flow rate adjustments discussed above were implemented. These changes have caused the concentrations in well 27010 to remain below the PQL.
3/16/2016	NWBCS, shows loss of secondary performance criterion – downgradient	Sample concentrations in the NWBCS Original System and Northeast Extension downgradient performance wells were above the dieldrin PQL in FY16.	Corrective Action – Actions taken for the downgradient performance wells included increasing the recharge well flow rates at the northeast end of the recharge system in the vicinity of well 22512 and evaluating the potential

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
	concentration trends increasing.	Mann-Kendall trend analysis of the dieldrin data in NWBCS Original System performance wells indicates that the trends are increasing in three wells (37332, 37333, and 37600), with no trend in two wells (37330 and 37331). Similar conclusions are reached for the trends from visual inspection of dieldrin concentration vs. time graphs for the wells. Dieldrin concentrations in the Northeast Extension wells 22015 and 22512 exhibit decreasing and stale trends, respectively.	cause of the increasing dieldrin concentration trend in well 37333. An evaluation of the NWBCS recharge system was completed and recommendations for increasing the flow rates and redevelopment of recharge wells were implemented. If these changes, in combination with more effective treatment, do not resolve the problem, additional measures such as installing a new extraction well in the vicinity of well 22015 to intercept the Northeast Extension contaminant flow path, installing a new recharge well near well 22512, or other alternate options may be proposed. Current Status: Per Decision Document DD-36, finalized in May 2019, monitoring well 22084 was installed at the Northeast Extension on July 16, 2019. Evaluation is ongoing and may include modifying recharge volumes and/or locations to help maintain system containment. Installing a new extraction well to intercept the Northeast Extension flow has also been proposed to eliminate potential off-post migration of dieldrin. This is identified as an issue in Section 8.0.
***FY16 Operational Change Notices* – None issued in FY16**			
FY17 Trigger Events and Agency Notifications			
1/18/2017	Trigger Event – Railyard Containment System (RYCS) downgradient shut-off monitoring well exceeded CSRG for DBCP.	The DBCP concentration in well 03534 was slightly above the CSRG during the first quarter of FY17.	Corrective Action – In accordance with the LTMP, the five-year shut-off monitoring period was restarted with quarterly sampling required beginning in the second quarter of FY17. The DBCP concentrations in all shut-off wells were at or below the CSRG during the second through fourth quarters of FY17 and the first quarter of FY18. The Regulatory Agencies were notified, and in accordance with the LTMP annual monitoring will now take place during the first quarter of each fiscal year.
1/18/2017	Trigger Event – NWBCS Original System, loss of primary performance	The dieldrin concentration in cross-gradient performance well 27010 was slightly above the PQL during the first quarter of FY17.	Corrective Action – The dieldrin concentration in well 27010 increased to above the PQL in the first quarter of

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
	criterion – possible loss of plume-edge capture.	This well may not be within the capture zone of the NWBCS and contamination in the vicinity of the well could migrate off post at concentrations above the remediation goal.	FY17 and the flow rate adjustments discussed below were implemented. Increased the flow rates in Original System dewatering wells to expand the capture zone. Decreased flow rates in Original System recharge wells to reduce the gradient between the recharge wells and the dewatering wells, thereby expanding the capture zone. Increased Southwest Extension recharge well flow rate by approximately 10 percent to direct the main plume eastward. These changes have caused the concentrations in well 27010 to remain below the PQL.
3/27/2017	Trigger Event – NWBCS Original System, Individual effluent sample above CSRG.	NDMA concentration in NWBCS treatment plant effluent sample exceeded the current PQL during the second quarter of FY17.	Corrective Action – NDMA has been present in groundwater upgradient of the NWBCS Original system. Historically, NDMA has been detected sporadically in the NWBCS influent and effluent. There was no apparent system or operational issue associated with the exceedance. The influent concentration was a nondetect at < 0.003 µg/L, and the method blank for the lot was below the MRL. Based on the 2014 upgradient well detections being below the current PQL, the lack of detections of NDMA in the upgradient wells since 2014, and the influent result as non-detect, the reason for the effluent detection above the current PQL was not apparent. Because the NWBCS is not capable of treating groundwater for NDMA, no operational changes have been made. Quarterly monitoring will continue to evaluate frequency of detections exceeding the PQL.
5/15/2017	Trigger Event – NWBCS Original System, Individual effluent sample above CSRG.	NDMA concentration in NWBCS treatment plant effluent sample exceeded the current PQL during the third quarter of FY17.	
9/27/2017	Trigger Event – North Boundary Containment System (NBCS) treatment plant effluent exceeded PQL for NDMA.	NDMA concentration in NBCS treatment plant effluent sample exceeded the current PQL in July and August 2017.	Corrective Action – Two additional ultra-violet lamps were placed in service during first quarter FY18. The NDMA effluent concentration was below the PQL during the first quarter of FY18, and subsequent quarters.

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
FY17 Operational Change Notices			
Approved 2/2/2017	The Section 36 Lime Basins dewatering system did not meet the remediation goals in the expected time frame (September 2014).	In January 2016, the water elevation was slightly above the waste elevation in only one well (36238) inside the slurry wall. This goal was met in June 2016. In addition, an outward hydraulic gradient is still present at in the northern well pairs. Issued on 11/8/2016.	OCN-LTMP-2016-001 – Revised projected dates for dewatering goals based on NRAP-LTMP-2016-003, approved August 25, 2016. The projected date to meet the water elevation goal was changed to June 30, 2016. The new projected date to meet the inward hydraulic gradient in all well pairs is April 30, 2021. An interim date of November 2018 was proposed for tracking progress towards meeting the inward hydraulic gradient goal. Review in November 2018 showed continued progress toward meeting the goal.
Approved 2/2/2017	Confined flow system (CFS) alternate well sampling proposed in 2015 FYSR.	Higher chloride concentrations have been detected in CFS well 35083. Wells 02047 and 02048 were previously identified as alternate CFS wells and sampling them had not been necessary. Sampling wells 02047 and 02048 may help characterize if there is lateral or vertical migration of chloride in the A Sand or 1U Sand near well 35083. This is identified as an other finding in Section 9.1. Well 23193 was in the 1999 LTMP. It was thought to have been damaged in 2002, but camera inspections have found no evidence of damage and a sample was obtained in 2016. Issued on 12/19/2016.	OCN-LTMP-2016-002 – Wells 02047, 02048, and 23193 have been added to the CFS monitoring network. They are sampled twice-in-5-years.
Approved 4/20/2017	NWBCS water level monitoring well 22075 is obstructed and unusable. Bedrock Ridge Extraction System (BRES) water level and water quality performance well 36578 is a one-inch diameter piezometer that requires upgrading.	Well 22075 is used to demonstrate hydraulic gradient for the NWBCS. Based on well camera inspection, it appears that a portion of the bentonite seal is obstructing the well. Well 36578 cannot be sampled with a pump. In addition, the majority of the BRES contaminants are volatile organic compounds (VOC) and the sampling concentrations may be affected by bailing.	OCN-LTMP-2017-001 – Well 22055 was used as an interim well until 22075 was replaced. Well 22075 was abandoned and Well 22083 was installed in September 14, 2017. Well 36578 was over-drilled and well 36250 was installed September 18, 2017.

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
Approved 6/30/2017	TCLEA is present above the CBSG in the BANS influent.	The CBSG for TCLEA was promulgated after the RODs were completed. Existing groundwater data associated with the treatment systems do not provide reporting limits sufficiently low to determine whether TCLEA is present above the CBSG in the plant influents or effluents.	OCN-LTMP-2017-002 – TCLEA was added to the CSRG list for BANS. The method was recertified with a sufficiently low reporting limit.
Approved 10/5/2017	Several water level network wells were damaged or destroyed during construction activities along 104th Ave. One was also damaged in Section 8 during construction of the Parkfield Wetlands.	New wells were installed to provide replacement wells for the Long-Term Monitoring Plan for Groundwater and Surface Water (LTMP) network.	OCN-LTMP-2017-003 – The following changes were made to the LTMP water level tracking network: • Replace well 37348 with well 37497 • Replace well 37351 with well 37498 • Replace well 37429 with well 37499 • Replace well 08027 with well 08060
FY18 Trigger Events and Agency Notifications			
2/6/2018	Trigger Event – Off-post Groundwater Intercept and Treatment System (OGITS) Individual effluent sample above CSRG for fluoride.	Fluoride concentration in OGITS treatment plant effluent sample exceeded the current CSRG in January 2018.	Corrective Action – The OGITS does not treat for fluoride, so the exceedance is not an indication of treatment plant performance problems. The fluoride effluent concentration was below the CSRG during the third quarter of FY18 and subsequent quarters.
2/6/2018	Trigger Event – NBCS, Individual effluent sample above CSRG for fluoride.	Fluoride concentration in NBCS treatment plant effluent sample exceeded the current CSRG in January 2018.	Corrective Action – The NBCS does not treat for fluoride, so the exceedance is not an indication of treatment plant performance problems. The fluoride effluent concentration was below the CSRG during the third quarter of FY18 and subsequent quarters.
7/9/2018	Trigger Event – NWBCS, Southwest Extension, downgradient performance well 27522 exceeded CSRG for dieldrin.	The dieldrin concentration in well 27522 was slightly above the CSRG during the second quarter of FY18. The dieldrin exceedance was likely caused by a brief downtime in FY16 and FY17 due to extraction well maintenance (e.g., well redevelopment and hardware replacement) and decreased extraction flows due to plant downtime (e.g., power outages), which may have allowed temporary bypass of contaminated groundwater.	Corrective Action – Because this was the first indication of increasing trend in this well, the well was re-sampled in the fourth quarter of FY18 to confirm the exceedance and increasing trend in dieldrin concentration. The confirmation sample contained dieldrin at a concentration less than the PQL.

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
9/17/2018	Trigger Event – BANS Individual effluent sample above CSRG for 12DCLE and TCLEA.	12DCLE concentration in BANS treatment plant effluent sample exceeded the current CSRG in July 2018. TCLEA concentration in BANS treatment plant effluent sample exceeded the current CSRG in August 2018.	Corrective Action – Carbon adsorbers were rotated and fresh carbon was added in August. The 12DCLE and TCLEA effluent concentrations were below the CSRG during the fourth quarter of FY18.
FY18 Operational Change Notices			
Approved 6/14/2018	With the completion of the Groundwater Mass Removal Project (GWMRP) post-shut off-monitoring continued long-term monitoring is required for the South Tank Farm area.	The GWMP Post-Shut-Off Monitoring Completion Report was finalized in June 2018. Benzene was detected above the historical maximum in well 01687 in 2012. Subsequent monitoring did not detect benzene or indicate movement of benzene toward Lower Derby Lake. However, well 01600 is being added to the water quality tracking network to provide monitoring near Lower Derby Lake.	OCN-LTMP-2018-001 – Well 01600 was added to the water quality tracking network. Monitoring will be conducted on a twice-in-5-year schedule and will include volatile organic compounds with benzene and chloroform as indicator analytes.
Approved 10/5/2018	As a result of the 2014 on-post plume mapping, a dieldrin flow path migrating north out of Basin A was identified that is not intercepted by the BANS or BRES. In addition, some VOCs were also above their respective CSRGs in source monitoring wells for the South Plants SPSA-2d Ditch.	Monitoring of the dieldrin pathway is warranted to ensure the remedy continues to meet performance goals. The mass flux is estimated to be very extremely low. Revision to monitoring at South Plants SPSA-2d Ditch source area to include VOCs is required to evaluate the effectiveness of the remedy.	OCN-LTMP-2018-002 – Wells 25004 and 36112 were added to the water quality tracking network to monitor the dieldrin pathway. Monitoring will be conducted on a twice-in-5-year schedule and will include dieldrin, arsenic, DIMP, and dithiane. Indicator analytes for South Plants SPSA-2d Ditch water quality tracking wells 01044, 01047, 01101 and 01528 were revised to include carbon tetrachloride, chloroform and DBCP. Monitoring will be conducted on a once-in-5-year schedule.
FY19 Trigger Events and Agency Notifications			
10/2/2018	Trigger Event – Missed water level measurement.	Water level tracking well 24109 and off-post water level monitoring well 37337 were identified as damaged and water levels could not be measured.	Corrective Action – At the time it was proposed to construct a new well to replace well 24109. On 12/19/2018, a downhole video identified the obstruction as soft bentonite, and it was cleared from the well, thus

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
			allowing a water level measurement to be made. No further action is required for well 24109. Well 37337 was filled with asphalt during repaving along 96th Avenue. OCN-LTMP-2020-001 documents removing 37337 from the LTMP water level tracking network. Nearby well 37440 provides adequate information to map the water table in this area. 37337 is being evaluated for relocation in support of water quality monitoring downgradient of the NWBCS.
12/13/2018	Trigger Event – Missed water quality measurement data collection from one damaged on-post well—02048.	CFS well 02048 could not be sampled due to an obstruction where the pump could not be lowered deeper than approximately 10 feet below the top of casing (TOC). Well 02048 has not been measured or sampled since July 1999, and it is possible that during cover construction the casing was impacted, causing a break and offset in the PVC casing 10 feet below the current TOC.	Attempts to clear the obstruction on the sample date were unsuccessful. Repair of well 02048 is unlikely due to the depth of the obstruction. Since this well is included in the CFS monitoring network along with well 02047, it is proposed to review the results of data for well 02047, sampled at a depth of 70 feet, and then determine the necessity of a deeper well to evaluate the water-bearing zone in the Denver Formation 1U sand approximately 130-140 feet below TOC. Water Team discussions in February and April 2019. Evaluation pending.
5/31/2019	Trigger Event – BANS, Individual effluent sample above CSRG for 12DCLE.	12DCLE concentration in BANS treatment plant effluent sample exceeded current CSRG in April 2019.	Corrective Action – The DCLE effluent concentration was below the CSRG when resampled in May 2019. Carbon rotation will occur every 90 days to mitigate carbon breakthrough.
9/19/2019	Trigger Event – NBCS, Missed performance water quality measurement.	Performance well 37362 will no longer be sampled due to increased traffic volume along 96th Avenue.	Corrective Action – NBCS performance well 24207 was drilled 11/18/2019 to replace 37362. Relocating the well to an area south of the 96th Avenue provides a safe, long-term location for downgradient performance monitoring.
FY19 Operational Change Notices			
Approved 2/21/2019	During the 2015 Five-Year Review, NDPA was identified in groundwater	Groundwater and treatment plant sampling were conducted in 2017/2018 to determine whether NDPA should be added to the treatment plants CSRG lists.	OCN-LTMP-2019-001 – NDPA CBSG was added as a CSRG for the NBCS and NWBCS to ensure that the boundary systems protect groundwater quality off post. The CBSG was added as a CSRG for the OGITS

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
	above the CBSG of 0.005 µg/L. The CBSG for NDPA was promulgated after the On-Post and Off-Post RODs were completed and no CSRG for NDPA was identified in the RODs.	Review of treatment plant data shows that NDPA is present above the CBSG in all plant influents at concentrations above the CBSG. Groundwater data and historical information indicate that RMA is a source of NDPA contamination in groundwater.	consistent with the system goal to provide beneficial impact on groundwater quality. The LTMP was revised to include NDPA on the CSRG tables and require monitoring for treatment plant influent, effluent, and water quality performance wells. In addition, NDPA was added to select water quality tracking wells and off-post CSRG exceedance network wells. The ROD was modified to include the NDPA CBSG as an ARAR for the NBCS, NWBCS and OGITS.
Approved 2/21/2019	During the 2010 Five-Year Review, 1,4-dioxane was identified as an emerging contaminant requiring evaluation at RMA.	Characterization of 1,4-dioxane in groundwater occurred over several monitoring events between 2011 and 2018. The groundwater data confirm that concentrations of 1,4-dioxane exist in in groundwater above the CBSG of 0.35 µg/L and indicate that RMA is a source of 1,4-dioxane contamination in groundwater.	OCN-LTMP-2019-002 – 1,4-dioxane was added to select water quality tracking wells and off-post CSRG exceedance network wells to monitor plume concentrations and extent.
Approved 2/28/2019	CSRG exceedance network monitoring wells 37351 and 37429 were destroyed.	Several monitoring wells were damaged or destroyed during construction activities along 104th Avenue. New wells were installed to provide replacement wells for the LTMP network. Two of the wells are part of the CSRG exceedance monitoring network.	OCN-LTMP-2019-003 – The following changes are made to the LTMP CSRG exceedance network: • Replaced well 37351 with well 37498 • Replaced well 37429 with well 37499 Note: OCN-LTMP-2017-003 was previously issued to revise the water level tracking network for these new wells. This OCN revises the CSRG exceedance network.
Approved 3/21/2019	Downgradient monitoring at the NBCS has shown concentrations of some contaminants above the CSRGs. Evaluations in the 2005 and 2010 Five-Year Reviews concluded that these detections were not representative of system effectiveness but were indicative of residual	As part of the 2015 Five-Year Review, an evaluation of the hydrogeology in the area north of the NBCS slurry wall was completed to further evaluate water quality downgradient of the system and the mechanisms causing contaminant concentrations to be above the CSRGs. Recommended changes to the downgradient performance well monitoring network include replacing five wells with alternate wells that are expected to be more representative of system performance.	OCN-LTMP-2019-004 – To provide continuity in system performance monitoring, both the existing NBCS performance wells and proposed alternate wells listed below will be sampled concurrently for three years beginning in FY19: 2010 LTMP Well / Alternate Well 23405 / 23253 24006 / 24412 24418 / 24163 24421 / 24164

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
	contamination present before construction of the system and slow migration of contaminants through fine-grained sediments.		37362 24429 Wells will be sampled for all LTMP analytes. Because this change is limited in scope to three years of monitoring, no changes are being made to the LTMP. Sampling will be conducted in accordance with the OMC SQAPP. Monitoring results will be reported in the ASRs.
Approved 4/11/2019	Recent monitoring results downgradient from the NWBCS have shown dieldrin present above the reporting limit and practical quantitation limit.	Fourteen wells downgradient and cross gradient of the NWBCS were sampled for dieldrin in FY19 to help delineate the extent of the dieldrin plume off post. This is identified as an issue in Section 8.0.	OCN-LTMP-2019-005 – Because this change is limited in scope to one sample event, no changes were made to the LTMP. Results were reported in the NWBCS 2019 Downgradient Groundwater Sampling DSR (Navarro 2020j).
Approved 5/29/2019	NBCS alluvial performance water level monitoring well 23513 appears to have a plugged well screen.	Water levels measured since February 2019 show that there has been no fluctuation in water levels consistent with other wells in the vicinity.	OCN-LTMP-2019-007 – Replaced NBCS alluvial performance water level monitoring well 23513 with adjacent alluvial well 23527. Well 23527 will be monitored as a well pair with 23533 to evaluate the [reverse] gradient across the NBCS slurry wall.
Approved 9/23/2019	NBCS well 37362 is unsafe to sample due to increased traffic volume along 96th Avenue.	The NBCS performance network was evaluated to determine the need for a replacement well. Since a suitable alternate well was not available, the Army replaced the well to maintain the existing LTMP monitoring network.	OCN-LTMP-2019-008 – NBCS performance well 24207 was drilled 11/18/2019 to replace 37362. It is south of the RMA perimeter trail on Refuge property, approximately 120 ft south of the existing location. Relocating the well to an area south of the road provides a safe, long-term location for downgradient performance monitoring.
Approved 12/12/2019	The groundwater elevation goal at CADT well 36217 has not been met.	Since 2014, when achievement of the performance criterion was required, the groundwater elevation goal at well 36217 has not been met. As a result, an evaluation was completed to assess the current system conditions and evaluate the potential for additional dewatering. Evaluation of existing conditions indicates that there is hydraulic control due to flow directed towards the extraction trench through active dewatering.	OCN-LTMP-2019-009 – Because the hydraulic gradient toward the extraction trench represents containment, the LTMP was revised to incorporate demonstration of hydraulic control as an alternate performance goal for the CADT.
Approved 12/17/2019	Additional water level information required for Shell Trenches.	Water level information from new monitoring well will aide in developing more accurate maps depicting water level contours inside the Shell	OCN-LTMP-2019-010 – In accordance with NRAP-2019-004, well 36255 was installed on 8/26/2019 and added to

Table 4.1-1. Summary of Agency Notifications and Operational Change Notices

Date	Issue	Description	Corrective Action or Change
		Trenches slurry wall, thus providing greater reliability to evaluate location-specific Performance Goal target elevations relative to the bottom of historical disposal trenches. Wells 36528, 36530, 36532, 36535, and 36537 are located between the IRA and ROD slurry walls. Water level data for these wells do not provide useful information to evaluate the effectiveness of the remedy.	the LTMP Shell Trenches quarterly water level monitoring network. Wells 36528, 36530, 36532, 36535, and 36537, located between the two slurry walls, were removed from the LTMP Shell Trenches quarterly water level monitoring network.
Approved 12/12/2019	Revise LTMP reporting requirements to allow for combination of Five-Year Summary Review (FYSR) and last Annual Summary Report (ASR) in the five-year reporting period.	The LTMP required completion of ASRs for each reporting period and a FYSR as a complement to the Five-Year Review Report.	OCN-LTMP-2019-011 – Combining the ASR and FYSR will increase efficiency in reporting and will provide a comprehensive evaluation of monitoring data and system performance for the Five-Year Review period.
FY20 Operational Change Notices			
Approved 05/12/2020	Water level network well 37337 was destroyed during construction activities along 96th Avenue in 2018.	Well 37337 is no longer needed for water level tracking.	OCN-LTMP-2020-001 – Well 37337 was removed from the LTMP water level tracking network.
Approved 05/12/2020	During the 2010 and 2015 Five-Year Reviews, 1,4-dioxane was identified in groundwater above the CBSG of 0.035 µg/L. The CBSG for 1,4-dioxane was promulgated after the On-Post and Off-Post RODs were completed and no CSRG for 1,4-dioxane was identified in the RODs.	Characterization of 1,4-dioxane in groundwater occurred over several monitoring events between 2011 and 2018. The groundwater data confirm that concentrations of 1,4-dioxane exist in in groundwater above the CBSG of 0.35 µg/L and indicate that RMA is a source of 1,4-dioxane contamination in groundwater.	A Focused Feasibility Study was completed in 2019 to evaluated remedial alternative for RMA groundwater. OCN-LTMP-2020-002 – 1,4-dioxane CBSG was added as a CSRG for the NBCS and NWBCS to ensure that the boundary systems protect groundwater quality off post. The LTMP was revised to include 1,4-dioxane on the CSRG tables and require monitoring for treatment plant influent, effluent, and water quality performance wells. In addition, 1,4-dioxane was added to select water quality tracking wells and off-post CSRG exceedance network wells.

Note: An operational change notice was not issued under OCN-LTMP-2019-006.

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Annual evaluations against the LTMP performance criteria are provided in Annual Summary Reports (ASRs). Results of effluent monitoring for compliance are provided in quarterly effluent reports. A listing of the reports issued during this five-year review period are provided on Table 4.1-2.

Table 4.1-2. Quarterly Effluent Reports and Annual Summary Reports for FY15 – FY19

RMA Treatment Plant Effluent Water Quality Data Reports	
Treatment Plant Effluent Water Quality Data Report First Quarter Fiscal Year 2015	May 14, 2015
Treatment Plant Effluent Water Quality Data Report Second Quarter Fiscal Year 2015	July 31, 2015
Treatment Plant Effluent Water Quality Data Report Third Quarter Fiscal Year 2015	December 1, 2015
Treatment Plant Effluent Water Quality Data Report Fourth Quarter Fiscal Year 2015	March 15, 2016
Treatment Plant Effluent Water Quality Data Report First Quarter Fiscal Year 2016	May 16, 2016
Treatment Plant Effluent Water Quality Data Report Second Quarter Fiscal Year 2016	September 8, 2016
Treatment Plant Effluent Water Quality Data Report Third Quarter Fiscal Year 2016	December 2, 2016
Treatment Plant Effluent Water Quality Data Report Fourth Quarter Fiscal Year 2016	March 14, 2017
Treatment Plant Effluent Water Quality Data Report First Quarter Fiscal Year 2017	May 16, 2017
Treatment Plant Effluent Water Quality Data Report Second Quarter Fiscal Year 2017	July 20, 2017
Treatment Plant Effluent Water Quality Data Report Third Quarter Fiscal Year 2017	November 9, 2017
Treatment Plant Effluent Water Quality Data Report Fourth Quarter Fiscal Year 2017	February 7, 2018
Treatment Plant Effluent Water Quality Data Report First Quarter Fiscal Year 2018	April 26, 2018
Treatment Plant Effluent Water Quality Data Report Second Quarter Fiscal Year 2018	August 15, 2018
Treatment Plant Effluent Water Quality Data Report Third Quarter Fiscal Year 2018	November 27, 2018
Treatment Plant Effluent Water Quality Data Report Fourth Quarter Fiscal Year 2018	February 14, 2019
Treatment Plant Effluent Water Quality Data Report First Quarter Fiscal Year 2019	April 4, 2019
Treatment Plant Effluent Water Quality Data Report Second Quarter Fiscal Year 2019	July 11, 2019
Treatment Plant Effluent Water Quality Data Report Third Quarter Fiscal Year 2019	October 23, 2019
Treatment Plant Effluent Water Quality Data Report Fourth Quarter Fiscal Year 2019	January 9, 2020
RMA Annual Groundwater and Surface Water Summary Reports	
Fiscal Year 2015 Annual Summary for Groundwater and Surface Water	September 28, 2016
Fiscal Year 2016 Annual Summary for Groundwater and Surface Water	September 27, 2017
Fiscal Year 2017 Annual Summary for Groundwater and Surface Water	September 21, 2018
Fiscal Year 2018 Annual Summary for Groundwater and Surface Water	September 26, 2019
Fiscal Year 2019 Annual Summary and Five-Year Summary for Groundwater and Surface Water	November 6, 2020

4.1.1.1 On-Post and Off-Post Extraction and Treatment Systems

This section presents a summary of the extraction and treatment systems in the On-Post and Off-Post OUs. Detailed evaluations of these systems are presented in the 2020 FYSR (Navarro 2020b) and the system locations are shown in Figure 3.0-1.

Northwest Boundary Containment System (#61)

The NWBCS is a containment system designed to prevent the off-post migration of contaminated groundwater and includes three different components: the Original System, the NWBCS Northeast Extension, and the NWBCS Southwest Extension. The NWBCS Original System, located in the southeast quarter of Section 22, was installed in 1984 to intercept and treat groundwater contaminant plumes migrating from the South Plants and the Basins A, C, and F areas to the RMA boundary. The system includes extraction and recharge wells to create a reverse (counter-regional) hydraulic gradient to contain the contaminant plumes. A soil-bentonite barrier was installed across a part of the system to help contain contaminant migration.

The NWBCS Northeast Extension, which was added in 1990, included the installation of two additional extraction wells and extension of the slurry wall. The Southwest Extension, which was installed in 1991, included the installation of 4 additional extractions wells. The two extensions were added to supplement the original system to prevent the off-post migration of contaminated groundwater in flow paths that the original system did not capture.

Extracted groundwater is treated at the NWBCS treatment plant. Contaminated groundwater for the combined system is processed through a granular activated carbon (GAC) adsorption system prior to injection to the aquifer. The ROD established CSRGs for the NWBCS effluent for ten contaminants potentially present in the groundwater that migrates toward the northwest boundary. These contaminants and their respective CSRGs/practical quantitation limits (PQLs) during the FYR period, are listed in Table 4.1-3.

Table 4.1-3. Northwest Boundary Containment System (NWBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Volatile Halogenated Organics	Trichloroethylene	3		ROD health-based value
	Chloroform	6		CBSG[3]
Organophosphorous Compounds; Sarin (Isopropylmethyl Phosphonofluoridate [GB]) Agent Related	DIMP	8		CBSG
Organochlorine Pesticides	Dieldrin	0.002	0.013 [2a]	CBSG
	Endrin	2		CBSG
	Isodrin	0.06		ROD health-based value
Other Organic Compounds	NDMA	0.00069	0.009 [2b]	CBSG
	NDPA [4]	0.005		CBSG
	1,4-Dioxane [4]	0.35		CBSG
Arsenic	Arsenic	2.35		ROD health-based value

Notes:
[1] Containment System Remediation Goal
[2] Practical Quantitation Limit. The ROD identified PQLs for the following analytes were updated as follows:
[a] Dieldrin – Effective April 2012; [b] NDMA – Effective September 2016
[3] Colorado Basic Standard for Groundwater
[4] NDPA and 1,4-Dioxane added in April 2020

The Army completed a focused FS in 2019 to determine the appropriateness of the 1,4-dioxane CBSG for each system and evaluate the need for remediation of 1,4-dioxane in groundwater at RMA. Recommendations in the FS included adding the 1,4-dioxane CBSG to the CSRG lists for NWBCS (Navarro 2019e).

The 2010 LTMP includes performance criteria separately for the Original System, Northeast Extension and Southwest Extension. The performance criteria for the NWBCS Original System are as follows:

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 Army 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 five years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

The performance criteria for the NWBCS Northeast Extension and the Southwest Extension are as follows:

- 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 the CSRGs/PQLs in downgradient performance wells.

Downgradient performance wells identified in the 2010 LTMP are used to monitor downgradient concentration trends.

North Boundary Containment System (#62)

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 sources of the Basins C and F Plume contamination are the two basins that were used for disposal of a wide range of chemical wastes between the late 1950s and the early 1970s. The treatment processes consist of carbon adsorption and ultra-violet oxidation.

CSRGs for the NBCS effluent were established for 23 contaminants potentially present in the groundwater migrating toward the north boundary. Of these compounds, which are listed with their respective CSRGs in Table 4.1-4, chloride and sulfate levels were to be reduced to CSRGs through attenuation over time periods of 30 and 25 years (i.e., by 2026 and 2021), respectively.

Table 4.1-4. North Boundary Containment System (NBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Volatile Aromatic Organics	Benzene	3		ROD health-based value
	Xylenes	1,000		ROD health-based value
	Toluene	1,000		CBSG/MCL
Organosulfur Compounds: Mustard Agent Related	1,4-Oxathiane	160		ROD health-based value
	Dithiane	18		ROD health-based value
Organosulfur Compounds: Herbicide Related	CPMS	30		ROD—EPA Region VIII Health Advisory Value
	CPMSO2	36		ROD—EPA Region VIII Health Advisory Value
	CPMSO	36		ROD—EPA Region VIII Health Advisory Value
Organophosphorous Compounds; Sarin (Isopropylmethyl Phosphonofluoridate [GB]) Agent Related	DIMP	8		CBSG
Organophosphorous Compounds; Pesticide Related	Atrazine	3		CBSG/MCL
	Malathion	100		ROD health-based value
Organochlorine Pesticides	Aldrin	0.002	0.014 [2a]	CBSG
	Dieldrin	0.002	0.013 [2a]	CBSG

Table 4.1-4. North Boundary Containment System (NBCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
	Endrin	2		CBSG
	Isodrin	0.06		ROD health-based value
Other Organic Compounds	DBCP	0.2		CBSG/MCL
	NDMA	0.00069	0.009 [2b]	CBSG
	NDPA [5]	0.005		CBSG
	1,4-Dioxane [5]	0.35		CBSG
Arsenic	Arsenic	2.35		ROD health-based value
Anions	Fluoride	2 mg/L		CBSG; Agricultural standard
	Chloride	250 mg/L		CBSG
	Sulfate	540 mg/L		ROD background value

Notes:
[1] Containment System Remediation Goal; micrograms per liter (µg/L) unless otherwise noted.
[2] Practical Quantitation Limit. The ROD identified PQLs for the following analytes were updated as follows:
[a] Aldrin and Dieldrin – Effective April 2012; [b] NDMA – Effective September 2016
[3] Colorado Basic Standard for Groundwater
[4] Maximum Contaminant Level
[5] NDPA and 1,4-Dioxane added in April 2020

The Army completed a focused FS in 2019 to determine the appropriateness of the 1,4-dioxane CBSG for each system and evaluate the need for remediation of 1,4-dioxane in groundwater at RMA. Recommendations in the FS included adding the 1,4-dioxane CBSG to the CSRG lists for NBCS (Navarro 2019e). The FS recommended treatment using advanced oxidation at the NBCS; however, treatability studies are required to determine the most appropriate specific advanced oxidation potential system. The Army is also in the process of designing a new Consolidated Water Treatment Plant (CWTP) to replace the aging NBCS, NWBCS, and OGITS. Completion of the treatability studies and implementation of treatment for 1,4-dioxane at the NBCS is being coordinated with design and construction of the CWTP. Construction of the new treatment facility is tentatively scheduled to begin in FY23, pending funding and regulatory agency approval of the design.

The 2010 LTMP performance criteria for the NBCS are as follows:

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.

Secondary Performance Criterion:

- If unable to maintain reverse hydraulic gradient due to factors beyond Army 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 five years. If visual inspection is unclear, statistical or other evaluation criteria will be considered.

Downgradient performance wells identified in the 2010 LTMP are used to monitor downgradient concentration trends. Downgradient monitoring at the NBCS has shown concentrations of some contaminants above the CSRGs. Evaluations in the 2005 and 2010 Five-Year Reviews concluded that these detections were not representative of system effectiveness but were indicative of residual contamination present before construction of the system and slow migration of contaminants through fine-grained sediments.

As part of the 2015 Five-Year Review (Navarro 2016h), an evaluation of the hydrogeology in the area north of the NBCS slurry wall was completed to further evaluate water quality downgradient of the system and the mechanisms causing contaminant concentrations to be above the CSRGs. Five wells were identified for replacement with alternate monitoring wells that were expected to be more representative of system performance.

During this FYR period, concerns were identified related to monitoring continuity, lack of complete information regarding the proposed alternate wells, and the desire to compare data from the existing and proposed wells. To provide continuity in system performance monitoring, both the existing NBCS performance wells and proposed alternate wells are being sampled concurrently for three years beginning in FY19.

Railyard Containment System (#58)

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 (Foster Wheeler 1996) as integral to controlling the migration of these contaminant plumes.

The Irondale Containment System, 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 granular activated carbon treatment system. The system treated water from the Irondale, Railyard, and Motor Pool areas. The Irondale and Motor Pool extraction systems met shut-off criteria in 1997 and 1998, respectively. Approval of the CCR for shutdown of the Irondale system was received on May 21, 2003, and approval of the CCR for the Motor Pool shutdown was received on October 25, 2011.

When the Irondale and Motor Pool extraction systems were shut off, treatment of the remaining Railyard Plume was moved from the Irondale Containment System to the new RYCS in July

2001. The RYCS treatment process consisted of carbon adsorption. Recharge of the treated water was also transferred from the Irondale Containment System to the RYCS.

The CSRGs established in the On-Post ROD for the Irondale Containment System for trichloroethylene and dibromochloropropane (DBCP) apply to RYCS and are listed in Table 4.1-5.

Table 4.1-5. Railyard Containment System (RYCS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	CSRG Source
Volatile Halogenated Organics	Trichloroethylene	5	CBSG[2]/MCL[3]
Other Organic Compounds	DBCP	0.2	CBSG/MCL

Notes:
[1] Containment System Remediation Goal
[2] Colorado Basic Standard for Groundwater
[3] Maximum Contaminant Level

The 2010 LTMP 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.

The shut-off criteria were met for the RYCS, and a pre-shut-off monitoring plan was developed. The RYCS pre-shut-off monitoring program was successfully completed during FY14 (Navarro 2015i). In addition to analyzing for the CSRG analytes DBCP and trichloroethylene, an expanded analyte list was monitored to confirm that no other contaminants were present above CBSGs. The shut-off process was initiated in May 2016. The *Railyard Containment System Shut-Off Sampling and Analysis Plan*, and associated Decision Document DD-34, were approved by the Regulatory Agencies (Navarro 2016k) and the RYCS was shut down on May 25, 2016. Shut-off monitoring began in 2017 and will be conducted for at least five years.

Basin A Neck System (#59)

The BANS is a mass removal system that treats water migrating from former Basin A through the Basin A Neck area as well as water extracted by the Complex (Army) Disposal Trenches dewatering system, the BRES, and the Lime Basins dewatering system. The BANS was constructed as an IRA and incorporated in the final remedy in the On-Post ROD. Consistent with the RAOs for on-post groundwater treatment systems, the following objectives were included in the LTMP:

- 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.
- Accelerate groundwater remediation within RMA.

The treatment processes at BANS consist of air stripping, vapor- and liquid-phase carbon adsorption, and chemical precipitation. The ROD CSRGs for the BANS effluent were established for 22 contaminants potentially present in the groundwater migrating toward the Basin A Neck and these contaminants and their respective CSRGs are listed in Table 4.1-6. CSRGs for three additional contaminants (1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene) were added when treatment of Lime Basins groundwater was transferred to the BANS in 2011 (TtEC 2011a). 1,1,2,2-Tetrachloroethane (TCLEA) was added to the CSRG list for BANS in 2017. The CBSG for TCLEA was promulgated after the On-Post ROD was completed. A fact sheet entitled, *Minor Change to the Record of Decision for the On-Post Operable Unit Basin A Neck System Containment System Remediation Goals* was completed in May 2017 to document changes to the ROD (Army 2017).

Table 4.1-6. Basin A Neck System (BANS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Volatile Halogenated Organics	1,2-Dichloroethane	0.40[3]		CBSG[3]
	1,1,1-Trichloroethane	200		CBSG/MCL[4]
	1,1,2,2-Tetrachloroethane	0.18		CBSG
	1,1-Dichloroethylene	7		CBSG/MCL
	1,2-Dichlorobenzene	600[5]		CBSG/MCL
	1,3-Dichlorobenzene	94[5]		CBSG
	1,4-Dichlorobenzene	75[5]		CBSG
	Carbon tetrachloride	0.30		CBSG
	Chlorobenzene	100		CBSG/MCL
	Chloroform	6		CBSG
	Tetrachloroethylene	5		CBSG/MCL
	Trichloroethylene	5		CBSG/MCL
Volatile Hydrocarbon Compounds	DCPD	46		Off-Post ROD health-based value
Volatile Aromatic Organics	Benzene	5		CBSG/MCL
Organosulfur Compounds: Mustard Agent Related	1,4-Oxathiane	160		Off-Post ROD health-based value
	Dithiane	18		Off-Post ROD health-based value

Table 4.1-6. Basin A Neck System (BANS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Organosulfur Compounds: Herbicide Related	CPMS	30		EPA Region VIII Health Advisory Value
	CPMSO2	36		EPA Region VIII Health Advisory Value
	CPMSO	36		EPA Region VIII Health Advisory Value
Organophosphorous Compounds; Pesticide Related	Atrazine	3		CBSG/MCL
Semivolatile Halogenated Organics	Hexachlorocyclopentadiene	50		CBSG
Organochlorine Pesticides	DDT	0.1		CBSG
	Dieldrin	0.002	0.013 [2]	CBSG
	Endrin	2		CBSG
Arsenic	Arsenic	50		CBSG
Mercury	Mercury	2		CBSG/MCL

Notes: [1] Containment System Remediation Goal
[2] Practical Quantitation Limit. The ROD identified PQL for Dieldrin was updated – Effective April 2012
[3] Colorado Basic Standard for Groundwater
[4] Maximum Contaminant Level
[5] Adopted based on change to the ROD documented in the Explanation of Significant Differences for Lime Basins DNAPL Remediation Project (TtEC 2011a)

The 2010 LTMP mass removal 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.

Bedrock Ridge Extraction System (#28)

The On-Post ROD identifies the following remedy for the Section 36 Bedrock Ridge Plume:

- *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 2000 in accordance with the On-Post ROD (Foster Wheeler 1996) to prevent further migration of the Section 36 Bedrock Ridge Plume northeast of the Basin A area toward the First Creek drainage. The ROD remedy was modified as documented in the ESD for the Bedrock Ridge Groundwater Plume Extraction System (Washington Group International 2006) to document a cost reduction from the ROD estimate. The extracted water is treated and recharged to the groundwater at the BANS. 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 was installed and became operational in 2005. The BRES CCR was approved in September 2008 (Washington Group International 2008). The CSRGs for BANS, which are listed in Table 4.1-6, apply to the treated BRES effluent because this water is treated at BANS.

The 2010 LTMP performance criteria for the BRES are as follows:

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.

Off-Post Groundwater Intercept and Treatment System (OGITS) (#94)

The OGITS is a mass removal system designed to treat contaminated alluvial groundwater off post. The mass removal objectives presented 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.

The system consists of two separate extraction systems, the First Creek Pathway System (FCS) and the Northern Pathway System (NPS). The systems are located along Highway 2 north of RMA and downgradient of the NBCS. Each system consists of extraction wells and recharge wells or recharge trenches for return of treated groundwater to the alluvial aquifer. Modifications to the NPS extraction and recharge systems were made in 2006 due to residential and commercial development in the area. The modified system includes extraction wells and recharge trenches along a railroad easement upgradient of the original system (George Chadwick Consulting 2005). Extraction and recharge wells in the development area were abandoned. However, due to funding issues, the modification was not fully completed by the landowner, leaving a gap in the extraction system. As such, the NPS currently operates as a combination of the original system and modified system to extract contaminated alluvial groundwater downgradient of the NBCS. The original and modified NPS have been operating concurrently since 2006.

The remaining original NPS system operates in an area where the existing lease will expire in 2022. Due to developmental pressure, the Army will not be able to obtain an extension of the lease in this area and has been negotiating for an easement for the linear extraction system, or modified NPS. Additional extraction wells will be installed to address the current gap in extraction coverage and enable the existing downgradient system to be abandoned. Investigation of this issue was initiated in this FYR period, and the design and installation of the extraction system in the gap area is ongoing.

Extracted groundwater from the FCS and NPS is treated at the OGITS by carbon adsorption. CSRGs for the OGITS effluent were established for 34 contaminants potentially present in the Off-Post OU; the contaminants and their respective CSRGs are listed in Table 4.1-7.

Table 4.1-7. Off-Post Groundwater Intercept and Treatment System (OGITS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Volatile Halogenated Organics	1,2-Dichloroethane	0.40		CBSG[3]
	1,3-Dichlorobenzene	6.5		ROD health-based value
	Chlorobenzene	25		CBSG/MCL[4]
	Carbon tetrachloride	0.30		CBSG
	Chloroform	6		CBSG
	Tetrachloroethylene	5		CBSG/MCL
	Trichloroethylene	3		ROD health-based value
Volatile Aromatic Organics	Benzene	3		ROD health-based value
	Ethylbenzene	200		ROD health-based value
	Xylenes	1,000		ROD health-based value
	Toluene	1,000		CBSG/MCL
Volatile Hydrocarbon Compounds	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)	CPMS	30		EPA Region VIII Health Advisory Value
	CPMSO2	36		EPA Region VIII Health Advisory Value
	CPMSO	36		EPA Region VIII Health Advisory Value

Table 4.1-7. Off-Post Groundwater Intercept and Treatment System (OGITS) CSRG Analytes

Chemical Group	ROD CSRG Analyte	CSRG[1] (µg/L)	PQL[2] (µg/L)	CSRG Source
Organophosphorous Compounds; Sarin (Isopropylmethyl Phosphonofluoridate [GB]) Agent Related	DIMP	8		CBSG
Organophosphorous Compounds; Pesticide Related	Atrazine	3		CBSG/MCL
	Malathion	100		ROD health-based value
Semivolatile Halogenated Organics	Hexachlorocyclopentadiene	0.23		CBSG
	Chlordane	0.03		CBSG
Organochlorine Pesticides	Aldrin	0.002	0.014 [2a]	CBSG
	Dieldrin	0.002	0.013 [2a]	CBSG
	Endrin	2		CBSG
	Isodrin	0.06		ROD health-based value
	DDT	0.1		CBSG
	DDE	0.1		CBSG
Other Organic Compounds	DBCP	0.2		CBSG/MCL
	NDMA	0.00069	0.009 [2b]	CBSG
	NDPA [5]	0.005		CBSG
Arsenic	Arsenic	2.35		ROD health-based value
Anions	Fluoride	2 mg/L		CBSG; Agricultural standard
	Chloride	250 mg/L		CBSG
	Sulfate	540 mg/L		ROD background value

Notes:

[1] Containment System Remediation Goal; µg/L unless otherwise noted.
[2] Practical Quantitation Limit. The ROD identified PQLs for the following analytes were updated as follows:
[a] Aldrin, Dieldrin – Effective April 2012; [b] NDMA – Effective September 2016
[3] Colorado Basic Standard for Groundwater
[4] Maximum Contaminant Level
[5] NDPA added in April 2020

The 2010 LTMP performance criteria for the OGITS are as follows:

- 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.

4.1.1.2 Other Operating On-Post Groundwater Remedial Actions

Complex (Army) Disposal Trenches Slurry Walls (Dewatering) (#17)

The selected remedy presented in the On-Post ROD for the Complex (Army) Disposal Trenches slurry walls is as follows:

> *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.*

Performance criteria were initially established in the remedial design document for the Complex (Army) Disposal Trenches (RVO 1997) and included inward gradient and groundwater elevation goals. Based on the 2015 FYR evaluation and recommendations, an evaluation of the dewatering system was completed (Navarro 2019r). As a result, the criteria were revised and are stated in the LTMP as follows:

- Demonstrate groundwater elevations in performance monitoring wells 36216 and 36217 are below the target elevations of 5,226 and 5,227 ft mean sea level, respectively, or
- Demonstrate hydraulic gradient from the performance monitoring well locations is toward the extraction trench.
- Maintain positive gradient from the outside to the inside of the barrier wall (for as long as active dewatering is occurring).

To meet the performance criteria, water is extracted at a flow rate that typically ranges between 1 and 2 gpm. Extracted groundwater is piped to the BANS for treatment. The lowering of the water table is also aided by the construction of a RCRA-equivalent cover over the trench area. The CSRGs for the BANS, which are listed in Table 4.1-6, apply to the treated Complex (Army) Disposal Trenches effluent because this water is treated at BANS.

Shell Disposal Trenches Slurry Walls (Dewatering) (#17)

The selected remedy presented in the On-Post ROD for the Shell Disposal Trenches (SDT) slurry walls is as follows:

> *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 performance criterion established in the remedial design document for the SDT (RVO 1997) is presented below.

- Demonstrate groundwater elevations are below the disposal trench bottom elevations within the slurry wall enclosure.

The SDT containment remedy includes a slurry wall encircling the disposal trenches in addition to a RCRA-equivalent cover. Evaluation of groundwater elevation data during design resulted in final remedy selection that does not include active dewatering.

Section 36 Lime Basins Slurry/Barrier Wall (Dewatering) (#47)

The Lime Basins O&M has two remedy components related to groundwater: slurry wall dewatering and DNAPL remediation.

The Lime Basins soil remedy presented in the On-Post ROD was changed in 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. Lime Basins dewatering began in 2009 and groundwater extracted by the Lime Basins dewatering system was initially treated at the CERCLA Wastewater Treatment Facility and reinjected in the Lime Basins recharge trenches. The CERCLA Wastewater Treatment Facility was decommissioned in 2010, and Lime Basins groundwater is now treated at the BANS and reinjected in the BANS recharge trenches.

For the Lime Basins, the *Amendment to the ROD for the On-Post OU, Rocky Mountain Arsenal Federal Facility Site, Section 36 Lime Basins Remediation, Basin F Principal Threat Soil Remediation* (Amendment to the ROD for Section 36 Lime Basins and Former Basin F) (TtEC 2005) provides the following standard and monitoring provisions:

- *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 identified in the LTMP consistent with the requirements stated in the ROD Amendment 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 (5,242 ft) inside the barrier wall (for as long as the surrounding local groundwater table is in the alluvium).

The Lime Basins slurry wall dewatering system consists of six dewatering wells located inside the slurry-wall enclosure. Water levels are monitored inside and outside the slurry wall at six well pairs.

Section 36 Lime Basins DNAPL Remediation (O&M) (#47)

In August of 2009, DNAPL was discovered in some of the Lime Basins dewatering wells. A Remedial Investigation/Feasibility Study was conducted and the Lime Basins DNAPL remedy was chosen and implemented. Eight monitoring wells (four well pairs adjacent to the slurry wall) were installed in late FY12, and water level and water quality data collection specified in the Design Analysis Report (TtEC and URS 2012) began in FY13.

An ESD was prepared to document the remedy selection and change to the On-Post ROD (Tetra Tech 2011a). The selected remedy for Lime Basins DNAPL includes the following O&M components:

- Monthly DNAPL measurement and removal of recoverable quantities of DNAPL from the sumps of six dewatering wells. DNAPL monitoring and recovery frequency may be modified based on changes in the rate of DNAPL accumulation, following consultation with and approval from the Regulatory Agencies.
- Quarterly water-level measurements, DNAPL measurement (and removal, where appropriate), and VOC analyses (including the five DNAPL-related compounds) will be performed at the following monitoring and dewatering wells:
  - Monitoring Wells - 36231, 36232, 36233, 36234, 36235, and 36236
  - Dewatering Wells - 36315, 36316, 36317, 36318, 36319, and 36320
- Semi-annual water-level measurements, DNAPL measurement (and removal, where appropriate), and VOC analyses (including the five DNAPL-related compounds) will be performed at the following monitoring wells:
  - 36054, 36212, 36237, 36238, 36239, 36240, 36241, and the eight new wells 36242, 36243, 36244, 36245, 36246, 36247, 36248 and 36249

Data collected during this FYR period are discussed in Section 6.3.2.4.

North Plants Fuel Release (#40)

The light non-aqueous phase liquid (LNAPL) associated with groundwater was first identified beneath the North Plants manufacturing area in 1993. Delineation of the LNAPL was initially conducted in July 2001 as part of the North Plants Structures Demolition and Removal Project, 100 Percent Design Package (Foster Wheeler 2001). In 2001, attempts were made to recover the LNAPL (approximately 18 gallons were recovered) until demolition activities in the area required abandonment of the well and cessation of recovery in February 2002. Continuation of LNAPL recovery was planned to follow completion of North Plants surface remedial actions. The *North Plants Soil Remediation Project, Release Evaluation Report* (TtFW 2004) concluded that LNAPL was present in association with groundwater beneath the former North Plants Production Area. During the 2005-2010 FYR period, water levels and LNAPL thickness were monitored and LNAPL and groundwater sampling were conducted to characterize the LNAPL accumulation, assess potential groundwater impacts, and design a pilot LNAPL removal system. The results were reported in the *Petroleum Release Evaluation Report and Action Plan for LNAPL associated with Groundwater* (TtEC 2008d). 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. The Colorado Petroleum Storage Tank guidance documents are being used for this project.

The *Final North Plants Pilot LNAPL Removal Action Evaluation Report* was issued in April 2012 (URS Corporation 2012b). This report presented the monitoring results from March 2009 through May 2010. Additional monitoring was recommended consisting of monthly and then quarterly water level and LNAPL thickness measurements and continued through July 2014. To confirm that potentially mobile LNAPL did not accumulate in the piezometers and recovery wells in a sufficient thickness for recovery operations, the piezometers and recovery wells were monitored annually during this FYR period. As of the end of FY19, sufficient LNAPL has not been present in the wells to commence recovery operations.

4.1.2 Completed Groundwater Remedies this FYR Period

4.1.2.1 On-Post Quality Monitoring (#50a)

Surface water quality has been monitored by collecting and analyzing data from streams, ditches, lakes, and ponds at RMA since the late 1980s. The objective for the on-post Surface Water Monitoring Program is to ensure that there are no unacceptable effects on biota from surface water contamination.

Long-term on-post surface water monitoring was conducted through the end of FY09. During the multi-year period when contaminated soil areas were excavated, surface water quality was monitored as it entered and left the RMA site boundary including the downstream off-post area. Historically, when contaminated soil was being excavated, no target analytes were detected in samples from the on-post First Creek surface water sampling sites near the northern boundary. Furthermore, contaminated soil with concentrations above site-specific action criteria was removed and disposed in landfills or was covered, thereby eliminating the potential for movement of contaminated soil to surface water. The soil remedy was completed in 2010.

An On-Post Short-Term Surface Water Sampling program was initiated in FY12 (URS 2012) and continued through FY17 to confirm that surface water quality was not adversely impacted by cover soils during the establishment of cover vegetation and that groundwater plumes are not migrating into the lakes.

The on-post surface water sampling locations are shown on Figure 6.3-77 and include:

- Borrow Area 5 Pond Outlet (SW24005)
- Former Basin E Pond Outlet (SW26002)
- North Plants (SW25101)
- Lake Ladora (SW02020, SW02021, SW02009)
- Lower Derby Lake (SW01006)

Data collected during this FYR period are discussed in Section 6.3.4-1. The *Surface Water Monitoring Program Monitoring Completion Report* summarizes the surface water data collected since the On-Post ROD and Off-Post ROD were signed. As documented in the MCR, monitoring actions under this project have been completed (Navarro 2020d). The EPA approved the MCR in May 2021.

4.1.2.2 Groundwater Mass Removal Project Post-Shut Off Monitoring (#60a)

The Groundwater Mass Removal Project (GWMRP) was implemented in 2006. The South Tank Farm (STF) component of the GWMRP, extracted groundwater from locations within the contaminant plume that contained the highest concentrations of benzene. The STF component of GWMRP was completed in June 2010, in conjunction with the demolition of the CERCLA Wastewater Treatment Plant (URS 2012c). The Groundwater Mass Removal project CCR was approved by the EPA on May 16, 2012 (EPA 2012) and the project was documented as complete in the 2015 FYRR.

Beginning in 2012, post shut-off monitoring for the STF component of the GWMRP was implemented to evaluate whether potential changes in the STF benzene plume extent, located in the southern half of Sections 1 and 2, could impact the water quality of Lower Derby Lake. The South Tank Farm System is shown in Figure 6.3-77.

Post-shut-off monitoring was completed for the GMRP Project in August 2017. The STF post-shut-off results confirmed that the benzene plume continues to be stable or is receding and is not migrating toward the lakes (Navarro 2018j).

Long-term monitoring is required for the STF area. The LTMP water level monitoring network that was used for the SFT post-shut-off water level monitoring will continue under the LTMP. The number of LTMP water quality wells used for monitoring the benzene plume has increased from four wells to nine wells.

As documented in the *Groundwater Mass Removal Project Post-Shut-Off Monitoring Completion Report* (Navarro 2018j), remedial actions under this project have been completed. The EPA approved the CCR on January 7, 2020.

4.2 ON-POST SOIL REMEDY SELECTION AND IMPLEMENTATION

The On-Post ROD specified the following RAOs for the On-Post soil remedy:

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 [hazard index] HI greater than 1.0 (noncarcinogenic) based on the lowest calculated reasonable maximum exposure (5^{th} percentile) Preliminary Pollutant Limit 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 Human Health Risk Characterization.*

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 unexploded ordnance).

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.

The selected remedy, ROD standards, and ROD goals are presented below in the context of the Implementation Projects.

4.2.1 On-Post Soil Remedies Under Construction

Projects discussed in this section include those under construction and cover projects where construction is complete and Interim O&M is being performed.

4.2.1.1 Integrated Cover System Interim Operations and Maintenance: Basin A Consolidation and Remediation Area (#15), South Plants Balance of Areas and Central Processing Area (#34), Complex (Army) Disposal Trenches Remediation Cover (#38), Shell Disposal Trenches 2-foot Soil Covers (#39), and Section 36 Lime Basins Cover (#47)

Operation and maintenance requirements of the ICS are detailed in the *RCRA-Equivalent, 2-, and 3-ft Covers Long-Term Care Plan* (LTCP), Revision 2 (TtEC 2011d) as modified by approved O&M Change Notices (OCNs). Sites within the ICS have groundwater treatment and monitoring requirements which are documented in the 2010 LTMP (TtEC and URS 2010). The LTCP identifies the following compliance standards:

- Percolation (RCRA-equivalent covers only): less than or equal to 1.3 millimeters per year (mm/year) of water measured in the lysimeters over a rolling 12-month evaluation.
- Cover thickness (all covers): a minimum of 42-inch-thick soil cover layer above the capillary barrier material for RCRA-equivalent covers, a minimum of 36 inches of soil for 3-ft covers, and a minimum of 24 inches of soil for 2-ft covers.
- A vegetation standard (RCRA-equivalent covers only) for maintaining cover vegetation.

The ICS has been in the Interim O&M Period, as defined by Section 1.0 of the LTCP, since the Final Inspection held on April 21, 2010. The Interim O&M Period is the period between completion of construction and a determination that the cover is Operational and Functional

(O&F), which is based on cover performance. Discussion of O&M activities during this FYR period are provided in Section 6.3.6.3. The EPA, in coordination with the Colorado Department of Public Health and the Environment (CDPHE), Tri-County Health Department (TCHD), and the Army, will make the O&F determination for the ICS when a sufficient amount of performance data have been collected to show conformance with the cover performance standards. During the quarterly caps and covers O&M status meeting held on January 22, 2020, the Army suggested that enough ICS performance data had been collected to begin preparing the CCR – Part 2. The regulatory agencies agreed that preparation of the ICS CCR – Part 2 was appropriate. The Army is currently drafting the report to support an O&F determination and will submit it for agency approval in 2020. Long-term O&M will be conducted after the O&F determination. Though the ICS has not attained O&F status, the cover system did begin the mandatory compliance period on April 21, 2015 per Section 1.0 of the LTCP.

4.2.1.2 Shell Disposal Trenches RCRA-Equivalent Cover Interim Operations and Maintenance (#39)

Operation and maintenance requirements for the SDT RCRA-equivalent cover are detailed in the LTCP (TtEC 2011d) as modified by approved OCNs. The LTCP identifies the following compliance standards for RCRA-equivalent covers:

- Percolation: less than or equal to 1.3 mm/year of water measured in the lysimeters over a rolling 12-month evaluation.
- Cover thickness: a minimum of 42-inch-thick soil cover layer above the capillary barrier material.
- A vegetation standard for maintaining cover vegetation.

Operation and maintenance requirements of the SDT RCRA-equivalent cover also included operation of the Soil Cover Moisture Monitoring System (SCMMS) in accordance with the Soil Cover Moisture Monitoring System O&M Plan (TtEC 2006b). Operation of the SCMMS began in July of 2007 and continued through October of 2019. Termination of the SCMMS monitoring was documented in OCN-LTCP-2019-003.

The SDT RCRA-Equivalent Cover is currently in the Interim O&M Period as defined by Section 1.0 of the LTCP. The Interim O&M Period is the period between completion of construction and a determination that the cover is O&F, which is based on cover performance. Discussion of O&M activities during this FYR period are provided in Section 6.3.6.3. The EPA, in coordination with CDPHE, TCHD, and the Army, will make the O&F determination for the SDT RCRA-Equivalent Cover when enough performance data have been collected to show conformance with the cover performance standards. The CCR – Part 2 will provide the basis for an EPA O&F determination. This document is scheduled for preparation after the percolation exceedance corrective measures performed in 2019 and 2020 are shown to be effective. Long-term O&M will be conducted after the O&F determination. Though the SDT-RCRA-Equivalent Cover has not attained O&F status, the cover began the mandatory compliance period on April 21, 2015 per Section 1.0 of the LTCP.

4.2.2 Operating On-Post Soil Remedies

4.2.2.1 Hazardous Waste Landfill Operations and Maintenance (#8)

Operation and maintenance requirements for the Hazardous Waste Landfill (HWL) are documented in the approved HWL Post-Closure Plan (Navarro 2019d) as modified by approved OCNs. The O&M of the HWL includes the performance of routine inspections, Leachate Collection System (LCS) and Leak Detection System (LDS) maintenance, Action Leakage Rate (ALR) analysis, LCS/LDS wastewater management and disposal, LCS/LDS wastewater quality assessment, and groundwater monitoring and assessment. Requirements for each of these aspects of HWL O&M are detailed in the HWL Post-Closure Plan and its appendices. Discussion of monitoring data generated during O&M activities during this FYR period is provided in Section 6.3.6.1 for cover maintenance and inspections and Section 6.3.3.6 for post-closure groundwater monitoring. Long-term O&M of the HWL began after completion of the final inspection by the Regulatory Agencies, which occurred on May 20, 2009.

4.2.2.2 Enhanced Hazardous Waste Landfill Operations and Maintenance (#13)

Operation and maintenance requirements for the ELF are documented in the approved ELF Post-Closure Plan (Navarro 2020f) as modified by approved OCNs. The O&M of the ELF includes the performance of routine inspections, LCS/LDS maintenance, ALR analysis, LCS/LDS wastewater management and disposal, LCS/LDS wastewater quality assessment, and groundwater monitoring and assessment. Requirements for each of these aspects of ELF O&M are detailed in the ELF Post-Closure Plan and its appendices. Discussion of monitoring data generated during O&M activities during this FYR period is provided in Section 6.3.6.2 for cover maintenance and inspections and Section 6.3.3.7 for post-closure groundwater monitoring. Long-term O&M of the ELF began after completion of the final inspection by the Regulatory Agencies, which occurred on May 27, 2010.

4.2.2.3 Basin F/Basin F Exterior Part 2: RCRA-Equivalent Cover Operations and Maintenance (#46)

CERCLA O&M requirements for the Basin F/Basin F Exterior RCRA-equivalent cover (Basin F cover) are detailed in the LTCP (TtEC 2011d) as modified by approved OCNs. RCRA post-closure O&M requirements for Basin F are captured in the *Basin F Post-Closure Plan* (TtEC 2011c) as modified by approved OCNs. The LTCP and *Basin F Post-Closure Plan* identify the following compliance standards for RCRA-equivalent covers:

- Percolation: less than or equal to 1.3 mm/year of water measured in the lysimeters over a rolling 12-month evaluation.
- Cover thickness: a minimum of 42-inch-thick soil cover layer above the capillary barrier material.
- A vegetation standard for maintaining cover vegetation.

The Basin F Cover was in the Interim O&M Period as defined by Section 1.0 of the LTCP until September 18, 2019 when the EPA provided a letter to the Army documenting their determination that the cover was O&F (EPA 2019a). The EPA, in coordination with CDPHE, TCHD, and the Army, made the O&F determination for the Basin F Cover based on performance data that showed conformance with the cover performance standards. The performance data was presented by the Army in the Basin F/Basin F Exterior Remediation Project Part 2 CCR – Part 2 (Navarro 2017e), which was approved by the EPA on September 19, 2017 (EPA 2017). The Basin F Cover entered the O&M Period defined by the LTCP after the O&F determination had been made.

The Basin F Cover is also in the post-closure period according to Section 1.0 of the *Basin F Post-Closure Plan*. The O&M of Basin F includes the performance of routine inspections and groundwater monitoring and assessment. Discussion of monitoring data generated during O&M activities during this FYR period is provided in Section 6.3.6.4 for cover maintenance and inspections and Section 6.3.3.8 for post-closure groundwater monitoring. The Basin F Cover began the mandatory compliance period on March 2, 2015 per Section 1.0 of the *Basin F Post-Closure Plan*.

4.2.3 Completed On-Post Soil Remedies

4.2.3.1 Sanitary Sewer Manhole Plugging Phase II (#35)

The selected remedy in the On-Post ROD for the Sanitary Sewers component of the soil remedy requires:

> *Sanitary/Process Water Sewers—Void space inside sewer manholes is plugged with a concrete mixture to prohibit access and eliminate the manholes as a potential migration pathway for contaminated groundwater. Aboveground warning signs are posted every 1,000 ft along the sewer lines to indicate their location underground.*

The ROD remediation standards that apply to the project include:

> *Interrupt exposure pathway by permanently plugging all sanitary sewer manholes.*
>
> *Meet air quality and odor standards that are ARARs.*

The ROD goals that apply to the project include the following:

> *Control emissions, as necessary, during remediation.*
>
> *Control air emissions as necessary to attain criteria that will be developed via an air pathway analysis program that will ensure that the remedial action will be protective of human health and the environment and minimize nuisance odors.*

Sanitary Sewer Manhole Plugging Project

The Phase II Sanitary Sewer Manhole Plugging project was comprised of one Study Area Report (SAR) site and one non-SAR site as follows:

- Western Study Area-7A located in Sections 3, 4, and 34
- Non-SAR Site located in Section 35

Remediation at the two sites involved plugging the void space with concrete inside 50 sanitary sewer manholes and installation of five sanitary sewer pipeline markers. Plugged manholes and sanitary sewer pipeline markers each were installed with one engraved brass monument and one flexible warning marker.

As documented in the CCR (TtEC 2008a) remedial actions for this portion of the project have been completed. The EPA approved the CCR on February 17, 2009.

No caps, covers, or treatment facilities are required by the ROD for this remediation project, so no long-term O&M is required. Inspections of the plugged sanitary sewers and brass monuments are performed as part of the CERCLA FYR process. The property involved in this project is subject to restrictions on land and water use and maintenance of institutional controls.

Addendum 1

Land use control monitoring performed in 2009 and 2010 identified a lack of markers for the abandoned segment of sewer between former Lift Station 392 in Section 34 and Manhole 65 in Section 35. This segment of sewer is approximately 3,500 ft in length, exceeding the 1,000-foot marker spacing required by the ROD. The corrective action identified was installation of markers along this segment of the abandoned sewer.

During field verification of the alignment of the abandoned sewer, one additional manhole was identified that required plugging to satisfy ROD requirements. Manhole 2-A was mistakenly identified during design as Manhole 2 and believed to be part of a sewer line that did not require plugging. However, review of RMA records and field verification revealed that Manhole 2-A was part of sewer line NCSA-8a and required to be plugged.

As a result, Design Change Notice (DCN)-SSP2-003 was completed to add plugging of Manhole 2-A and installation of four sanitary sewer markers to the Sanitary Sewer Manhole Plugging Project - Phase II. The additional work was comprised of two SAR sites, NCSA-8a and WSA-7a. Remediation included plugging the void space with concrete inside one sanitary sewer manhole, installation of four concrete sewer markers, and installation of engraved brass monuments indicating the depth of the abandoned sewer. The work was completed in the fall of 2012.

As documented in the CCR Addendum 1 (TtEC 2013) remedial actions for this portion of the project have been completed. The EPA approved the CCR Addendum 1 on December 16, 2013.

Addendum 2

During 2014, a portion of deteriorated sanitary sewer line in Section 35 was replaced and the original sewer line was abandoned. The manholes along the abandoned segment of sewer line are part of the ROD-identified sewer site, NCSA-8a, which included a remedy requirement to plug the manholes. DCN-SSP2-004 was generated to document the additional plugging requirements for the previously completed Sanitary Sewer Manhole Plugging Project Phase II. Remediation included plugging the void space with concrete inside four sanitary sewer manholes and installation of an engraved brass monument indicating the depth of the abandoned manhole.

As documented in the CCR Addendum 2 (Navarro 2017j) remedial actions for this portion of the project have been completed. The EPA approved the CCR Addendum 2 on August 18, 2017.

Addendum 3

In 2018, DCN-SSP2-005 was completed to add plugging of Manholes 71A, 74 and 74A to the Sanitary Sewer Manhole Plugging Project – Phase II. Manholes 74 and 74A are part of SAR site NCSA-8a. Manhole 71A is a non-SAR site providing tie in from Building 130 to NCSA-8a. These manholes were also identified as future use manholes during design; however, the manholes are no longer required for service of existing structures.

Remediation included plugging the void space with concrete inside three sanitary sewer manholes and installation of an engraved brass monument indicating the depth of the abandoned manhole. Plugging these manholes completes the ROD requirements for abandoned manholes along NCSA-8a.

No waste was generated during the project that required disposal. Sanitary sewer manhole covers were sent off site to a scrap metal recycler and concrete waste and washout material was recycled in accordance with the project design. No COCs were identified during the Phase II Sanitary Sewer Manhole Plugging project design (TtEC 2007a). No confirmatory samples were collected during the project and no contingent soil volume was identified for excavation.

No significant disturbance to vegetation occurred during remediation of the Phase II Sanitary Sewer Manhole Plugging II project. As a result, no revegetation activities were required during the project.

As documented in the CCR Addendum 3 (Navarro 2020h) remedial actions for this portion of the project have been completed. The EPA approved the CCR Addendum 3 on March 5, 2020.

4.2.3.2 Secondary Basins Soil Remediation Part 2, Basin C Supplemental Soil Excavation (#37)

The Secondary Basins Soil Remediation project was listed as completed in the 2005 FYRR (Army 2007). However, due to identification of additional human health exceedance (HHE) and biota risk soils, supplemental soil excavation was completed in 2019.

The selected remedy in the On-Post ROD for the Secondary Basins Soil Remediation Project requires:

> *Excavation and landfill of human health exceedance soil and excavation and consolidation to Basin A of soil posing a potential risk to biota. The consolidated material is contained under the Basin A cover. The excavated area is backfilled with on-post borrow material.*

The ROD remediation standards that apply to the project include:

> *Excavate all contaminated soil identified in the ROD for treatment, landfilling, or consolidation that corresponds to the areal and vertical extent detailed by the soil volume calculations in the administrative record.*
>
> *Meet air quality and odor standards that are ARARs.*

The ROD remediation goals that apply to the project include:

> *Control emissions, as necessary, during remediation.*
>
> *Control air emissions as necessary to attain criteria that will be developed via an air pathway analysis program that will ensure that the remedial action will be protective of human health and the environment and minimize nuisance odors.*

The original Secondary Basins Soil Remediation project addressed remediation of HHE and biota soils within Basins C and D and areas adjacent to these basins, including five ditch segments, collectively identified as NCSA-2d: Basin B Drainage Ditches. All remediation required by the *Secondary Basins Soil Remediation Project 100 Percent Design Package* (Foster Wheeler 2000) was completed between April 2001 and February 2003, as documented in the *Secondary Basins Soil Remediation Construction Completion Report* (TtEC 2004).

In May of 2007, additional confirmatory sampling was conducted at various locations throughout the RMA to investigate potential contamination along former ditches. One of eight confirmatory samples taken within ditch site NCSA-2d indicated that surface soil in a portion of ditch segment B-2 exceeded HHE soil contamination criteria. The Secondary Basins Soil Remediation Project NCSA-2d (Basin B Drainage Ditch) Contingent Soil Volume Project was completed in 2008 to remove the additional HHE soil (TtEC 2009).

In the fall of 2014, a Post-Remedy Soil Sampling Program (PRSSP) surface soil sampling effort consisting of 307 samples was completed to provide additional information about post-remedy surface soil conditions (Navarro 2014). As part of that effort, three of the 307 soil samples collected were located in the former Basin C. One of the 307 samples (SS26PR0097), located in the southwest corner of the former basin along the influent ditch, contained dieldrin exceeding the ROD acute human health site evaluation criteria (Navarro 2014). Subsequently, additional sampling was completed in Basin C (PRSSP Phase 2) to determine the extent of the contamination above the ROD human health soil evaluation criteria.

In 2018, the Basin C Supplemental Excavation Soil Remediation Project (Figure 4.2-1) was completed to remove the additional HHE and biota risk soil identified within former Basin C, as documented in DCN-SB-024 (Navarro 2018g).

A total of 1,066 bank cubic yards (bcy) of HHE soil and 545 bcy of biota risk soil were disposed off site in a permitted hazardous waste landfill, Clean Harbors, Deer Trail, Colorado. Incidental concrete and brick debris were encountered during excavation and was disposed along with the soil.

A total of 59 Verification Soil Samples were collected during this project, and a total of 348 bcy of additional soil were excavated based on the sample results. The Data Summary Report for the Basin C Supplemental Soil Excavation (Navarro 2019k) provides detailed discussion of sampling conducted in accordance with the *Basin C Supplemental Soil Excavation Sampling and Analysis Plan* (Navarro 2018g). Sample locations and analytical results are also included in the Data Summary Report.

As documented in the CCR (Navarro 2019k), remedial actions under this project have been completed. No caps, covers, or treatment facilities are required by the ROD for this remediation project, so no long-term O&M is required. The property involved in this project is subject to restrictions on land and water use. The EPA approved the CCR on January 30, 2020.

4.3 OTHER REMEDY COMPONENTS

There were no other remedy components under construction or completed during this FYR period.

4.3.1 Other Operating Remedy Components

4.3.1.1 Site-Wide Biota Monitoring (#48)

The On-Post ROD includes provisions for biomonitoring both during remediation, as continuing biological studies for design refinement, and as part of long-term monitoring. To address the long-term biomonitoring requirement, the Biological Advisory Subcommittee developed the Long-Term Contaminant Biomonitoring Program for Terrestrial Ecological Receptors at Rocky Mountain Arsenal (BAS 2006). The BMP was developed to evaluate the effectiveness of the RMA remedy for biota as required by the ROD. Phase 1 of the BMP included collection of starling brain and kestrel egg samples between 2007 and 2013. Although the starling evaluation was completed as planned, the kestrel portion of the BMP could not be completed as outlined in the BMP due to lack of nest box occupancy. As a result, sampling requirements for program completion were revised to focus on soil sampling rather than collection of kestrel samples. A summary of the results of the biomonitoring program is provided under data review in Section 6.3.5.

4.3.1.2 Land Use Controls (#99)

The On-Post ROD includes ICs, also termed LUCs, restricting the current and future use of real property and resources within the RMA boundaries. These primary ICs prohibit residential development, use of ground or surface water as a source of potable water, consumption of fish and game, agricultural activities (except those required for remedial actions or erosion control), and major alteration of the hydrogeologic characteristics of RMA. The ICs also require preservation and management of wildlife habitat to protect endangered species, migratory birds, and bald eagles. Additionally, in accordance with the February 3, 1993 letter from Lewis D. Walker (Walker 1993) and the February 19, 1993 letter from John L. Spinks (Spinks 1993), the Army and the USFWS will neither build, use, nor allow use of any basements at RMA unless the Army or USFWS prepares a feasibility study that addresses the impact of the use of basements on human health and the environment and substantiates that such impacts are minimal.

The LUCP (Navarro 2013) provides a framework for implementation and monitoring of LUCs, ensuring that workers and visitors at RMA are safe and facilities are protected. The LUCP incorporated the primary LUCs required by the On-Post and Off-Post RODs, provides discussion on access controls and activity management, and describes other institutional or engineering controls for specific areas of RMA.

Areas of RMA where property and management authority have been transferred to the USFWS are governed by National Wildlife Refuge System regulations in Title 50, Subchapter C of the

Code of Federal Regulations (CFR). These regulations provide the USFWS with the authority to manage the entire National Wildlife Refuge System, including the Refuge. These regulations also close all areas of RMA included in the National Wildlife Refuge System to the public unless these areas are opened by regulation, individual permit, or public notice. Access to areas of the RMANWR that are not opened to the public is controlled using signs, regulations, and periodic monitoring by USFWS Law Enforcement.

Physical access to RMA is and will continue to be restricted. Although the USFWS maintains a public access gate at the southwest corner of the site near the USFWS Visitor Center, access is permitted only to the areas of the refuge designated for public use by the USFWS. The remainder of RMA operates as a closed facility with access available only to authorized workers and visitors. The perimeter fence with limited access points (West, South, North and Northwest Gates) limits site access to those people who have legitimate activities at RMA. The west and south gates are automated gates requiring access codes for entry. The north and northwest gates are manual gates intended for use by treatment system personnel and are locked when not in use. The north gate is also intended for use by heavy delivery trucks. Signs throughout the site identified boundaries of restricted areas and provided access restrictions. In addition to signs, the USFWS has installed many locking gates to prevent public access to closed portions of the refuge.

The USFWS provides information at the Visitor Center and at the kiosks outside the Visitor Center to help visitors understand which areas of RMA are accessible. In addition, the USFWS maintains signs on the refuge to control access to areas that are not opened to the public. Additional information related to RMA access controls is provided in the Rocky Mountain Arsenal Access Plan (Army 2016b). The Army maintains access control to Army-retained areas. Additional access restrictions in the form of engineering controls (fences, signs and obelisks) are maintained for waste containment areas in accordance with the *RCRA-Equivalent, 2-, and 3-Foot Covers Long-Term Care Plan* (TtEC 2011d), *Hazardous Waste Landfill Post-Closure Plan* (Navarro 2019d), *Enhanced Hazardous Waste Landfill Post-Closure Plan* (Navarro 2020f) and *Basin F Post-Closure Plan* (TtEC 2011c). The engineering controls associated with the landfills also satisfy the requirements of 40 Code of Federal Regulations (CFR) §264.14 and 6 Code of Colorado Regulations (CCR) 1007-3 §264.14 for security.

The LUCP also lists other areas that require additional ICs. These provide specific limitations commensurate with the risk presented by the area or the feature being protected. Included are additional ICs for the buried lake sediments (SSA-3b), access restrictions for the covers, sanitary sewers, and protection of groundwater remedy structures. The LUCP also identifies requirements for notification to the Regulatory Agencies when there are violations of land use controls or activities inconsistent with land use restrictions.

In April 2013, the USFWS initiated a formal process to remove/modify the game consumption restriction with respect to bison on RMA. In order to effectively manage the prairie restoration process, it is necessary to maintain the bison population at an appropriate level through periodic removal of animals. When appropriate and consistent with the Department of the Interior Bison Conservation Initiative 2020, animals may be transferred to other Department of the Interior lands. Animals may also be donated to other conservation partners, including tribes, states, or other intertribal organizations. However, whenever animals leave the refuge's possession, it becomes possible that they could be consumed by the public at some point in the future. To support this effort, a Tissue Contaminant Study has been initiated to obtain data to evaluate the risk associated with human consumption of bison. Evaluation of risk will be determined based on an EPA-approved risk assessment, which will include public involvement. If risks are determined to be acceptable, the ROD and LUCP may be modified accordingly. Although additional coordination with the regulatory agencies is needed for completion of the risk assessment, there is no impact on protectiveness of the remedy because the existing LUC on game consumption continues to be implemented while the study is being performed.

Annual monitoring of land use controls is required to ensure they remain effective and are protective of human health and the environment. Annual reports documenting the results of the monitoring have been issued for each fiscal year in the FYR period (Navarro 2015a, 2016a, 2018l, 2018a. 2019a). These reports identify any issues with maintenance or implementation of LUCs, provide corrective actions for these issues, and track follow-up of previously identified issues. Results of monitoring activities are discussed in Section 6.3.7.

4.3.1.3 Off-Post Institutional Controls (#98)

Land Use Controls, in the form of Institutional Controls, were established as part of the selected remedy for the Off-Post OU (HLA 1995). The Off-Post ROD identifies the objective of the Institutional Controls as "prevent the future use of groundwater exceeding remediation goals."

The primary mechanism for implementing the institutional controls is a well permit notification program developed in conjunction with the Office of the State Engineer (SEO), TCHD and the Army. Beginning in 1996, the Army has provided maps to the SEO to identify the off-post area where groundwater could potentially exceed groundwater CSRGs. In 2011, the well notification program was modified to include both the potential CSRG exceedance area and the historic area of contamination identified in the ROD. The notification areas are shown on Figure 4.3-1. For new wells permitted within the notification areas, the SEO includes a notice on the permit informing the permittee that the well is located in an area where groundwater contamination may exceed groundwater quality standards, or where groundwater contamination may be encountered.

During the FYR period, dieldrin was detected above the PQL downgradient of the NWBCS. Additional sampling completed in 2019 resulted in identification of a narrow dieldrin plume extending to the northwest of the NWBCS. Adjustment of the well notification area is needed to include the area of the dieldrin plume on the overall well notification map and the revised areas need to be provided to the SEO.

In addition, the Off-Post ROD requires a deed restriction that prohibits drilling new alluvial wells and use of deeper groundwater underlying the Shell Property until such groundwater no longer contains contamination in exceedance of groundwater CSRGs established in the ROD. The deed restriction is defined in the *Declaration of Covenants among Shell, the United States, and the State of Colorado* dated February 2, 1996. The covenants were recorded by the Adams County Clerk and Recorder on June 11, 1996.

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5.0 PROGRESS SINCE 2015 FIVE-YEAR REVIEW

5.1 PROTECTIVENESS STATEMENTS FROM 2015 FYR

The protectiveness statements presented below are quoted from the 2015 FYR:

> *The protection of human health and the environment by the remedial actions in both the On-Post and Off-Post OUs is discussed below. All controls are in place to adequately minimize risks. Because the remedial actions in both the On-Post and Off-Post OUs are currently protective of human health and the environment, the remedy for the entire site is protective of both human health and the environment.*

On-Post Operable Unit

> *The remedy for the On-Post OU is protective in the short term for human health and the environment. Placement of contaminated soils and debris in the HWL, ELF, and Basin A has been completed with engineered cap/cover systems in place. These sites have specific groundwater monitoring and ongoing cover O&M programs that monitor remedy effectiveness. Fences and signs are maintained around these areas and ICs prohibiting intrusive activities are in place to prevent exposure. Groundwater contamination is being treated to remediation goals at the RMA boundary as well as on post at the RYCS and at the BANS, and operation and maintenance plans are in place to ensure long-term protection. The long-term and operational groundwater and surface water monitoring programs effectively monitor contaminant migration pathways on post and ensure effective operation of the treatment systems as well as track off-post contamination trends. The long-term groundwater and surface water monitoring programs were revised during the current FYR period to ensure contaminant migration is being adequately controlled, and monitoring continued in accordance with these programs. Long-term biomonitoring was implemented during the FYR period; however, the program was not completed in accordance with the plan. Risks to human health and the environment are also minimized through implementation of LUCs restricting land and groundwater use to prevent exposures from occurring. A final LUCP was completed and monitoring of LUCs to ensure protectiveness continued during this FYR period. To be protective in the long-term, remedy designs need to be reviewed and potential adjustments made at the ICS (including the SDT cover), dewatering systems, groundwater containment and mass removal systems, and Basin C. Monitoring adjustments are needed for groundwater and surface water. Evaluations for NDPA and 1,4-dioxane need to be conducted or completed. Requirements to complete the BMP need to be determined and implemented. Land use controls need to be reviewed and adjustments to implementation or monitoring made as necessary.*

Off-Post Operable Unit

> *The remedy at the Off-Post OU is protective in the short term of human health and the environment. Remedial activities completed have adequately addressed all exposure pathways that could result in unacceptable risks in these areas. Groundwater contamination is being treated to Off-Post ROD remediation goals at the RMA boundary as well as at the OGITS. Groundwater monitoring plans and*

system operation and maintenance plans are in place to ensure long-term protection. Protective measures will continue until groundwater concentrations meet the CSRGs.

5.2 STATUS OF RECOMMENDATIONS AND FOLLOW-UP ACTIONS FROM 2015 FYR

The EPA 2001 Five-Year Review Guidance (EPA 2001) states that "all issues that currently prevent the response action from being protective or may do so in the future" should be documented as FYR issues in the FYRR. Such issues are to be documented along with follow-up actions needed to ensure the proper management of the remedy. The guidance also states the FYRR should identify "early indicators of potential remedy problems." The 2015 FYRR identified fifteen issues for which recommendations for follow-up actions were provided. Table 5.2-1 lists and describes the issues and summarizes the recommendations, follow-up status, and actions taken for each. Other unresolved concerns from EPA, CDPHE, or TCHD identified in the 2015 FYRR were addressed as part of ongoing consultation with the regulatory agencies with operational adjustments as appropriate.

Two issues from the 2015 FYRR dealt with emerging contaminants. n-Nitrosodi-n-propylamine (NDPA) was detected above the CBSG in RMA groundwater. NDPA is a contaminant associated with some dinitroaniline-based herbicides. The herbicide Planavin, a dinitroaniline-based herbicide, was produced in South Plants and associated wastes were disposed on site. Groundwater monitoring during the FYR period confirmed the presence of NDPA above the CBSG upgradient of the NBCS, NWBCS, FCS and NPS. As a result, the ROD was revised to include an NDPA CSRG for these systems and the LTMP was revised to include long-term performance and water quality tracking monitoring. The 1,4-dioxane investigation was carried forward in 2015 from the initial identification of the issue in the 2010 FYRR. During the FYR period, groundwater characterization was concluded, and a feasibility study was completed to identify remedial actions for 1,4-dioxane (Navarro 2019e). The ROD was revised to include the 1,4-dioxane CSRG for the NBCS and NWBCS and the LTMP was revised to include long-term performance and water quality tracking monitoring.

In addition, per- and polyfluoroalkyl substances (PFAS) were identified as emerging contaminants during this FYR period. The Army conducted an investigation in accordance with Army guidance (Army 2016a, 2018) and Department of Defense guidance (DoD 2018) to assess the potential for PFAS groundwater contamination, specifically PFOA and PFOS, at the RMA (Navarro 2017h). The results of the investigation indicated detectable levels of PFOA/PFOS in RMA groundwater, although only one location near the South Plants spill area (near well 01525) was above the EPA health advisory level. Treatment plant and off-post data indicated that RMA is not a significant source of PFAS contamination in groundwater (Navarro 2020i). However, the LTMP was revised to include PFOA/PFOS monitoring for select wells in the site-wide water quality tracking network and continued monitoring at the treatment plants.

Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
3 and 4	Presence of dieldrin above the PQL in the NWBCS downgradient performance wells and plant effluent.	Continue to review plant operations for potential modifications to address exceedances. Perform additional monitoring to determine concentration trend. Monitoring wells 37125, 37334, 37335, 37336, 37337, 37385, 37430, and 37442 should be added to the Containment System Remediation Goal (CSRG) Exceedance network to determine the extent of the off post dieldrin plume downgradient of the NWBCS.	Operational changes implemented during 2012 and 2013 enabled the NWBCS to meet the dieldrin PQL throughout the five-year review period and no further treatment modifications were necessary. Off-post monitoring wells were sampled to determine the extent of the dieldrin plume downgradient of the NWBCS. Results are shown on Figure 5.2-1. Identification of the long-term monitoring network needs to be completed.	June 30, 2023 (projected)
4	Land Use Controls - Commerce City Prairie Gateway Planned Unit Development (PUD) includes "(p)ublic gardening and similar cultivation of land, nursery, and supplementary to the primary public use" for a parcel of the Prairie Gateway, which appears inconsistent with the land use restrictions in place Commerce City Prairie Gateway PUD includes potential uses that appear inconsistent with the residential use restriction.	Coordinate with Commerce City to ensure appropriate changes are made to the Prairie Gateway PUD to resolve conflicts with LUCs. Revise the LUCP to describe communication requirements with Commerce City.	The Commerce City Planning Department has confirmed in writing that the agricultural use and residential uses contained in the Prairie Gateway PUD would not be approved while the restrictions were in force and stated that this issue will be corrected at the next revision to the Prairie Gateway PUD. In December 2016, Congress passed the National Defense Authorization Act for Fiscal Year 2017, which modified the Refuge Act to include provisions for Commerce City to modify or remove the restriction that prohibits the use of the property for residential or industrial use, provided a determination is made that the property will be protective of human health and the environment for the proposed use with an adequate margin of	September 30, 2025 (projected)

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Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
			safety following the modification or removal of the restriction. In addition, the Army revised the LUC monitoring requirements in 2018 to include an annual visual inspection of the Prairie Gateway to look for evidence of activities that are inconsistent with the existing land use controls or objectives. The inspections did not identify any residential or agricultural uses during the five-year review period. However, this remains an open issue until the PUD is revised to eliminate potential uses in conflict with the land use restrictions.	
3	Land Use Controls - Signs around site SSA-3b are not maintained as required by the LUCP.	Revise the LUCP to describe the control process used by the Army and USFWS to prevent excavation. Replace the area closed signs with markers that better convey the actual excavation restriction.	The signs around site SSA-3b were replaced with markers indicating the excavation restriction and were maintained throughout the five-year review period. The LUCP was revised to clarify the requirements.	August 31, 2016
4	Land Use Controls - Land transfers outside federal ownership. Previous land transfers and discussion of potential future land transfers appear inconsistent with the FFA and ROD requirement that the United States retain ownership of RMA.	Coordinate with the Regulatory Agencies and USFWS to resolve whether land transfers are consistent with the terms of the FFA, ROD, and Refuge Act.	The Army and USFWS met with the regulatory agencies several times during the FYR period to discuss the issue and options for incorporating land transfer discussion into the LUCP. Because CERCLA 120(h) requirements are independently applicable, the parties agreed that no change to the LUCP was needed. Land transfers outside federal ownership remain restricted by the ROD.	August 27, 2020

Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
3	Presence of metals above the aquatic life standard in surface water at two sampling locations.	Additional monitoring and evaluation.	Follow-up sampling and evaluation have been completed. Although surface water samples exceed aquatic life criteria, the presence of surface water is limited, and topography prevents downstream or off-post migration. Former Basin E surface soils were evaluated in FY19 resulting in the conclusion that metals in the Basin E surface water result from naturally occurring metals in soil (Navarro 2019b). A Surface Water Monitoring Completion Report was finalized October 15, 2020 (Navarro 2020b).	October 15, 2020
3	Percolation measurements at the three lysimeters within the Shell Disposal Trenches RCRA-equivalent cover have exceeded the percolation compliance standard. Excess percolation could mobilize contaminants to the groundwater.	Perform cover soil testing to evaluate potential causes of percolation. Prepare Corrective Measures Plan of Action once causes are identified.	Field investigations were completed, and the root cause of excess percolation was determined to be preferential flow associated with the moisture monitoring probes. A Corrective Measures Plan of Action was prepared to remove the probes and repair the cover (Navarro 2019s). Work was completed in April 2020 and is documented in the Integrated Cover System Shell Disposal Trenches RCRA-Equivalent Cover Percolation Exceedance Corrective Measures Completion Report (Navarro 2020m). Routine percolation monitoring is ongoing.	December 9, 2020

Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
3	The Shell Disposal Trenches groundwater elevations did not meet the remediation goals in the expected time frame.	Evaluate existing monitoring program to determine if additional monitoring is necessary. Evaluate impacts and feasibility of potential additional dewatering to achieve the dewatering goal.	A dewatering evaluation was completed in March 2019 (Navarro 2019x) concluding that dewatering was unnecessary. The conclusion was disputed by CDPHE. A subsurface investigation to determine actual trench bottom elevation was completed in June 2020 (Navarro 2020a), which resolved the dispute. The LTMP was revised to include the new trench bottom elevation (OCN-LTMP-2020-005), resolving the dispute. Two new monitoring wells were installed to provide better definition for water table inside the slurry walls. Monitoring is ongoing.	November 6, 2020
3	The Complex (Army) Disposal Trenches dewatering system did not meet the remediation goals in the expected time frame.	Evaluate existing monitoring program to determine if additional monitoring is necessary. Evaluate impacts and feasibility of potential additional dewatering to achieve the dewatering goals.	An evaluation was completed in March 2019 concluding that additional dewatering was unnecessary as the current active dewatering system adequately maintains hydraulic control within the slurry wall. The existing monitoring network is adequate to demonstrate effectiveness of the existing dewatering system in maintaining hydraulic gradient towards the extraction trench through active dewatering (Navarro 2019r). The LTMP was revised to incorporate demonstration of hydraulic control as an alternate performance goal (OCN-LTMP-2019-009).	December 12, 2019

Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
3	The Section 36 Lime Basins dewatering system did not meet the remediation goals in the expected time frame.	Evaluate existing monitoring program to determine if additional monitoring is necessary. Review monitoring data and determine estimated target dates for achieving compliance with the dewatering goals.	The target date for groundwater elevation below the bottom of waste was set at June 2016. This goal was met in June 2016 and maintained throughout the five-year review period. The goal of inward hydraulic gradient in all well pairs has not been achieved. A goal of September 2024 was established to track progress toward meeting the goal.	September 30, 2024 (projected)
3	The CBSG for 1,1,2,2-Tetrachloroethane (TCLEA) was promulgated after the RODs were completed and TCLEA is present above the standard in the BANS influent. Existing groundwater data associated with the treatment systems do not provide reporting limits sufficiently low to determine whether TCLEA is present above the CBSG in the plant influents or effluents.	Add TCLEA to the CSRG list for BANS. Complete additional data review and evaluate analytical method for achievement of CBSG.	The On-Post ROD and LTMP were revised to incorporate TCLEA into the CSRG list for BANS (Army 2017; OCN-LTMP-2017-002). The analytical method was recertified with a sufficiently low reporting limit.	June 29, 2017

Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
3	Soil sampling completed in the fall of 2014 identified an exceedance of ROD soil evaluation criteria in one location at Basin C.	Perform additional sampling to investigate the exceedance and extent of contamination. Complete remedial evaluation and prepare CERCLA Decision Document as needed for remedy selection.	Additional soil sampling was completed in 2015 and 2016 to delineate the exceedance area. The existing Basin C remedial design was revised to capture the work. Removal of contaminated soil was completed in August 2018. The Construction Completion Report (CCR) was approved January 30, 2020 (Navarro 2019k).	September 27, 2019
4	Private drinking water well 359A has DIMP concentrations exceeding the CBSG. Bottled water is being provided.	Replace existing well to provide alternate water source.	The existing well was replaced on November 11, 2016. However, the new well, 359D, exceeded the DIMP CBSG in 2017 and 2019. Bottled water is being provided to minimize exposure. Evaluation of the new well and potential alternate solutions is ongoing.	November 21, 2016
3	Over 1,000 sinkholes were identified in the northern portion of the Integrated Cover System (ICS).	Fill large holes and monitor small holes for changes. Evaluate potential impacts on percolation. Repair if necessary.	Large holes were filled. A representative set of holes were selected to monitoring changes and qualitative observations showed that the holes were consistently decreasing in size and increasing in vegetation density. No additional repairs were necessary.	January 24, 2018

Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
3	At the Bedrock Ridge Extraction System, rising concentrations of three contaminants (1,2-dichloroethane, tetrachloroethylene and trichloroethylene) have been observed in one downgradient performance monitoring well.	Conduct additional monitoring and evaluation of system performance.	Supplemental monitoring using existing wells was performed starting in June 2017 but was inconclusive (Navarro 2018b). Two additional monitoring wells were installed in July 2019. Monitoring of the new and existing wells is being conducted semiannually through 2021 (Decision Document DD-36, Navarro 2019t). Evaluation is ongoing.	April 30, 2022 (projected)
3 and 4	n-Nitrosodi-n-propylamine (NDPA) has been detected above the CBSG in RMA groundwater as part of EPA's oversight monitoring program and is not currently monitored at RMA.	Perform investigation for NDPA. Evaluate existing information as well as additional groundwater samples to determine whether NDPA should be added to the CSRG lists. Prepare a CERCLA decision document to document the evaluation.	An investigation was completed confirming the presence of NDPA above the CBSG in the treatment plant influents. Effluent concentrations were below the CBSG and the existing treatment systems were deemed effective. The On-Post and Off-Post RODs were revised to add the NDPA CBSG as a CSRG at NBCS, NWBCS and OGITS (Army 2020). The LTMP was revised to include long-term monitoring for NDPA (OCN-LTMP-2019-001).	February 21, 2019

Table 5.2-1. Status of Follow-Up Actions to Address 2015 FYR Issues

OU#	2015 FYR Issue	Recommendation	Current Status	Completion Date (if applicable)
3	Kestrel egg sample results showed several monitoring locations above the No Observed Adverse Effect Concentration (NOAEC). The Biomonitoring Program was suspended in 2014 after difficulties in collecting the planned samples. Sampling requirements to complete the program have not been determined.	Complete the data summary report and determine the requirements for completion of the BMP. Determine if CERCLA decision document is needed.	Soil sampling was conducted in lieu of additional kestrel sampling due to difficulties in collecting kestrels and to limit impacts to the kestrel population. Soil sampling was completed in November 2017 and a Data Summary Report was issued (Navarro 2018i). Results indicated no concentrations of dieldrin above the screening criteria, indicating that the remedy effectively eliminated significant exposure pathways in the area sampled. A draft Monitoring Completion Report was prepared in December 2018 and is awaiting EPA review. No additional CERCLA documentation is needed.	Field Work June 14, 2018 Documentation November 30, 2022 (projected)
3	Groundwater monitoring has identified 1,4-dioxane in RMA groundwater above the CBSG. Evaluation of 1,4-dioxane has not been completed.	Complete data summary report and technical evaluation. Determine if CERCLA decision document is needed.	Data Summary Reports were completed for 1,4-Dioxane Characterization (Navarro 2017i) and the Emerging Contaminants Sampling Program (Navarro 2019aa). A Focused Feasibility Study was completed to provide an evaluation of the remedial alternatives for addressing 1,4-dioxane in groundwater and advance oxidation was the selected alternative for the NBCS (Navarro 2019e). The On-Post ROD was revised to add the CBSG as a CSRG for the NBCS and NWBCS (Army 2020). Treatability testing is underway to support potential treatment system changes.	April 13, 2020

6.0 FIVE-YEAR REVIEW PROCESS

6.1 GENERAL

The RMA FYR was conducted by the Army in accordance with Paragraph 36.3 of the FFA and CERCLA, Section 121(c). The Operations and Maintenance Contractor (OMC) for RMA is Navarro Research and Engineering, Inc. The following individuals participated in the review:

- Scott Ache, OMC Regulatory Compliance Manager
- Tom Butts, TCHD Environmental Health Consultant
- Scott Greene, Army Remedy Execution, Team Leader
- Roberta Ober, Army Regulatory Compliance Manager (retired)
- Kelly Cable, RMA Remedy Execution
- Carol Rieger, OMC Hydrogeologist
- Jeffrey Lindquist, Chief, Civil Law Division, 4th Infantry Division and Fort Carson
- Lou Greer, OMC Environmental Safety and Health
- Sairam Appaji, EPA Remedial Project Manager
- Kim Hoffman, OMC Site Inspector
- Dorthea Hoyt, EA Engineering, Science, and Technology, Inc.
- Mike Jones, OMC Caps and Covers and Quality Manager
- Seth Kennedy, OMC Sample Lead
- Tony LaChance, OMC Program Manager
- Gayle Lammers, OMC Treatment Operations Manager
- Nicole Luke, OMC Project Scientist/Technical Writer
- Carl Mackey, OMC Vegetation Expert
- Susan Newton, CDPHE RMA Project Manager
- Steve Singer, PWT Hydrogeologist
- Vince Stewart, Sentinel Consulting Services
- Wade Thornburg, OMC Sampling and Monitoring Manager
- Melody Mascarenez, CDPHE

This FYRR addresses only inspection findings that have the potential to affect the protectiveness of the remedy that were identified during the FYR inspections. These issues are reported in Section 8.0 of this report. Other inspection findings that do not affect current or future protectiveness are included under Other Issues in Section 9.1. The Army will continue to coordinate actions taken associated with these findings with the regulatory agencies to ensure that the overall remedy remains effective.

As appropriate, specific documents were summarized in this review to illustrate the basis for conclusions of the FYR. On-site personnel responsible for all aspects of the remedy implementation were involved in developing the 2020 FYRR.

6.2 COMMUNITY INVOLVEMENT AND PUBLIC NOTIFICATION

The FYR public notification began on March 30, 2020, with public notices printed in the *Denver Post, Front Porch (Central Park), Commerce City Sentinel-Express,* and *Brighton Blade,* officially announcing the review was underway. The notice stated the U.S. Army was seeking community input during this process and community members were encouraged to submit any concerns or issues they would like to see addressed during the review. The FYR public notice and a fact sheet about the review were also posted on the RMA Web site – www.rma.army.mil.

Additionally, 14 community interviews were conducted in April and May by the Army's Public Affairs Office and members of the Public Affairs Subcommittee from the USFWS, EPA, CDPHE and TCHD. The interviewees were asked about any community concerns related to the cleanup, how the overall cleanup is functioning, and if they had any additional comments, questions, or suggestions regarding the cleanup.

The respondents interviewed represented the surrounding communities, including elected officials and citizens. All respondents knew of RMA as a former environmental cleanup site that had become a national wildlife refuge, and most respondents lived in the surrounding communities during the cleanup. Most respondents had extensive understanding of the history of military and agricultural manufacturing at RMA; its designation as a Superfund site; the passage of the Refuge Act; and the remediation undertaken to transform RMA into a national wildlife refuge. They learned of the site from living in the immediate vicinity, working in government, being involved with the development of nearby residential communities, or serving or volunteering with community organizations or environmental advocacy groups.

Most respondents had no concerns about the cleanup. Three respondents voiced concerns about the current state of the cleanup. Concerns included:

- Uncertainty about whether RMA is a source of PFAS in local groundwater
- Inadequate ongoing community involvement
- Maintenance of institutional controls
- Groundwater contamination in the areas north and northwest of the site
- Elimination of kestrels from the biomonitoring program

One respondent expressed concern about whether airborne and water contamination could be migrating onto RMA from other sources in the community. The respondent worried that the remedy or wildlife health could be compromised from off-site contamination coming onto RMA.

Most respondents expressed a high level of confidence in the remedy and in the parties responsible for its management and oversight. Several noted that they receive regular briefings from site managers or have other opportunities to get updates and ask questions. They expressed appreciation for the ongoing communication and coordination with both RMA and refuge managers. Additionally, several respondents stressed the importance of the long-term maintenance of the landfills and waste consolidation areas.

Four of the 14 respondents mentioned community concerns about the overall environmental health of Commerce City apart from the RMA cleanup. These residents expressed concerns about potential hydraulic fracking near RMA and questioned whether fracking would disrupt the remedy. Although these comments do not identify concerns or issues related to RMA, they are worth noting as they demonstrate the overall awareness of the respondents to environmental concerns.

Responses to all of the interviews are summarized in Appendix A.

As part of the FYR process, RMA public affairs staff review and update the Community Involvement Plan to address any opportunities or concerns identified during the community interviews. In 2016, after interviewing community stakeholders as part of the 2015 FYR process, RMA public affairs representatives updated the Community Involvement Plan to address community needs as the site entered the Operation & Maintenance phase of the remedy. In alignment with the updated plan, the Arsenal expanded its website to provide more information about the environmental cleanup and offer easier access to annual monitoring reports, the 2015 FYRR and other documents that detail remedy performance or address emerging topics of community interest. Also, in alignment with the plan, RMA staff met regularly with local government leaders and staff to update them on the remedy, provided annual briefings to the Commerce City Council, created and distributed fact sheets and other materials to highlight upcoming projects, and responded to community and media questions received through the Community Information Line. In addition, RMA staff conducted three community presentations, developed background materials and answered community questions in advance of groundwater and subsurface soil sampling completed to confirm the absence of chemical agent. Arsenal staff also provided a briefing and site tour to representatives from the Stapleton Denver development to inform them about the remedy and invite them to contact Arsenal representatives with future questions.

As part of the 2020 FYR process, the Arsenal expanded the number of community interviews conducted to include more representatives from the Spanish-speaking community and areas north of the site, where new residential developments have brought significant population growth. Overall, those interviewed expressed a high level of confidence in the remedy and its management and satisfaction with the opportunities they had to ask questions or receive information about upcoming projects. They indicated, however, that new residents, members of the Spanish-speaking community and newly elected officials would benefit from more information about the site's history as a former manufacturing and environmental clean-up site. Community members living north and northwest of the site also indicated they would like to better understand the groundwater remediation program and the progress being made toward achieving groundwater remediation goals. As part of the FYR process, Rocky Mountain Arsenal public affairs staff will review and revise the site's Community Involvement Plan to address identified community needs.

6.3 DOCUMENT AND DATA REVIEW

A wide variety of documentation and data were reviewed while preparing this FYRR. A complete list of references is available in Section 12.0.

6.3.1 On-Post and Off-Post Extraction and Treatment System Evaluation

This section presents a summary of data evaluation of the extraction and treatment systems in the On-Post and Off-Post OUs. Detailed presentations and evaluations of all the groundwater remedies and monitoring programs for fiscal year 2015 (FY15) through FY19 FYR period are presented in the ASRs and Five-Year Summary Report (FYSR) for Groundwater and Surface Water (Navarro 2020b).

Effluent monitoring is performed quarterly for each system to demonstrate compliance with the ROD CSRGs. Each system has a list of analytes for which CSRGs were developed in the On-Post and Off-Post RODs based on groundwater contaminants present at the system. Compliance is maintained when the four-quarter moving average is below the corresponding CSRG or PQL for each analyte. Currently, PQLs serve as the remediation goals for aldrin, dieldrin and NDMA. Effluent monitoring results are provided in quarterly effluent monitoring reports, listed on Table 4.1-2, and are summarized in the following sections.

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 the location of the system and whether it is a containment or mass removal system. Depending on the criteria, performance monitoring includes water quality monitoring for all systems and in most cases water level monitoring. Concentration trends are determined by visual inspection of time versus concentration plots and supported by the use of Mann-Kendall statistical analysis as part of the data quality assurance review as options presented in the LTMP. The Mann-Kendall test is used to determine whether a data series illustrates an upward or downward trend over time. In some cases, operational wells are included in the performance monitoring networks as well, thereby serving a dual purpose. A performance evaluation is completed annually, and results are provided in the ASRs listed on Table 4.1-2. A summary of each system's performance is provided in the following Sections 6.3.1.1 to 6.3.1.6.

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

- Evaluate and optimize system performance, and
- Ensure that RAOs are achieved.

Most of the operational wells—which include extraction, recharge and monitoring wells—are used for water level monitoring to ensure optimal extraction and recharge system operation. Some selected wells are also used for water quality monitoring of indicator analytes. These monitoring data are used to evaluate and adjust the system to optimize operations 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 modified independently from the 2010 LTMP.

6.3.1.1 Northwest Boundary Containment System (#61)

NWBCS Operations and Compliance

The NWBCS operated at an average flow rate of 944 gpm over the five-year reporting period and removed a total of 24.3 pounds of contaminants (Table 6.3-1). The major contaminants removed via treatment included chloroform and dieldrin. The total cost to operate the treatment plant from 2015 through 2019 was $3,250,492.

Table 6.3-1. NWBCS Five-Year Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gallons)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation	Total Downtime (hours)
2015	947	497,672,334	5.1	Chloroform – 3.77 Dieldrin – 1.04 Endrin ketone – 0.15	116,000	$644,314	19
2016	922	478,050,985	7.6	Chloroform – 4.77 Toluene – 1.44 Dieldrin – 0.99 Endrin ketone – 0.19	51,200	$745,674	164
2017	943	509,830,968	5.2	Chloroform – 3.75 Dieldrin – 1.02 Endrin ketone – 0.17	41,900	$610,604	24.5
2018	960	508,718,273	1.2	Dieldrin – 1.2 Endrin ketone – 0.02	63,700	$594,104	31.25
2019	947	509,945,939	5.2	Chloroform – 3.74 Dieldrin – 1.16 Endrin ketone – 0.14	65,000	$655,796	47.25
Total	**944 (average)**	**2.50 billion**	**24.3**	**—**	**221,800**	**$3,250,492**	**286**

Monitoring is conducted for the NWBCS treatment plant influent and effluent to demonstrate compliance with remediation goals. The system effluent for the NWBCS was analyzed quarterly using the LTMP CSRG analyte list for the NWBCS and annually using the complete ROD CSRG list. Complete effluent monitoring results are provided in quarterly effluent reports (listed on Table 4.1-2). Effluent concentrations for all contaminants were below their respective CSRGs except for dieldrin in FY15, as shown on Figure 6.3-1. During the first quarter of FY15, the dieldrin concentration was 0.024 µg/L, exceeding the PQL of 0.013 µg/L. Fresh carbon was pulsed to two of the adsorbers in reaction to this exceedance. The effluent was resampled and the concentration of dieldrin was below the reporting limit. The effluent slightly exceeded the PQL again in the fourth quarter of FY15 with a concentration of 0.0146 µg/L. During FY15, an operational concern was identified with the quantity of fines present within the influent and effluent sumps, which was considered a potential reservoir for adsorbed dieldrin. Accumulated sump sludge was removed from both sumps in January 2016 to reduce the fines present within the plant flow. Effluent dieldrin concentrations in FY16 through FY19 were all below the PQL and frequently below the reporting limit.

There were also two detections of NDMA slightly above the PQL in the second and third quarters of FY17. However, in both cases, the corresponding influent sample was below the PQL. There is no treatment for NDMA at the NWBCS. An additional sample was collected in the third quarter and both the influent and effluent results were below the reporting limit. The regulatory agencies were notified of these events and no further action was necessary.

The effluent met the four-quarter moving averages throughout the five-year review period for all CSRG analytes as shown on Figure 6.3-2.

NWBCS Performance Evaluation

Quarterly water level monitoring is conducted in the performance water level wells to demonstrate that a reverse hydraulic gradient is maintained, and the plumes are captured. Annual or quarterly sampling of the performance water quality wells is conducted to monitor the upgradient, cross-gradient, and downgradient groundwater quality. Figure 6.3-3 shows the NWBCS monitoring wells, extraction wells, recharge wells, slurry walls and groundwater elevation contours for the most recent monitoring. The performance evaluation is completed for the three distinct portions of the NWBCS since they have different performance criteria identified in the LTMP.

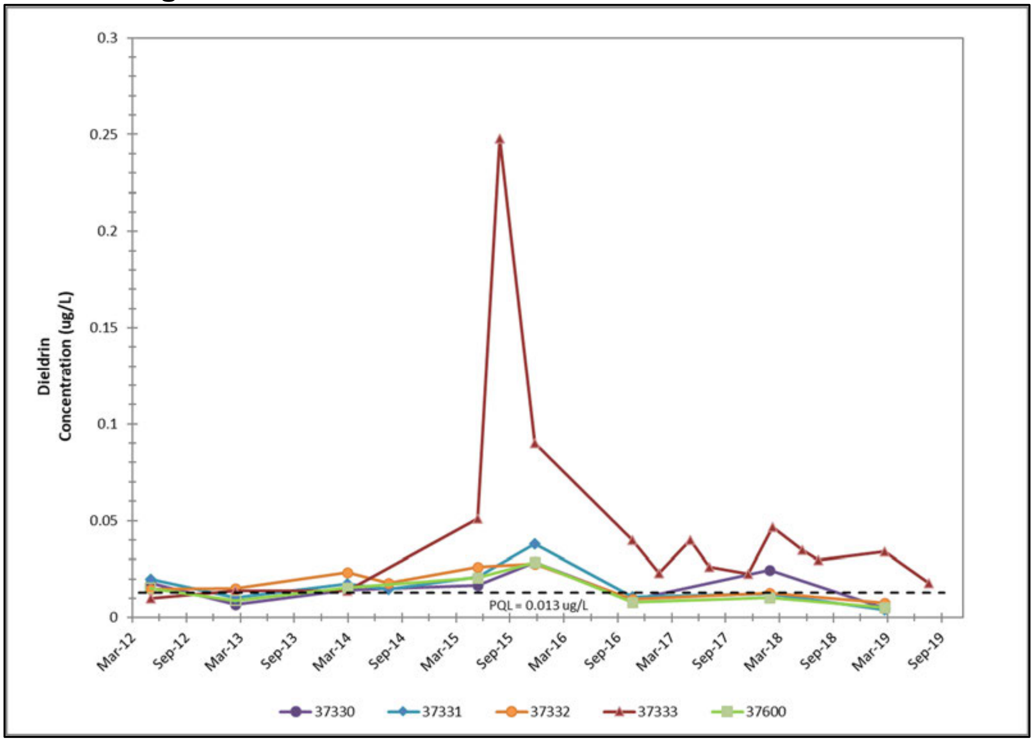
NWBCS Original System

The reverse hydraulic gradient and plume capture were maintained for the five-year review period. Monitoring results for each quarter are included in the quarterly effluent reports. The most recent reverse gradient monitoring results are provided on Figure 6.3-4.

Plume-edge capture at the NWBCS Original System can be verified by sample results for cross-gradient performance well 27010. In FY15 and FY16, the dieldrin concentration in well 27010 exceeded the PQL, indicating potential bypass. Flow rates in the southernmost extraction and recharge wells were adjusted and have successfully improved the plume-edge capture. Sample results beginning in FY17 were below the PQL and remained below the PQL over the rest of the five-year period. The water-table map on Figure 6.3-3 shows groundwater flow near upgradient well 27500, which is near the southwest end of the original NWBCS, is captured by the system.

Although primary performance criteria were met for the NWBCS, evaluation relative to the secondary performance criterion is ongoing to support system optimization. In the event that downgradient performance wells show analytes that are above CSRGs/PQLs, concentration trends are evaluated using visual inspection or Mann-Kendall statistical analysis. During the five-year reporting period, only dieldrin occurred in downgradient performance wells at concentrations exceeding CSRGs/PQLs (Table 6.3-2). For dieldrin, Figure 6.3-5 shows the dieldrin concentrations in the downgradient performance wells since the PQL was reduced to 0.013 µg/L in FY12. Although each of the five performance wells had at least one exceedance of the PQL, Mann-Kendall statistical analysis did not identify increasing trends.

Figure 6.3-5 Northwest Boundary Original System Downgradient Performance Well Concentrations – Dieldrin



NWBCS Northeast Extension

Plume capture at the Northeast Extension is demonstrated by the southwesterly gradients shown on Figure 6-3-3. To support system optimization, downgradient performance well water quality is monitored regularly. Dieldrin was detected above the PQL in downgradient performance wells 22015 and 22512 (Table 6.3-2). These data are consistent with data from previous years. Since FY12, the dieldrin concentrations in wells 22015 and 22512 have not shown increasing trends based on Mann-Kendall analysis. Dieldrin concentrations in the Northeast Extension performance wells are shown on Figure 6.3-6a. Although the trends are not increasing, the prolonged detection of dieldrin contamination in these wells has prompted additional evaluation to determine probable causes.

Figure 6.3-6a Northwest Boundary Northeast Extension Downgradient Performance Well Concentrations – Dieldrin

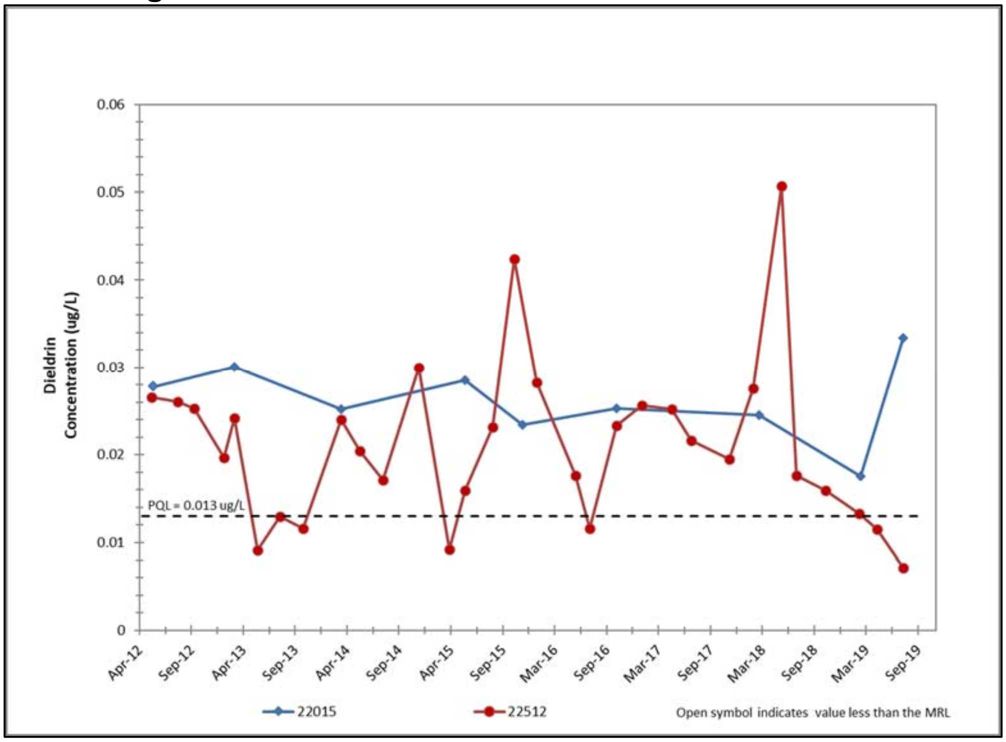


Figure 6.3-6b Northwest Boundary Southwest Extension Downgradient and Crossgradient Performance Well Concentrations – Dieldrin

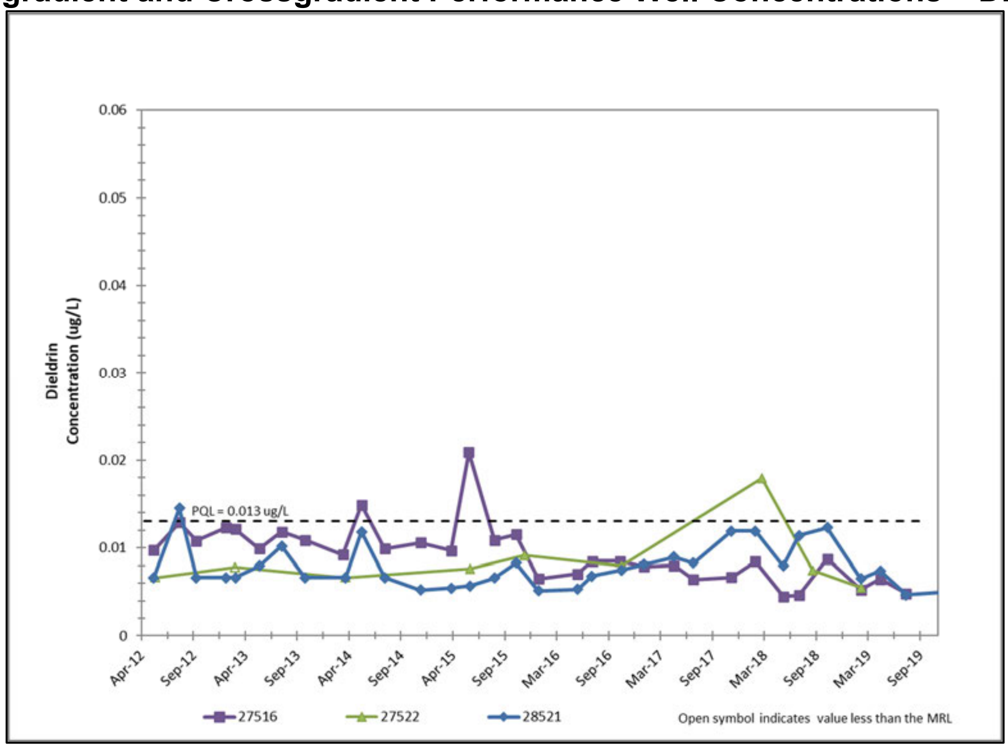


Table 6.3-2. Five-Year Summary CSRG Analyte Sampling from NWBCS Downgradient and Cross-Gradient Performance Wells

CSRG Analyte	CSRG/PQL (µg/L)	Samples with Concentrations at or above the CSRG or PQL/Number of Samples Collected										
		SWE			Original System						NEE	
		27522	27516	28521	27010	37330	37331	37332	37333	37600	22015	22512
Arsenic	2.35	0/5	N/A	N/A	0/6	0/5	0/5	0/5	0/6	0/5	0/5	0/6
Chloroform	6	0/5	N/A	N/A	0/6	0/5	0/5	0/5	0/6	0/5	0/5	0/6
DIMP	8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dieldrin [1a]	0.002/0.013	1/5	1/20	0/20	2/15	3/5	2/5	2/5	15/15	2/5	6/6	16/20
Endrin	2	0/5	0/20	0/20	0/15	0/5	0/5	0/5	0/15	0/5	0/6	0/20
Isodrin	0.06	0/5	0/20	0/20	0/15	0/5	0/5	0/5	0/15	0/5	1/6	1/20
NDMA [1b]	0.00069/0.009	0/5	N/A	N/A	0/6	0/5	0/5	0/5	0/6	0/5	0/5	0/6
NDPA	0.005	0/2	N/A	N/A	0/3	0/2	0/2	0/2	0/3	0/2	0/2	0/2
Trichloroethylene	3	0/5	N/A	N/A	0/6	0/5	0/5	0/5	0/6	0/5	0/5	0/6

Notes:

1. The ROD indicates PQLs for the following analytes:
   [a] Dieldrin – Effective April 2012
   [b] NDMA – Effective September 2016

SWE – Southwest Extension

NEE – Northeast Extension

N/A – Not applicable

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Historically, a small amount of contaminated flow from the Northeast Extension area migrates parallel to the slurry wall and is extracted by well 22309. Flow in the recharge wells creates a hydraulic barrier to off-post migration of this contaminated flow. However, in FY15, several analytes in addition to dieldrin were detected in well 37333 that are similar to those detected in Northeast Extension well 22508, located downgradient of the slurry wall. This suggests that a migration pathway from well 22508 to downgradient performance well 37333 may exist. In July 2019, well 22084 was installed downgradient of the slurry wall and upgradient of performance well 22512. This new well was sampled in August 2019 and dieldrin was detected at a concentration of 0.163 µg/L, which is greater than the PQL but lower that the concentration detected in 22508 (0.486 µg/L). Dieldrin in downgradient well 22512 was below the PQL at a concentration of 0.00715 µg/L. It is likely that groundwater flows from the area of well 22508 to well 22084 and 22512 based on evaluating water levels and concentration trends. In summer 2020, an exploratory investigation was conducted to determine whether there is a potential for flow around the northern terminus of the Northeast Extension slurry wall requiring additional extraction in the area, thus limiting the potential for system bypass. The evaluation is ongoing and is identified as an issue in Section 8.0.

Isodrin was detected in well 22512 at a concentration of 0.16 µg/L in November 2016 and in well 22015 at a concentration of 0.0773 µg/L in August 2019 but was previously not detected or detected at levels below the CSRG of 0.06 µg/L (Table 6.3-2). Sample results since these occurrences indicate that isodrin was not detected or remained below the CSRG.

NWBCS Southwest Extension

Plume capture at the Southwest Extension is demonstrated by the water elevation contours and flow directions on Figure 6.3-3. Dieldrin is the only CSRG analyte present at the Southwest Extension. Downgradient and cross-gradient performance wells are monitored quarterly or annually to support the evaluation. The dieldrin concentration exceeded the PQL in downgradient well 27522 in 2nd quarter FY18; however, Mann-Kendall statistical analysis shows there was no increasing trend. The dieldrin concentration also exceeded the PQL in cross-gradient well 27516 in 3rd quarter FY15. However, the concentration was below the PQL in all subsequent sample rounds and the long-term trend is decreasing. Dieldrin concentrations in the Southwest Extension performance wells are shown on Figure 6.3-6b (above).

6.3.1.2 North Boundary Containment System (#62)

NBCS Operations and Compliance

The NBCS operated at an average flow rate of 246 gpm over the five-year reporting period and removed a total of 33.8 pounds of contaminants (Table 6.3-3). The major contaminants removed via treatment included DCPD, DIMP, CCL4, trichloroethylene, chloroform, dieldrin, and NDPA. The total cost to operate the treatment plant from 2015 through 2019 was $2,462,000. Figure 6.3-7 shows the locations of NBCS monitoring wells, extraction and recharge wells, slurry wall, the South Channel extraction wells and groundwater elevation contours for FY19.

Table 6.3-3. NBCS Five-Year Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gallons)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation	Total Downtime (hours)
2015	245	128,648,032	5.1	DIMP – 2.3 DCPD – 0.57 Chloroform – 0.49 Tetrachloroethylene – 0.39 Carbon tetrachloride – 0.27 Dieldrin – 0.27 Endrin – 0.12 Trichloroethylene – 0.09	40,000	$456,691	26.5
2016	236	125,413,025	5.4	DIMP – 1.54 DCPD – 0.95 Carbon tetrachloride – 0.73 Tetrachloroethylene – 0.61 Chloroform – 0.41 Dieldrin – 0.29 Trichloroethylene – 0.29 Endrin – 0.12	40,000	$479,923	55.3
2017	258	133,968,687	7.2	DIMP – 2.30 DCPD – 1.13 Tetrachloroethylene – 0.56 Carbon tetrachloride – 0.54 Chloroform – 0.54 Trichloroethylene – 0.33 Dieldrin – 0.29 Endrin – 0.16	40,000	$480,250	85.5
2018	261	137,482,648	7.3	DIMP – 2.05 DCPD – 2.01 Carbon tetrachloride – 0.60 Tetrachloroethylene – 0.60 Trichloroethylene – 0.50 Chloroform – 0.49 Dieldrin – 0.28 Endrin – 0.12	60,000	$493,126	8

Table 6.3-3. NBCS Five-Year Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gallons)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation	Total Downtime (hours)
2019	231	130,514,796	8.8	DCPD – 3.55 DIMP – 1.85 Carbon tetrachloride – 0.69 Trichloroethylene – 0.58 Chloroform – 0.47 Dieldrin – 0.30 NDPA – 0.30	40,000	$552,010	147.7
Total	**246 (average)**	**656.0 million**	**33.8**	**—**	**220,000**	**$2,462,000**	**323**

Monitoring is conducted for the NBCS treatment plant influent and effluent to demonstrate compliance with remediation goals. The system effluent for the NBCS was analyzed quarterly using the LTMP CSRG analyte list for the NBCS and annually using the complete ROD CSRG list. Complete effluent monitoring results are provided in quarterly effluent reports (listed on Table 4.1-2). The treatment plant influent and effluent concentrations for dieldrin and NDMA are shown in Figures 6.3-8 and 6.3-9. Effluent concentrations for all contaminants were below their respective CSRGs except for NDMA in FY17. During the fourth quarter of FY17, the NDMA concentration was 0.015 μg/L, exceeding the PQL of 0.009 μg/L. The effluent was resampled, and the concentration was confirmed. Two additional UV lamps were placed into service to ensure effective treatment. The NDMA concentration in the first quarter FY18 and subsequent quarters remained below the PQL. The NDMA concentration was also above the current PQL in the fourth quarter of FY16; however, the effective PQL at the time was 0.018 μg/L and the concentration of 0.0108 μg/L did not exceed the PQL in effect. The effluent met the four-quarter moving average throughout the five-year review period for all CSRG analytes as shown on Figure 6.3-10.

In accordance with the ROD, CSRGs for chloride and sulfate at the NBCS will be achieved through natural attenuation over time periods of 30 and 25 years (i.e., by 2026 and 2021), respectively. Concentrations of both anions have decreased since remedy implementation and were below their respective CSRGs in the NBCS effluent throughout the five-year review period. Chloride concentrations have decreased from over 400 mg/L to less than the CSRG of 250 mg/L. Since 2005, the chloride concentration has exceeded the CSRG only three times in the plant effluent. Sulfate concentrations have also attenuated to below the CSRG of 540 mg/L, which represents the natural background concentration. The long-term trends for both anions suggest that attenuation to the CSRGs will be achieved within the expected time frames.

Fluoride exceeded the CSRG of 2 mg/L once in the effluent, in the second quarter of FY18, with a reported concentration of 3.5 mg/L. The influent concentration was also reported at 3.5 mg/L and no action was taken. Influent and effluent concentrations returned to below the CSRG in the subsequent quarter. Average fluoride concentration for the NBCS effluent over the five-year review period was 1.8 mg/L.

NBCS Performance Evaluation

The primary performance requirement for the NBCS is to maintain a reverse hydraulic gradient across the system in the alluvium and to ensure plume-edge capture. Monitoring results for each quarter are included in the quarterly effluent reports and demonstrate that the reverse hydraulic gradient was maintained throughout the five-year review period. The most recent reverse gradient monitoring results are provided on Figure 6.3-11. Plume-edge capture at the NBCS can be verified by inspection of the water-table map in Figure 6.3-7. Water-table contours indicate that groundwater flow is being captured at the edges of the system.

Although primary performance criteria were met for the NBCS, evaluation supporting system optimization is ongoing relative to the secondary performance criterion. In the event that downgradient performance wells show analytes that are above CSRGs/PQLs, concentration trends are evaluated using visual inspection or Mann-Kendall statistical analysis. During the five-year reporting period, the only organic analytes detected downgradient above CSRGs/PQLs were dieldrin and NDMA, as shown on Table 6.3-4. For all other organic CSRG analytes, concentrations in all downgradient performance wells were below the CSRGs/PQLs. Anions chloride, fluoride, and sulfate were also detected downgradient of the system above the CSRGs.

As presented in Table 6.3-4, dieldrin concentrations were above the PQL in all 11 downgradient performance wells during the five-year review period. Figure 6.3-12 shows the dieldrin concentrations in the downgradient performance wells. Dieldrin concentrations in 9 of the 11 downgradient performance wells show decreasing or stable—where concentrations were neither increasing nor decreasing—trends using visual inspection and trend line regression. Because no visual trend could be determined, the Mann-Kendall test for trends was performed for wells 23436 and 24421. The dieldrin concentration trend in well 23436 is stable since sampling began in 2010, while no trend is discernible for well 24421 during the same time period. In addition, five alternate wells being considered for future monitoring in place of existing wells were sampled for dieldrin, and three of those wells had levels of dieldrin greater than the PQL (wells 24163, 24164, and 24429).

Figure 6.3-12 North Boundary Downgradient Performance Well Concentrations – Dieldrin

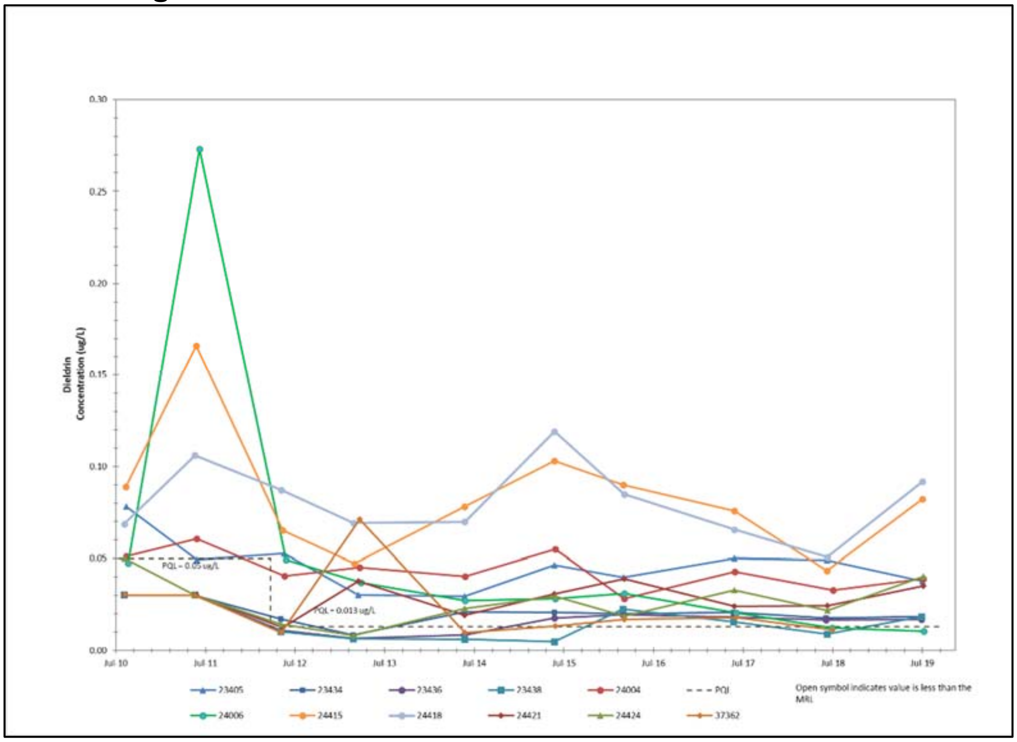

Figure 6.3-13 North Boundary Downgradient Performance Well Concentrations – NDMA

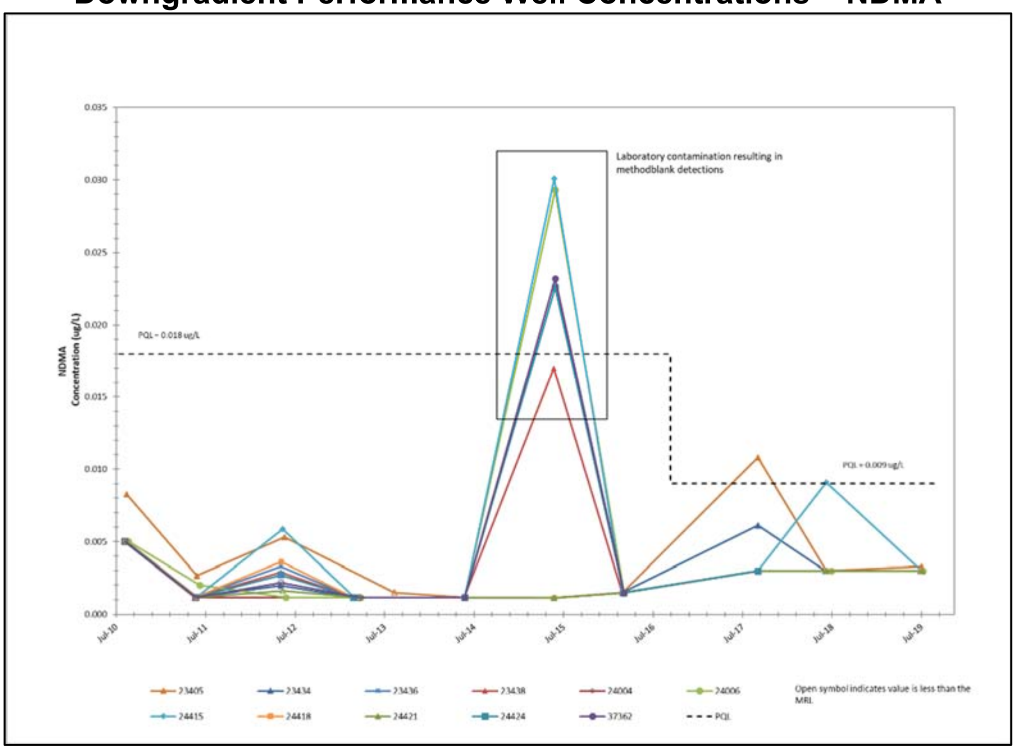

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Table 6.3-4. Five-Year Summary of CSRG Analyte Sampling from NBCS Downgradient Performance Wells

CSRG Analyte	CSRG/PQL (µg/L)	Samples with Concentrations at or above the CSRG or PQL/Number of Samples Collected										
		Section 23				Section 24						Off Post
		23405	23434	23436	23438	24004	24006	24415	24418	24421	24424	37362
1,2-Dichloroethane	0.40	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
1,2-Dichloroethylene	70	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
1,4-Oxathiane	160	N/A	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A
Aldrin [1a]	0.002/0.014	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Arsenic	2.35	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Atrazine	3	N/A	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A
Benzene	3	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Carbon tetrachloride	0.3	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Chloride	250,000	0/5	5/5	5/5	3/5	0/5	0/5	0/5	2/5	1/5	0/5	0/4
Chloroform	6	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
DBCP	0.2	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
DCPD	46	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Dieldrin [1a]	0.002/0.013	5/5	5/5	5/5	3/5	5/5	3/5	5/5	2/5	5/5	5/5	3/4
DIMP	8	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Dithiane	18	N/A	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A
Endrin	2	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Fluoride	2,000	0/5	0/5	1/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Isodrin	0.06	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Malathion	100	N/A	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A
Methylene chloride	5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
NDMA [1b]	0.00069/0.009	1/5	0/5	0/5	1/5	0/5	1/5	2/5	0/5	0/5	1/5	1/4
NDPA	0.005	0/2	0/2	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/2
CPMS	30	N/A	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A

Table 6.3-4. Five-Year Summary of CSRG Analyte Sampling from NBCS Downgradient Performance Wells

CSRG Analyte	CSRG/PQL (µg/L)	Samples with Concentrations at or above the CSRG or PQL/Number of Samples Collected										
		Section 23				Section 24						Off Post
		23405	23434	23436	23438	24004	24006	24415	24418	24421	24424	37362
CPMSO	36	N/A	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A
CPMSO2	36	N/A	N/A	N/A	N/A	N/A	0/1	N/A	N/A	N/A	N/A	N/A
Sulfate	540,000	0/5	5/5	5/5	0/5	0/5	0/5	0/5	1/5	1/5	0/5	0/4
Tetrachloroethylene	5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Toluene	1,000	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Trichloroethylene	3	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4
Xylenes	1,000	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/4

Notes:

N/A – Not applicable. Analysis for this contaminant is no longer required.

1. The ROD indicates PQLs for the following analytes:
   [a] Aldrin and Dieldrin – Effective April 2012
   [b] NDMA – Effective September 2016

The concentration of NDMA exceeded the PQL in four of the downgradient wells in June 2015. However, NDMA was also found in the method blank samples and the source was determined to be laboratory contamination. The NDMA concentration in well 23405 was 0.0108 µg/L in FY17, slightly above the PQL of 0.009 µg/L. Figure 6.3-13 (above) shows the NDMA concentrations in the downgradient performance wells. Trend analysis was not performed for NDMA because the majority of the sample results were below the reporting limits.

Regarding anions, six wells had concentrations of chloride, fluoride, and/or sulfate greater than CSRGs during the five-year review period. The concentrations of chloride and sulfate in the downgradient wells are expected to meet CSRGs by attenuation. By the end of the review period in FY19, only wells 23434 and 23436 remained above the CSRG. Fluoride was detected once above the CSRG in well 23436 but trend analysis indicates a stable trend.

As discussed in previous Five-Year Reviews, the downgradient detections are most likely caused by residual contamination and are not representative of system effectiveness. In particular for dieldrin, the concentrations present above the PQL in the downgradient wells are likely due to its lower solubility and more sorptive nature. Fluctuations in groundwater levels downgradient of the NBCS slurry wall caused by variations in the recharge trench flow rates and variable recharge from First Creek likely causes desorption of dieldrin from the aquifer sediments.

As part of the 2015 Five-Year Review (Navarro 2016h), an evaluation of the hydrogeology in the area north of the NBCS slurry wall was completed to further evaluate water quality downgradient of the system and the mechanisms causing contaminant concentrations to be above the CSRGs. Recommended changes to the downgradient performance well monitoring network include replacing five wells with alternate existing wells that are expected to be more representative of system performance.

During this FYR period, concerns were identified related to monitoring continuity, lack of complete information regarding the proposed alternate wells, and the desire to compare data from the existing and proposed wells. To provide continuity in system performance monitoring, both the existing NBCS performance wells and proposed alternate wells listed below are being sampled concurrently for three years beginning in FY19 (Navarro 2019l). This approach was developed consistent with the previous concurrent monitoring approach used to implement changes to the NBCS performance monitoring network in 2013.

2010 LTMP Well	Alternate Well
23405	23253
24006	24412
24418	24163
24421	24164
37362	24429

6.3.1.3 Railyard Containment System (#58)

The RYCS was designed to capture the Railyard DBCP plume. After the ICS was shut down, 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 RYCS.

RYCS Operations and Compliance

The RYCS operated at an average flow rate of 116 gpm and pumped a total volume of 100.2 million gallons during FY15 and FY16, removing a total of 0.34 pounds of contaminant mass (Table 6.3-5). DBCP was the major contaminant removed via treatment and the total cost to operate the treatment plant 2015 through 2016 was $145,452. Shut down of the RYCS occurred during the third quarter of FY16, on May 25, 2016, because it met ROD and LTMP shut-off requirements, and pre-shut-off monitoring was successfully completed. Shut-off monitoring is discussed in Section 6.3.3.10.

Table 6.3-5. RYCS Treatment Summary, FY15 and FY16

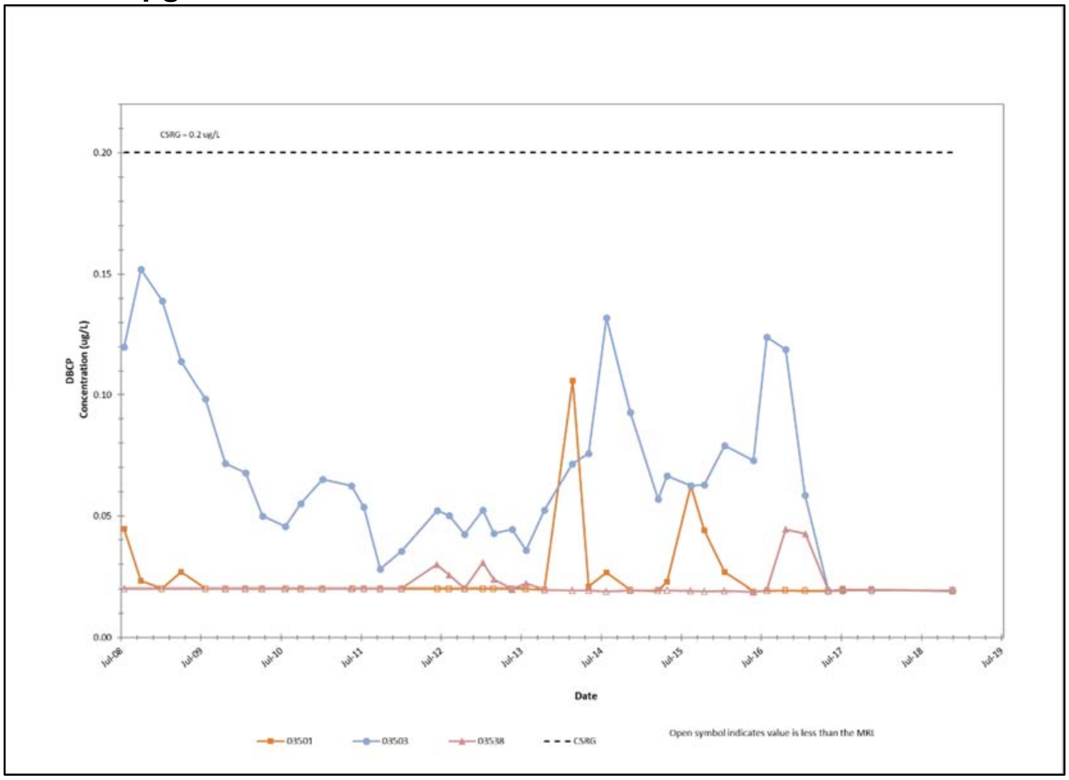
Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gallons)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation
2015	114	59,874,809	0.009	DBCP – 0.009	0	$86,482
2016	118	40,408,939	0.025	14DIOX – 0.022 DBCP – 0.003	0	$58,970
2017	NA	NA	NA	NA	NA	NA
2018	NA	NA	NA	NA	NA	NA
2019	NA	NA	NA	NA	NA	NA
Total	**116 (average)**	**100.2 million**	**0.034**	**DBCP 0.012**	**0**	**$145,452**

Monitoring was conducted for the RYCS treatment plant influent and effluent during FY15 and FY16 to demonstrate compliance with remediation goals. The system effluent for the RYCS was analyzed quarterly for DBCP and annually for trichloroethylene. Complete effluent monitoring results are provided in quarterly effluent reports (listed on Table 4.1-2). Effluent concentrations for both contaminants were below their respective CSRGs.

RYCS Performance Evaluation

Quarterly water level monitoring was conducted during FY15 and FY16 in the performance water level wells to demonstrate that the DBCP plume is captured. Figure 6.3-14 shows the locations of RYCS monitoring wells, extraction and recharge wells, and FY16 groundwater elevation contours when the system was operating. The DBCP concentrations have been below the CSRG of 0.2 μg/L since July 2008 in all monitored RYCS upgradient, downgradient, and cross-gradient performance and operational wells. Concentrations in the upgradient performance wells are shown on Figure 6.3-15.

**Figure 6.3-15 Railyard Containment System
Upgradient Performance Well Concentrations – DBCP**



6.3.1.4 Basin A Neck System (#59)

The BANS is a mass removal system that treats groundwater migrating from former Basin A through the Basin A Neck area as well as water extracted by the Complex (Army) Disposal Trenches dewatering system, the BRES, and the Lime Basins dewatering system.

BANS Operations and Compliance

The NBCS operated at an average flow rate of 22 gpm over the five-year reporting period and removed a total of 377.8 pounds of contaminants (Table 6.3-6). The major contaminants removed via treatment included trichloroethylene, DIMP, dithiane, tetrachloroethylene, chloroform, and CPMSO2. The total cost to operate the treatment plant from 2015 through 2019 was $2,311,443. Figure 6.3-16 shows the BANS monitoring wells, extraction wells, recharge trenches and slurry wall, and groundwater elevation contours.

Table 6.3-6. BANS Five-Year Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gallons)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation	Total Downtime (hours)
2015	23	11,910,038	96.1	Chloroform – 44.90 Trichloroethylene – 14.56 DIMP – 11.32 Dithiane – 8.88 CPMSO2 – 5.44 Tetrachloroethylene – 4.36	15,100	$456,295	27.5
2016	24	12,427,528	94.5	Chloroform – 29.22 Trichloroethylene – 19.64 DIMP – 19.23 Dithiane – 9.02 Tetrachloroethylene – 5.48 CPMSO2 – 5.09	13,600	$429,639	108.75
2017	22	11,698,512	66.0	Trichloroethylene – 16.77 DIMP – 16.33 Chloroform – 8.75 Dithiane – 8.26 Tetrachloroethylene – 5.86 CPMSO2 – 3.52	9,300	$472,882	27.25
2018	22	11,676,496	62.6	Trichloroethylene – 19.1 DIMP – 15.74 Dithiane – 7.36 Tetrachloroethylene – 6.21 Chloroform – 5.43 CPMSO2 – 3.16	13,000	$453,558	5.5
2019	20	10,625,842	58.6	Trichloroethylene – 17.8 DIMP – 13.5 Dithiane – 7.90 Tetrachloroethylene – 5.17 Chloroform – 4.49 CPMSO2 – 3.01	13,020	$499,069	35.75
Total	**22 (average)**	**58.3 million**	**377.8**	—	**64,020**	**$2,311,443**	**204.75**

Note:
Treatment at BANS includes groundwater extracted at the BANS, BRES, CADT, and Lime Basins.

Monitoring is conducted for the BANS treatment plant influent and effluent to demonstrate compliance with remediation goals. The system effluent was analyzed quarterly using the LTMP CSRG analyte list for the BANS. Complete effluent monitoring results are provided in quarterly reports (listed on Table 4.1-2). The treatment plant influent and effluent concentrations for 12DCLE and dieldrin are shown in Figures 6.3-17 and 6.3-18. Effluent concentrations for all contaminants were predominantly below their respective CSRGs during the review period.

In July 2018, the 12DCLE effluent concentration was 1.17 µg/L, exceeding the PQL of 0.4 µg/L. The effluent was resampled in August and the concentration was confirmed. In addition, the TCLEA concentration in the resample was 0.421 µg/L, exceeding the CSRG of 0.18 µg/L. Review of effluent concentrations for other compounds, particularly DIMP, dithiane and chloroform, also indicate that the carbon was nearing exhaustion. Fresh carbon was added to the system and the effluent was sampled again in September. All concentrations were below their respective CSRGs in this sampling round.

The concentration of 12DCLE in plant effluent exceeded the CSRG again in the third quarter of FY19. As a result, carbon rotation took place, and the effluent was resampled showing that 12DCLE was not detected. Although the BANS adsorbers typically had been rotated twice annually, an operational change was implemented to add fresh carbon and rotate the adsorbers every three months. Effluent concentrations of all CSRG contaminants remained below their respective CSRGs the remainder of the five-year review period. The effluent met the four-quarter moving averages throughout the five-year review period for all CSRG analytes as shown on Figure 6.3-19.

Although not a compliance requirement, reverse hydraulic gradient is monitored at the BANS as an operational consideration. The reverse hydraulic gradient at BANS was similar to its historical trend in previous five-year review periods. Although a reverse hydraulic gradient was not present on the far western and eastern ends of the system, it was maintained in the central part of the system, within the area of influence of the extraction system where the highest concentrations of contaminants have been measured.

BANS Performance Evaluation

<u>BANS Mass Removal</u>

The LTMP mass removal criterion refers to removing at least 75 percent of the contaminant plume mass migrating toward the system during a specified time period and is defined as contaminant mass flux. Mass removal is calculated annually and reported in the ASRs.

In accordance with the LTMP, mass removal has been calculated using all contaminants (excluding anions) and comparing mass in the effluent to the total mass in the plume. However, as contaminant concentrations decline in the future, the contaminant concentrations in the upgradient wells will approach the CRSGs/PQLs. This will result in decreasing mass removal percentages, even though treatment remains effective, because the differences in influent and effluent concentrations would be small, especially where the CSRG/PQL is near the MRL.

In FY18, a revised approach to evaluate contaminant mass removal at the BANS, as well as the OGITS First Creek System (FCS) and Northern Pathway (NPS) components, was developed to evaluate contaminant mass removal relative to the performance criterion by comparing calculated mass removed by the system to contaminant plume mass flux approaching the system. The revised technical approach focuses on measuring the effectiveness of mass removal at the point of capture (extraction) within each system, provides a quantitative measure of extraction system performance, and better quantifies contaminated groundwater not captured as an indication of potential system bypass. Quantitatively, the mass captured through system extraction is compared to the overall mass of the plume approaching the system, resulting in an overall percentage that is compared to the performance goal, currently 75 percent. Consistent with the methodology incorporated into the LTMP in 2012 (OCN-LTMP-2012-002), the well capture method is used to estimate the mass removal within the system capture zone and the transect method is used to estimate the mass flux outside of the capture zone for the BANS.

For FY18 and FY19, the regulatory agencies approved use of the revised approach to calculate the mass removal percentage for comparison against the performance goal. Mass removal estimates were 99.5 and 99.7 percent respectively, indicating very little system bypass. For FY15, FY16, and FY17, the original LTMP methodology was used to calculate and report the mass removal estimates. The calculated mass removal for each year is provided on Table 6.3-7. The revised method percent removals are also shown for comparison. As shown on Table 6.3-7, the BANS met the mass removal goal throughout the five-year review period. Because the original approach includes treatment system contaminant removal performance, the percent removal was declining as influent concentrations were decreasing, even as effluent concentrations remained below the CSRGs. The revised approach focuses on the extraction system performance by evaluating its effectiveness in capturing the approaching contaminant plume and accounts for contaminant mass not captured by the system. In conjunction with revising the mass removal calculation methodology, the mass removal performance criteria will be reviewed during the next FYR period and revised as appropriate for consistency with the new methodology.

Table 6.3-7. BANS Estimated Contaminant Flow Rate and Mass Removal, FY15 – FY19

Contaminant Flow Rate (gpm)	**FY15**	**FY16**	**FY17**	**FY18**	**FY19**
Capture Zone	16.1	16.3	15.1	14.81	13.6
Outside of Capture Zone	1.8	1.4	0.42	0.66	0.35
Total Flow Rate	**17.9**	**17.7**	**15.52**	**15.47**	**13.95**
Plume Mass Flux (lbs), LTMP Method					
Total Mass Flux	21.9	16.4	12.67		
Extracted Mass Removed	20.2	13.0	9.65		
Percent Mass Removed, LTMP Method, based on treatment	**91.5%**	**79.7%**	**76.2%**		
Plume Mass Flux (lbs), Revised Method					
Mass Flux, Outside of Capture Zone	0.14	0.1	0.04	0.07	0.05
Total Mass Flux	22.04	16.5	12.67	14.39	14.85
Extracted Mass (Inside Capture Zone)	21.9	16.4	12.63	14.32	14.80
Percent Mass Removed, Revised Method, based on extraction	**99.4%**	**99.4%**	**99.7%**	**99.5%**	**99.7%**

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Table 6.3-8. Five-Year Summary CSRG Analyte Sampling from BANS Downgradient Performance and Water Quality Tracking Wells

CSRG Analyte	CSRG/PQL (µg/L)	Samples with Concentrations at or above the CSRG or PQL/ Number of Samples Collected				
		Performance				Water Quality Tracking
		26501	26505	35505	35525	26006
1,1,1-Trichloroethane	200	0/5	0/5	0/5	0/5	0/1
1,1,2,2-Tetrachloroethane	0.18	0/5	0/5	0/5	0/5	N/A
1,1-Dichloroethylene	7	0/5	0/5	0/5	0/5	0/1
1,2-Dichlorobenzene	600	0/5	0/5	0/5	0/5	N/A
1,2-Dichloroethane	0.4	1/5	0/5	0/5	0/5	0/1
1,3-Dichlorobenzene	94	0/5	0/5	0/5	0/5	N/A
1,4-Dichlorobenzene	75	0/5	0/5	0/5	0/5	N/A
1,4-Oxathiane	160	0/5	0/5	0/5	0/5	0/2
Arsenic	50	0/5	0/5	0/5	0/5	0/2
Atrazine	3	0/5	0/5	0/5	0/5	N/A
Benzene	5	0/5	0/5	0/5	0/5	0/1
Carbon tetrachloride	0.3	0/5	0/5	0/5	0/5	0/1
Chlorobenzene	100	0/5	0/5	0/5	0/5	0/1
Chloroform	6	0/5	0/5	0/5	0/5	0/1
CPMS	30	0/5	0/5	0/5	0/5	0/2
CPMSO	36	0/5	0/5	0/5	0/5	0/2
CPMSO2	36	0/5	0/5	0/5	1/5	0/2
DCPD	46	0/5	0/5	0/5	0/5	0/1
Dieldrin [1a]	0.002/0.013	2/5	1/5	5/5	5/5	2/2
DIMP [2]	8	N/A	N/A	N/A	N/A	0/2
Dithiane	18	0/5	0/5	0/5	0/5	0/2
Endrin	2	0/5	0/5	0/5	0/5	0/2
Hexachlorocyclopentadiene	50	0/5	0/5	0/5	0/5	0/2
Mercury	2	0/5	0/5	0/5	0/5	N/A
NDMA [1b, 2]	0.00069/0.009	N/A	N/A	N/A	N/A	0/2
PPDDT	0.1	0/5	0/5	0/5	5/5	0/2
Tetrachloroethylene	5	0/5	0/5	0/5	0/5	0/1
Trichloroethylene	5	0/5	0/5	0/5	0/5	0/1

Notes:
N/A – Not applicable
1. The ROD indicates PQLs for the following analytes:
   [a] Dieldrin – Effective April 2012
   [b] NDMA – Effective September 2016
2. Analyte applicable for water quality tracking only.

BANS Downgradient Performance Wells

The second performance requirement is to demonstrate that concentrations in downgradient performance wells are below CSRGs/PQLs, or stable or decreasing if they are above the CSRGs/PQLs. Table 6.3-8 presents an overview of the FYR period water quality results for the BANS downgradient performance wells.

During the five-year reporting period, only 12DCLE, CPMSO2, DLDRN, and PPDDT occurred in downgradient performance wells at concentrations exceeding CSRGs/PQLs, although 12DCLE and CPMSO2 exceeded only once. For all other CSRG analytes, concentrations were below CSRGs/PQLs in downgradient performance wells. Dieldrin was the primary contaminant detected and was reported in all four downgradient wells. Figure 6.3-20 shows the dieldrin concentrations in the downgradient performance wells. Concentrations are stable or decreasing in all wells.

The concentrations of CSRG analytes CPMSO2 and PPDDT continue to remain above the CSRG in downgradient performance well 35525, although the concentration of CPMSO2 exceeded the CSRG only once in FY19. Figure 6.3-21 shows the PPDDT concentrations in the downgradient performance wells. Concentrations of 12DCLE, DLDRN, CPMSO2, and PPDDT are not increasing as verified by Mann-Kendall trend analyses completed as part of the data quality assurance review (Navarro 2020b).

Figure 6.3-20 Basin A Neck System
Upgradient and Downgradient Performance Well Concentrations – Dieldrin

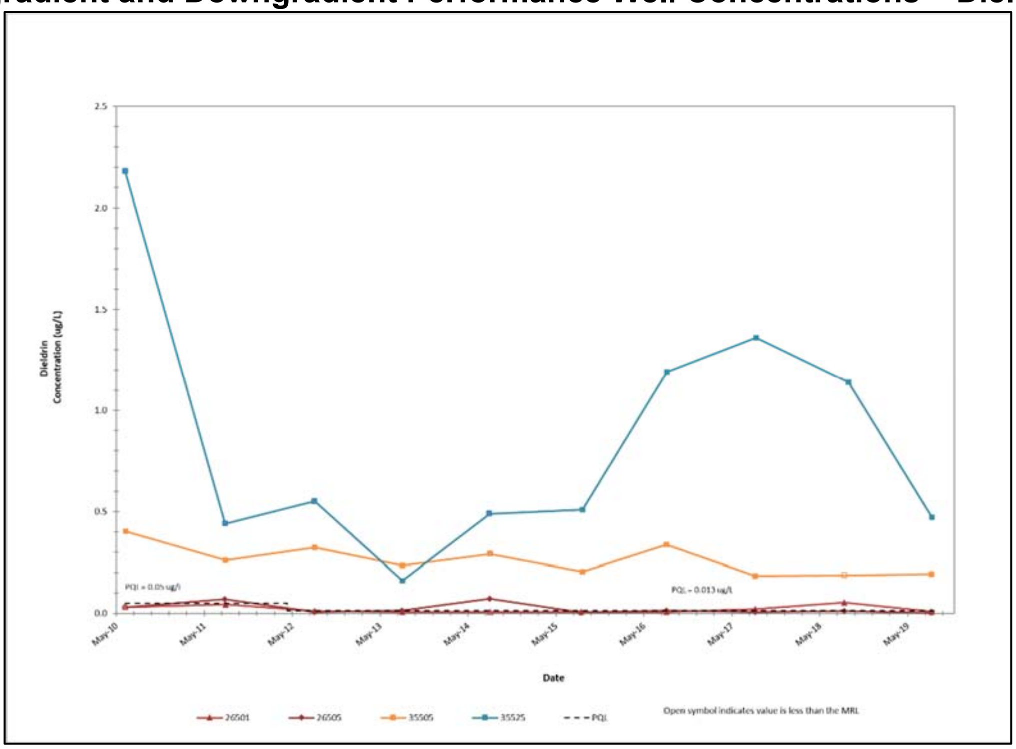
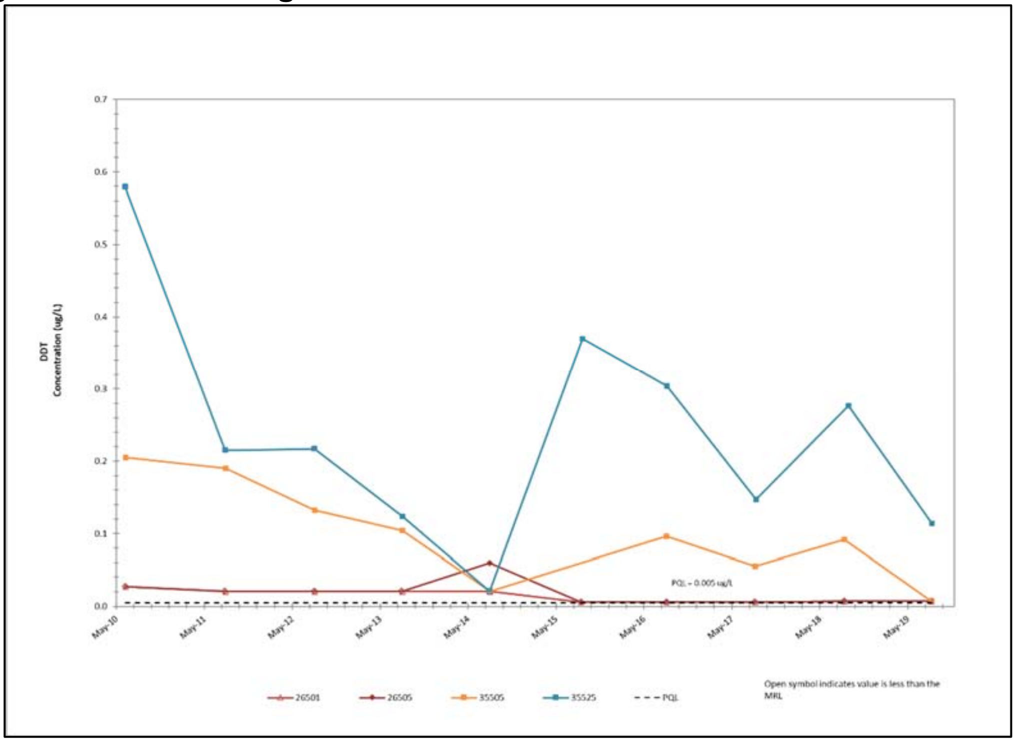


Figure 6.3-21 Basin A Neck System
Upgradient and Downgradient Performance Well Concentrations – PPDDT



6.3.1.5 Bedrock Ridge Extraction System (#28)

The BRES intercepts groundwater flowing northeast out of Basin A from the CADT area. The potentiometric surface indicates that the groundwater flows north-northwest in the vicinity of the extraction wells (see Figure 6.3-22).

BRES Operations and Compliance

Groundwater extracted from BRES is piped to BANS and compliance is achieved through treatment of groundwater to the CSRGs at BANS. BANS effluent compliance was maintained throughout the five-year review period as discussed in Section 6.3.1.4. Treated groundwater is reinjected at the BANS recharge trenches.

BRES Performance Evaluation

The BRES performance evaluation consists of evaluating plume capture and contaminant trends in downgradient wells. The map contours illustrated in Figure 6.3-22 indicate that the plume appeared to be generally captured based on potentiometric flow. Contaminant plume capture also was indicated at the west and east edges of the plume based on the potentiometric surface. There were no significant changes in the groundwater flow directions in the BRES during the FYR period.

Downgradient performance wells are monitored to demonstrate decreasing or stable concentration trends, or that concentrations are at or below CSRGs. Table 6.3-9 presents an overview of the FYR period water quality results for the BANS downgradient performance wells. The distributions of 12DCLE, chloroform, DIMP, tetrachloroethylene and trichloroethylene in performance wells upgradient and downgradient of the BRES for the five-year reporting period are shown in Figures 6.3-23 through Figure 6.3-27. Concentrations of these analytes are above the CSRGs in upgradient wells flowing towards the system, with the highest concentrations occurring in wells 36250 and 36567.

Concentrations of all analytes in downgradient performance wells 36555 and 36571 were below the CSRGs except for tetrachloroethylene in well 36571 in FY17. Concentrations of chloroform and tetrachloroethylene in well 36572 exceeded their respective CSRGs in FY16 and FY17; however, concentrations do not indicate increasing trends.

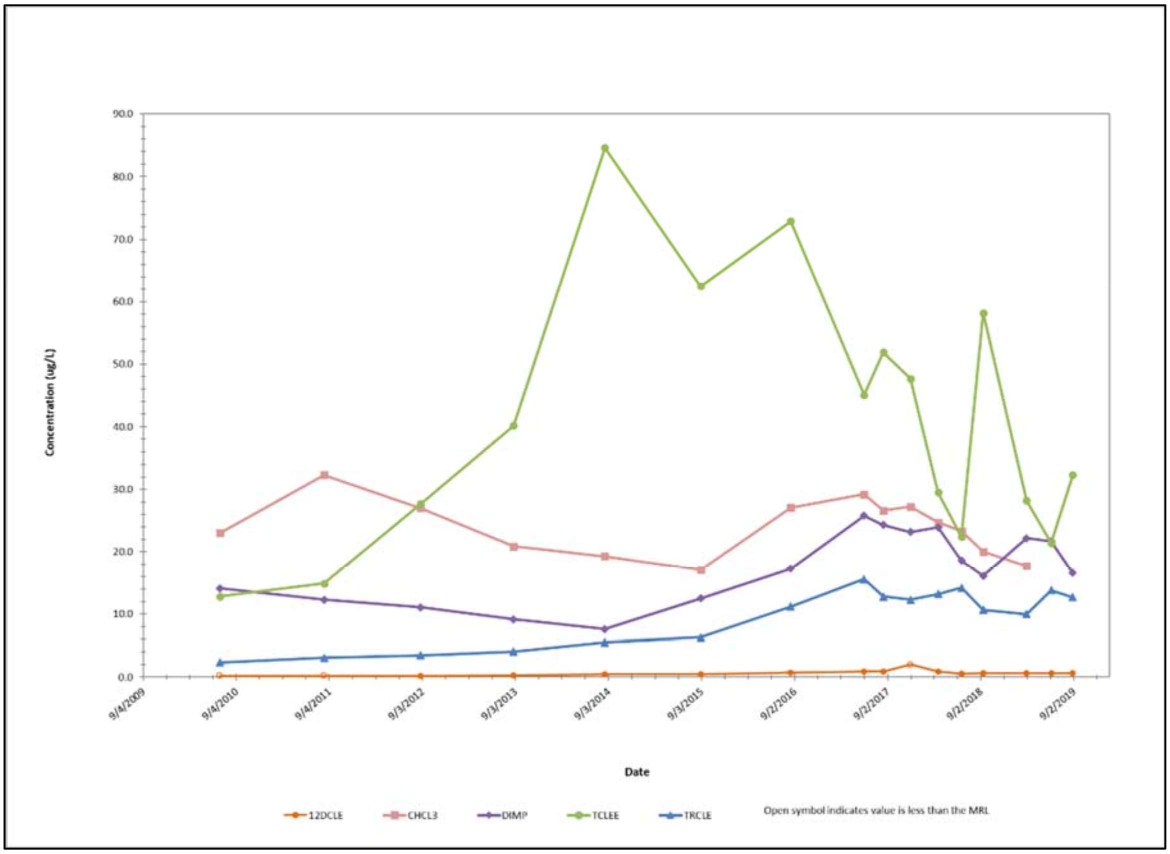
Well 36566 was above the CSRGs for 1,2-dichloroethane, chloroform, tetrachloroethylene, trichloroethylene and DIMP throughout the FYR period, and concentrations of 1,2-dichloroethane and trichloroethylene exhibit increasing trends. Figure 6.3-28 shows the analyte concentrations in downgradient performance well 36566. Well 36566 is located downgradient of the extraction system where the hydraulic gradient is much flatter than at the other downgradient performance wells. Therefore, the contamination in well 36566 would be expected to migrate much slower than in other areas of the plume. This was identified as an issue in the 2015 FYRR with a recommendation for additional monitoring to further evaluate system performance and determine if additional actions are needed.

Table 6.3-9. Five-Year Summary CSRG Analyte Sampling from BRES Downgradient Performance and Water Quality Tracking Wells

CSRG Analyte	CSRG/ PQL (µg/L)	Samples with Concentrations at or above the CSRG or PQL/ Number of Samples Collected				
		Performance				Water Quality Tracking
		36555	36566	36571	36572	25502
1,1,1-Trichloroethane	200	0/5	0/11	0/5	0/5	0/2
1,1,2,2-Tetrachloroethane	0.18	0/5	0/11	0/5	0/5	0/2
1,1-Dichloroethylene	7	0/5	0/11	0/5	0/5	0/2
1,2-Dichlorobenzene	600	0/5	0/11	0/5	0/5	0/2
1,2-Dichloroethane	0.4	0/5	10/11	0/5	0/5	0/2
1,3-Dichlorobenzene	94	0/5	0/11	0/5	0/5	0/2
1,4-Dichlorobenzene	75	0/5	0/11	0/5	0/5	0/2
1,4-Dioxane [3]	0.35	N/A	N/A	N/A	N/A	1/2
1,4-Oxathiane	160	0/5	0/5	0/5	0/5	N/A
Benzene	5	0/5	0/11	0/5	0/5	0/2
Carbon tetrachloride	0.3	0/5	2/11	0/5	0/5	0/2
Chlorobenzene	100	0/5	0/11	0/5	0/5	0/2
Chloroform	6	0/5	11/11	0/5	2/5	0/2
CPMS	30	0/5	0/5	0/5	0/5	N/A
CPMSO	36	0/5	0/5	0/5	0/5	N/A
CPMSO2	36	0/5	0/5	0/5	0/5	N/A
DCPD	46	0/5	0/11	0/5	0/5	0/2
Dieldrin [1a]	0.002/0.013	0/5	0/5	0/5	0/5	0/1
DIMP [2]	8	0/5	0/11	0/5	0/5	0/2
Dithiane	18	0/5	0/5	0/5	0/5	N/A
Endrin	2	0/5	0/5	0/5	0/5	0/1
Hexachlorocyclopentadiene	50	0/5	0/5	0/5	0/5	0/1
NDMA [1b,3]	0.00069/0.009	N/A	N/A	N/A	N/A	0/1
NDPA [3]	0.005	N/A	N/A	N/A	N/A	0/1
PPDDT	0.1	0/5	0/5	0/5	0/5	0/1
Tetrachloroethylene	5	0/5	11/11	1/5	2/5	0/2
Trichloroethylene	5	0/5	11/11	0/5	0/5	0/2

Notes:
N/A – Not applicable
1. The ROD indicates PQLs for the following analytes:
   [a] Dieldrin – Effective April 2012
   [b] NDMA – Effective September 2016
2. DIMP is not a BANS or BRES CSRG analyte, but the CBSG is provided for reference.
3. Reported under the Emerging Contaminants monitoring program.

Figure 6.3-28 Bedrock Ridge Extraction System Downgradient Performance Well 36566 Concentrations



Supplemental monitoring of existing wells was conducted in FY17 and FY18; however, results were inconclusive in determining whether the LTMP performance criteria are being met, and additional monitoring was deemed necessary. Two new monitoring wells, 36256 and 36257, were installed in July 2019 and monitoring of these wells indicates that the highest levels of CSRG analytes are present in well 36256, which is located between extraction wells 36302 and 36306. Concentrations of CSRG analytes in well 36257, located approximately 45 feet west of well 36302, are lower than those detected in 36256, indicating that plume capture is not occurring in the central part of the system. An evaluation of data collected from new and existing wells will continue through 2021 to evaluate system bypass within the BRES and the need for additional extraction to optimize plume capture. The BRES performance is identified as an Other Finding in Section 9.1.

6.3.1.6 Off-Post Groundwater Intercept and Treatment System (#94)

The OGITS includes two extraction and recharge systems consisting of extraction wells, recharge trenches, and recharge wells in the Northern Pathway and First Creek paleochannels. Groundwater is extracted within the FCS and NPS and a single plant treats the combined extracted water from both systems with carbon adsorption. The FCS began operation in January 1993 and the NPS began operating in May 1993.

OGITS System Operations and Compliance

The OGITS operated at an average flow rate of 209 gpm over the five-year reporting period and removed a total of 20.2 pounds of contaminants (Table 6.3-10). The major contaminants removed via treatment included DIMP, tetrachloroethylene and chloroform. The total cost to operate the treatment plant from 2015 through 2019 was $3,348,776. Figures 6.3-29 and 6.3-30 show the OGITS monitoring wells, extraction wells, recharge wells, and recharge trenches for the FCS and NPS, respectively.

Table 6.3-10. OGITS Five-Year Treatment Summary

Fiscal Year	Average Flow Rate (gpm)	Total Volume Treated (gallons)	Total Mass of Contaminants Removed (lbs)	Major Contaminants Removed (lbs)	Carbon Usage (lbs)	Cost of Operation	Total Downtime (hours)
2015	219	115,053,840	4.1	DIMP – 3.5 Chloroform – 0.22 Tetrachloroethylene – 0.21 DCPD – 0.05	40,000	$691,483	4
2016	204	107,500,968	4.5	DIMP – 3.9 Chloroform – 0.32 Tetrachloroethylene –0.17	60,000	$644,285	6
2017	215	115,431,570	4.9	DIMP 4.2 – Chloroform 0.35 – Tetrachloroethylene – 0.26	40,000	$670,664	38
2018	211	112,528,763	3.7	DIMP – 3.3 Chloroform – 0.21 Tetrachloroethylene –0.15	40,000	$639,004	27.25
2019	198	106,599,470	3.0	DIMP – 2.62 Tetrachloroethylene –0.16 Chloroform – 0.14	60,000	$703,340	14.5
Total	**209 (average)**	**557.1 million**	**20.2**	**—**	**240,000**	**$3,348,776**	**89.75**

Monitoring is conducted for the OGITS treatment plant influent and effluent to demonstrate compliance with remediation goals. The system effluent for the OGITS was analyzed quarterly using the LTMP CSRG analyte list for the OGITS and annually using the complete ROD CSRG list. Complete effluent monitoring results are provided in quarterly effluent reports (listed on Table 4.1-2). The treatment plant influent and effluent concentrations for chloride, fluoride, DIMP, and NDMA are shown in Figures 6.3-31 through 6.3-34. Effluent concentrations for all organic contaminants were below their respective CSRGs except for NDMA in the fourth quarter of FY17. A second sample was collected but the result was below the reporting limit. The NDMA concentration was also above the current PQL in the fourth quarter of FY16; however, the effective PQL at the time was 0.018 µg/L and the concentration of 0.0147 µg/L did not exceed the PQL in effect. The effluent met the four-quarter moving average throughout the five-year review period as shown on Figure 6.3-35.

The OGITS does not treat for the anions chloride, sulfate and fluoride. In accordance with the ROD, CSRGs for chloride and sulfate will be achieved through natural attenuation over time periods of 30 and 25 years (i.e., by 2026 and 2021), respectively. Effluent concentrations for chloride exceeded the CSRG from FY15 through FY17 and the moving average was above the CSRG until the third quarter of FY18. Concentrations decreased slightly over the five-year period and the four-quarter moving average has been below the CSRG since the third quarter of FY18 (Figure 6.3-35) demonstrating progress toward meeting the goal. For sulfate, the moving average has been below the CSRG since the third quarter of FY16 and concentrations continued to decrease over the five-year period. The long-term trends for both anions suggest that attenuation to the CSRGs will be achieved within the expected time frames.

Fluoride exceeded the CSRG of 2 mg/L once, in the second quarter of FY18, with a reported concentration of 2.6 mg/L. The influent concentration was also reported at 2.6 mg/L. A second sample was collected and the result was 1.3 mg/L, below the CSRG, and no action was taken. Influent and effluent concentrations were below the CSRG in the subsequent quarters. The average fluoride concentration for the OGITS effluent over the five-year period was 1.4 mg/L.

OGITS Performance Evaluation

Quarterly water level monitoring is conducted in the performance water level wells to monitor groundwater hydraulic gradients and flow directions and provide data for the mass removal calculations. Annual sampling of the performance water quality wells is conducted to monitor the upgradient, cross-gradient, and downgradient groundwater quality and to provide data for the mass removal calculations.

OGITS Mass Removal

The LTMP mass removal criterion refers to removing at least 75 percent of the contaminant plume mass migrating toward the system during a specified time period and is defined as contaminant mass flux. Mass removal is calculated annually and reported in the ASRs.

In accordance with the LTMP, mass removal has been calculated using all contaminants (excluding anions) and comparing mass in the effluent to the total mass in the plume. However, as contaminant concentrations decline in the future, the contaminant concentrations in the upgradient wells will approach the CRSGs/PQLs. This would result in decreasing mass removal percentages because the differences in influent and effluent concentrations would be small, especially where the CSRG/PQL is near the MRL. Treatment would also be unnecessary to meet ROD compliance requirements.

As discussed previously for the BANS, a revised approach to evaluate contaminant mass removal at the FCS and NPS, was developed in FY18 to evaluate contaminant mass removal relative the LTMP performance criterion by comparing calculated mass extracted by the system to the contaminant plume mass flux approaching the system. The revised technical approach focuses on measuring the effectiveness of mass removal at the point of capture (extraction) within each system, provides a quantitative measure of extraction system performance, and better quantifies contaminated groundwater not captured as an indication of potential system bypass. Quantitatively, the mass captured through system extraction is compared to the overall mass of the plume approaching the system, resulting in an overall percentage that is compared to the performance goal, currently 75 percent. For FY18 and FY19, the regulatory agencies approved use of the revised approach to calculate the mass removal percentage for comparison against the performance goal. Consistent with the methodology incorporated into the LTMP in 2012 (OCN-LTMP-2012-002), the well capture method is used to estimate the mass removal within flow approaching the FCS and NPS and the transect method is used to estimate the mass approaching each system.

First Creek System Mass Removal

The FCS met the mass removal goal each year of the five-year review period. Table 6.3-11 presents the results for the FCS mass removal evaluations. Prior to FY18, the mass removal percent averaged 79 percent. Using the revised approach, accounting for mass extracted, mass removal in FY18 and FY19 were estimated at 107 percent and 90 percent, respectively. The majority of the plume mass flux is attributed to chloride, sulfate, and fluoride. These analytes are not treated by OGITS but will meet CSRGs by attenuation, consistent with the on-post remedy.

While mass removal approximates 100 percent for the system, this potentially represents an overestimation attributable to combination of the variability in water quality across the system and the conservative assumptions utilized to calculate plume mass and captured mass. Discrepancies between the plume mass flux and captured mass may also be attributable to one or more of the following factors: position of plume transect located 800–1,200 feet upgradient of the extraction wells, the effect of recharged groundwater that contains a high percentage of mass attributable to anions that are not treated, and/or geochemical processes that may take place as contaminants migrate towards the extraction wells causing groundwater contaminant concentrations to change *in situ*.

Northern Pathway System Mass Flux and Mass Removal Estimates

The NPS met the mass removal goal each year of the five-year review period. Table 6.3-12 presents the results for the NPS mass removal evaluations. Prior to FY17, mass removal was calculated for all contaminants and for contaminants that exceeded CSRGs. For the NPS, only dieldrin and carbon tetrachloride exceed the CSRGs in the upgradient wells. As discussed above, inclusion of analytes where the influent was already meeting the CSRGs resulted in decreasing mass removal percentages because the differences in influent and effluent concentrations were small. Calculation of mass removal accounting for only those contaminants that required treatment to meet CSRGs showed mass removal between 76 and 94 percent.

The discrepancy between the plume mass flux and captured mass may be attributed to one of more of the following factors: position of plume transect located 200 feet upgradient of the extraction wells and the variability of analyte concentrations between the transect and points of extraction, the effect of recharged groundwater that contains a high percentage of mass attributable to anions not treated, and/or the conservative assumptions made to calculate mass removal relative to the heterogeneity of groundwater concentrations and flow rates

Table 6.3-11. First Creek System Estimated Contaminant Flow Rate and Mass Removal, FY15 – FY19

Contaminant Flow Rate (gpm)	FY15	FY16	FY17	FY18	FY19
Capture Zone	41.0	40.4	30.8	49.2	49.2
Outside of Capture Zone	1.4	1.4	1.4	1.7	1.7
Total Flow Rate	**42.4**	**41.8**	**32.2**	**50.9**	**50.9**
Plume Mass Flux[1] (lbs), LTMP Method					
Total Mass Flux[1]	4.9	6.3	5.08		
Extracted Mass Removed	3.9	5.0	3.96		
Percent Mass Removed, LTMP Method, based on treatment	**79.6%**	**79.4%**	**78.0%**		
Plume Mass Flux (lbs), Revised Method					
Mass Flux, Outside of Capture Zone				4,241	11,975
Total Mass Flux				231,637	211,227
Mass Flux, Inside of Capture Zone				227,396	199,252
Extracted Mass[2] (Inside Capture Zone)				247,296	190,018
Percent Mass Removed, Revised Method, based on extraction				**106.7%**	**89.9%**

Notes:

[1] Mass flux for FY15-FY17 calculated for organic contaminants only.

[2] Extracted mass can exceed plume mass due to recycle flow from recharge trenches.

Table 6.3-12. Northern Pathway System Estimated Contaminant Flow Rate and Mass Removal, FY15 – FY19

Contaminant Flow Rate (gpm)	FY15	FY16	FY17	FY18	FY19
Plume Approaching System	95.9	107	122	138.5	147
Extraction System	128.3	123	137	148.9	137
Influent (PPINNP)	132.9	126	129	--	--
Plume Mass Flux[1] (lbs), LTMP Method					
Total Mass Flux, Extraction Wells[2]	1.5	1.5	1.7		
Extracted Mass Removed	0.66	0.89	1.32		
Percent Mass Removed	44.0%	59.3%	**77.6%**		
Total Mass Flux, Analytes above CSRGs[2]	0.059	0.087	--		
Extracted Mass Removed, Analytes above CSRGs	0.045	0.082	--		
Percent Mass Removed, Analytes above CSRGs	**76.3%**	**94.3%**	**--**		
Plume Mass Flux (lbs), Revised Method					
Total Mass Flux[2]				396,450	429,450
Extracted Mass				412,670	358,093
Percent Mass Removed, Revised Method, based on extraction				**104%**	**83.4%**

Notes:

[1] Mass flux for FY15-FY17 calculated for organic contaminants only.

[2] There is no capture zone associated with the Northern Pathway System.

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Table 6.3-13. Five-Year Summary CSRG Analyte Sampling from OGITS Downgradient Performance Wells

CSRG Analyte	CSRG/PQL (µg/L)	Samples with Concentrations at or above the CSRG or PQL/ Number of Samples Collected											
		First Creek System			Northern Pathway System								
		37084	37110	37343	37027 [2]	37008	37009	37010	37011	37012	37013	37039 [2]	37452 [2]
1,2-Dichloroethane	0.40	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
1,3-Dichlorobenzene	6.5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
1,4-Oxathiane	160	0/5	0/5	0/5	0/4	0/5	0/5	0/5	0/5	0/5	0/5	0/4	0/4
Aldrin [1a]	0.002/0.014	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Arsenic	2.35	0/5	0/5	0/5	0/5	2/5	0/5	0/5	2/5	0/5	0/5	0/5	0/5
Atrazine	3	0/5	0/5	0/5	0/4	0/5	0/5	0/5	0/5	0/5	0/5	0/4	0/5
Benzene	3	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Carbon tetrachloride	0.30	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Chlordane	0.03	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Chloride	250,000	5/5	5/5	5/5	3/5	0/5	2/5	1/5	0/5	1/3	2/5	2/5	0/5
Chlorobenzene	25	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Chloroform	6	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
CPMS	30	0/5	0/5	0/5	0/4	0/5	0/5	0/5	0/5	0/5	0/5	0/4	0/5
CPMSO	36	0/5	0/5	0/5	0/4	0/5	0/5	0/5	0/5	0/5	0/5	0/4	0/4
CPMSO2	36	0/5	0/5	0/5	0/4	0/5	0/5	0/5	0/5	0/5	0/5	0/4	0/4
DBCP	0.2	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
PPDDT	0.1	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
PPDDE	0.1	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
DCPD	46	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Dieldrin [1a]	0.002/0.013	3/5	0/5	5/5	1/5	1/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
DIMP	8	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Dithiane	18	0/5	0/5	0/5	0/4	0/5	0/5	0/5	0/5	0/5	0/5	0/4	0/4
Endrin	2	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5

Table 6.3-13. Five-Year Summary CSRG Analyte Sampling from OGITS Downgradient Performance Wells

CSRG Analyte	CSRG/PQL (µg/L)	Samples with Concentrations at or above the CSRG or PQL/ Number of Samples Collected											
		First Creek System			Northern Pathway System								
		37084	37110	37343	37027 [2]	37008	37009	37010	37011	37012	37013	37039 [2]	37452 [2]
Ethylbenzene	200	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Fluoride	2,000	0/5	5/5	0/5	5/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Hexachlorocyclopentadiene	0.23	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Isodrin	0.06	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
Malathion	100	0/5	0/5	0/5	0/4	0/5	0/5	0/5	0/5	0/5	0/5	0/4	0/4
NDMA [1b]	0.0069/0.009	0/5	0/5	0/5	1/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5	1/5
NDPA	0.005	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	2/3	0/3	0/3
Sulfate	540,000	4/5	5/5	5/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5	0/5
Tetrachloroethylene	5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Toluene	1000	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Trichloroethylene	3	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5
Xylenes	1000	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/20	0/5

Notes:

1. The ROD indicates PQLs for the following analytes:
   [a] Aldrin and Dieldrin – Effective April 2012
   [b] NDMA – Effective September 2016
2. Cross-gradient well

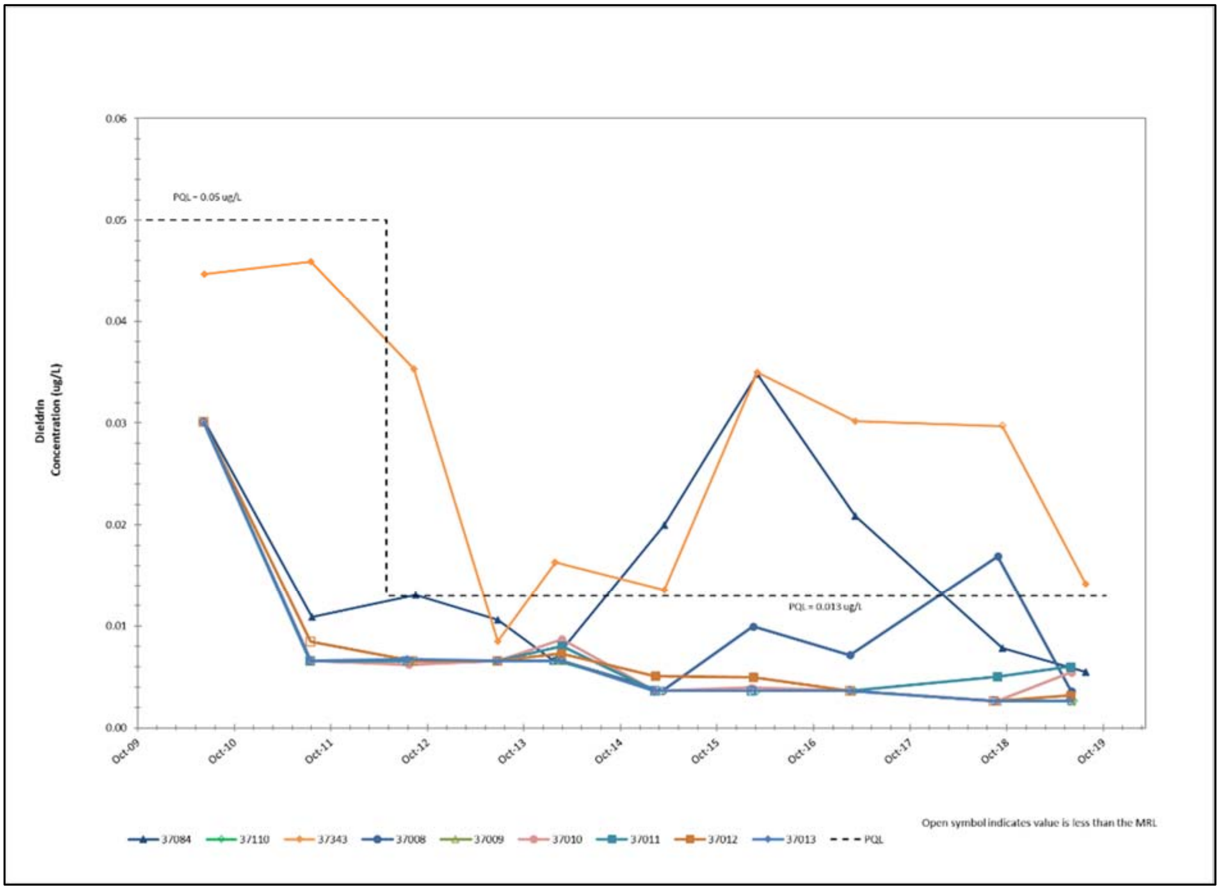
OGITS Downgradient Performance Wells

Table 6.3-13 (above) presents an overview of the FYR period water quality results for the FCS and NPS OGITS performance wells. Figures 6.3-36 through 6.3-39 show the downgradient performance well concentrations for dieldrin, DIMP, fluoride and arsenic.

First Creek System Downgradient Performance Evaluation

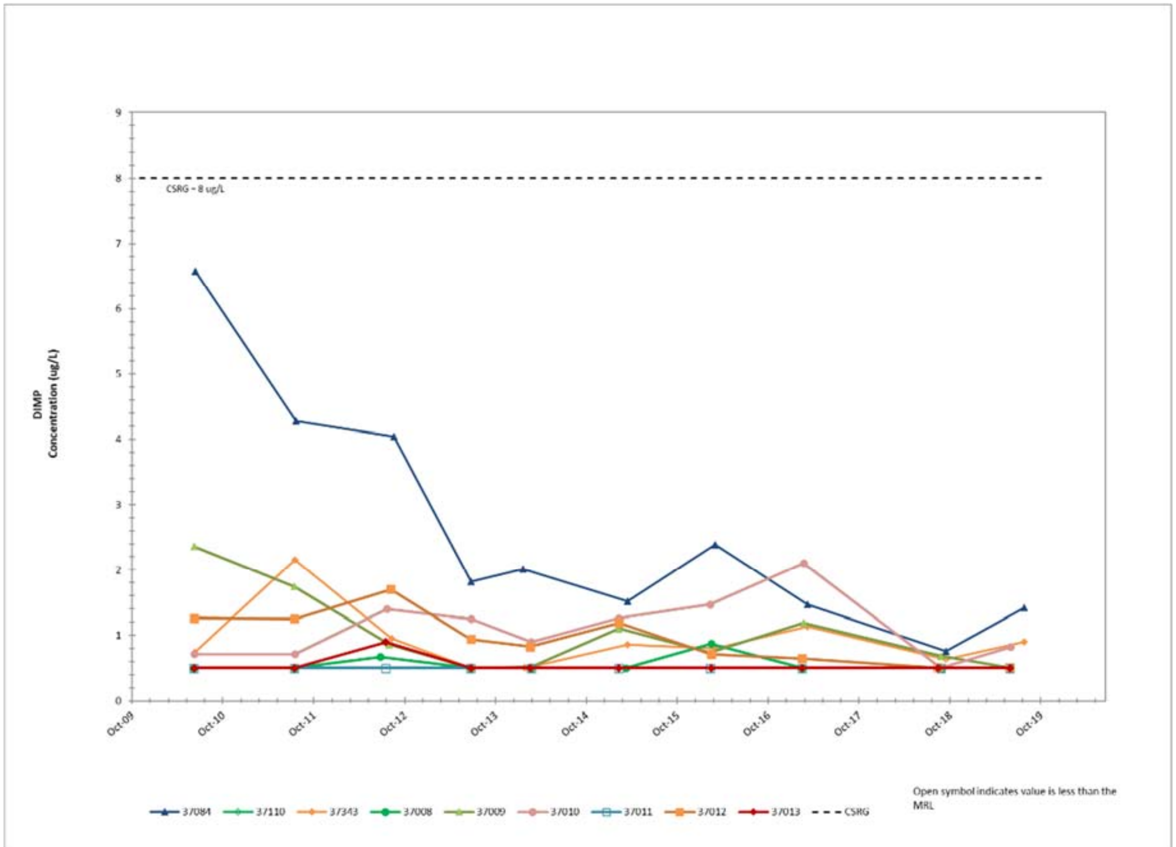
All three FCS downgradient performance wells had concentrations below the OGITS CSRGs/PQLs for the organic analytes, except for dieldrin in wells 37084 and 37343. Since FY16, the dieldrin concentration in both wells has continued to decrease (Figure 6.3-36). Dieldrin has never been detected in well 37110. It is expected that the dieldrin levels within the FCS will generally continue to decrease over time.

Figure 6.3-36 OGITS
Downgradient Performance Well Concentrations – Dieldrin



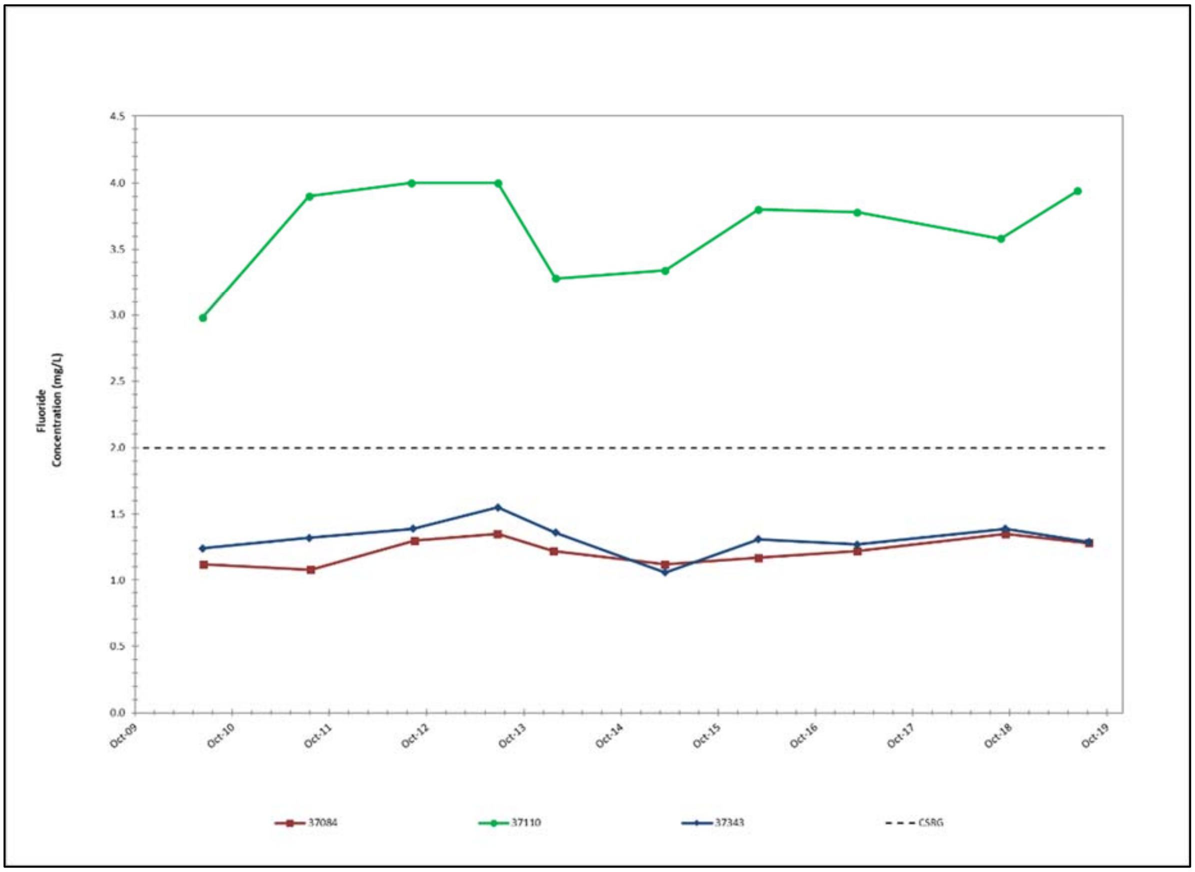
It is unlikely that the dieldrin detected downgradient is caused by bypass of the system, but rather dieldrin in soil was remobilized in groundwater due to fluctuating water levels in the vicinity of First Creek. Supporting this theory, DIMP occurs more frequently than dieldrin in wells located upgradient of the dewatering wells; however, DIMP levels in downgradient wells are below the CSRG and are decreasing or stable (Figure 6.3-37). Therefore, the dieldrin detections above the PQL are not believed to be indicative of system bypass.

Figure 6.3-37 OGITS
Downgradient Performance Well Concentrations – DIMP



The downgradient performance wells exceeded the CSRGs for chloride and sulfate, but concentrations are stable or decreasing and the inorganic standards for chloride and sulfate at OGITS will be met by attenuation consistent with the On-Post ROD. Fluoride also exceeded the CSRG in well 37110. Fluoride has historically been present in this well and the concentration is stable (Figure 6.3-38). The higher fluoride concentrations in this well appears unrelated to OGITS effectiveness because fluoride has been detected historically at concentrations higher than in the upgradient wells, which are located along the same groundwater flow path.

Figure 6.3-38 First Creek System Downgradient Performance Well Concentrations – Fluoride

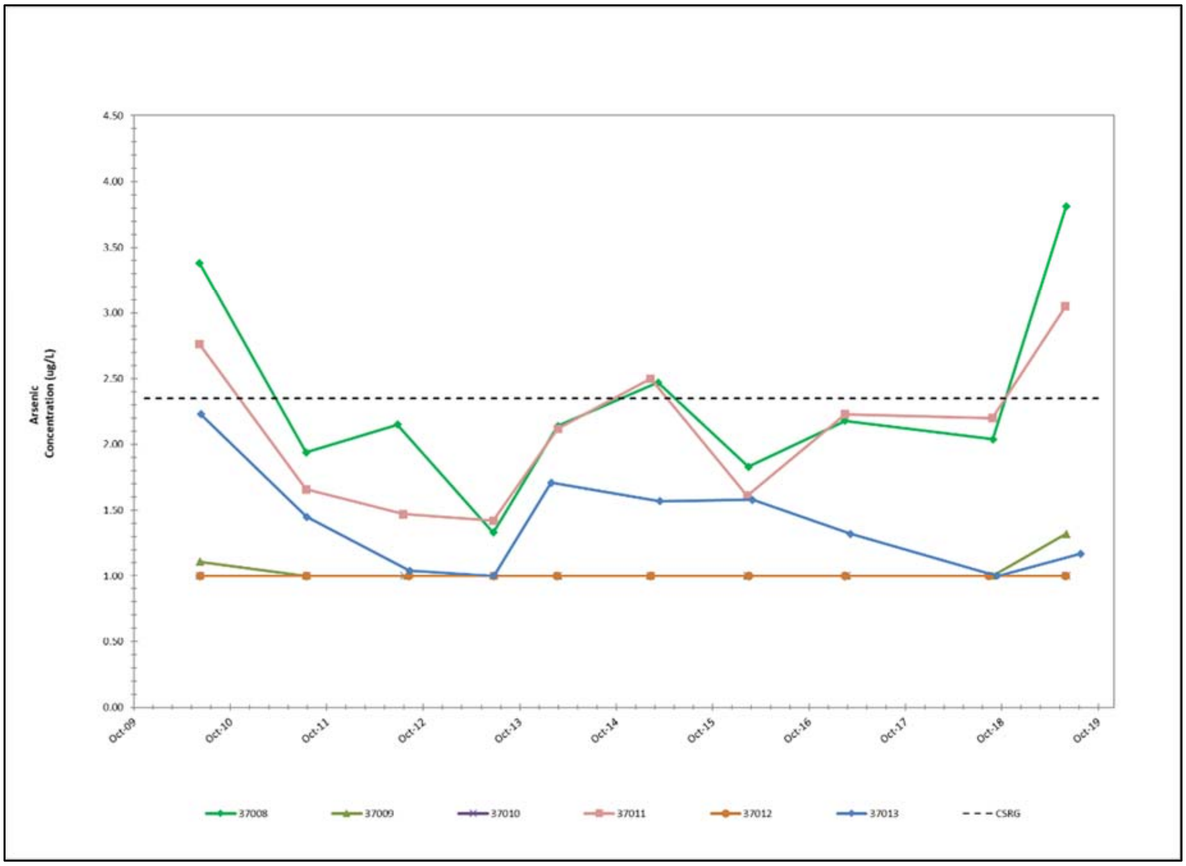


<u>Northern Pathway System Downgradient Performance Evaluation</u>

Monitoring results for CSRG analytes in downgradient performance wells 37008, 37009, 37010, 37011, 37012 and 37013 sampled during the FYR period are shown in Table 6.3-12. During the five-year reporting period, arsenic, chloride, dieldrin, NDMA and NDPA occurred in downgradient performance wells at concentrations exceeding CSRGs/PQLs. Sulfate also exceeded one time in FY18 in well 37013. For all other CSRG analytes, concentrations were below CSRGs/PQLs in downgradient performance wells. Observations of exceedances in NPS performance wells during the five-year reporting period include the following:

- Arsenic was detected at concentrations in exceedance of the CSRG in wells 37008 and 37011 in FY19 (Figure 6.3-39), but analyses indicate stable trends.
- Dieldrin was detected in well 37008 once in FY18 and the concentration exceeded the PQL, but the trend does not appear to be increasing (Figure 6.3-36).
- NDMA and NDPA were only detected in well 37013, and each time they were detected, the concentrations exceeded their respective PQLs. NDMA has been detected once in well 37013 over the past five years, while NDPA has been detected twice.

Figure 6.3-38 First Creek System
Downgradient Performance Well Concentrations – Arsenic



Although elevated concentrations of chloride and sulfate are present in groundwater within the NPS, concentrations are stable or decreasing and the standards are expected to be met by natural attenuation consistent with the On-Post ROD. Fluoride was reported at the CSRG once in well 37013. Fluoride may be naturally occurring, and results visually show stable trends for the wells across the NPS.

Dieldrin was reported once in cross-gradient well 37027 above the CSRG, but this well is in the capture zone for dewatering well 37816. Additionally, the dieldrin detection was flagged as questionable because the investigative and duplicate samples were incomparable.

In FY18, NDMA was detected above the CSRG in cross-gradient wells 37027 and 37452. These were one-time detections as NDMA was not detected above the reporting limit for the remainder of the reporting period.

Northern Pathway System Modifications

During the FYR period, additional monitoring detected dieldrin above the PQL in the gap between modified system extraction wells 37817 and 37818. The dieldrin plume extends downgradient to the original system extraction wells 37809 and 37810. As noted in previous ASRs, the capacity of NPS modified system extraction well 37818 has declined over the years, primarily due to biofouling. Upgradient performance wells near 37818 remain above the PQL for dieldrin. Existing monitoring wells were sampled in 2018 and additional samples were collected through direct push sampling in November 2019 to confirm the presence of dieldrin in the area. The results of the sampling indicate a broader dieldrin plume approaching the system and dieldrin above the PQL in the gap area. Figure 6.3-62 shows the extent of the dieldrin plume in the gap area and downgradient of the modified system. The plume is currently captured by the original system extraction wells; however, these wells are located in the expiring lease area and will not be available long term. An addition to the NPS extraction system is being designed and the system is being evaluated due to expiration of the lease on which several extraction wells are currently located, leaving a gap in extraction well coverage. The system modification will be designed to capture groundwater flowing through the gap between modified system extraction wells 37817 and 37818. Completion of the modified system to address dieldrin in the gap area and revision of the lease area to encompass the modified system are identified as issues in Section 8.0.

6.3.2 Other On-Post Groundwater Remedial Actions

This section presents a summary evaluation of other groundwater remedial actions currently operating within the On-Post OU.

6.3.2.1 Complex (Army) Disposal Trenches Slurry Walls (Dewatering) (#17)

The performance criteria for the CADT dewatering system are based on achieving water elevation goals (i.e., below the bottoms of the disposal trenches) and that the water levels inside the slurry wall are lower than the water levels outside the slurry wall (i.e., maintain an inward gradient). 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 (see Figure 6.3-40 for well locations). The groundwater pumped by the CADT dewatering system is treated at the BANS.

The performance criteria presented in the 2010 LTMP for the CADT system include the following:

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

The target elevations for wells 36216 and 36217 correspond to the disposal trench-bottom elevations at each location.

Since 2014, when achievement of the performance criterion was required, the groundwater levels in well 36216 have been below the target elevation; however, the elevation goal at well 36217 has not been met. Nonattainment of the groundwater elevation goal was identified as an issue in the 2015 FYRR. As a result, an evaluation was completed to assess the current system conditions and evaluate whether additional dewatering is warranted (Navarro 2019r).

Evaluation of existing conditions at the CADT indicated that there is hydraulic control at well 36217 due to flow directed towards the extraction trench through active dewatering. Because the hydraulic gradient toward the extraction trench represents containment, the LTMP was revised (OCN-LTMP-2019-009) to incorporate demonstration of hydraulic control as an alternate performance goal under the first performance criterion for the CADT as follows:

- Demonstrate groundwater elevations in performance monitoring wells 36216 and 36217 are below the target elevations of 5226 and 5227 feet, respectively, or
- Demonstrate hydraulic gradient from the performance monitoring well locations is toward the extraction trench.

Water levels in wells 36216 and 36217 have been generally decreasing since October 2016. Figure 6.3-40 presents the water levels in February 2019 and the potentiometric surface showing the hydraulic control was achieved at the CADT as groundwater flows toward the extraction trench at wells 36216 and 36217.

Relative to the second criterion, the inward gradient across the CADT slurry wall was maintained throughout the five-year review period. Figure 6.3-41 shows the quarterly groundwater elevations measured in well pairs 36218/36219 and 36220/36221 for FY19.

6.3.2.2 Shell Disposal Trenches Slurry Walls (Dewatering) (#17)

The performance requirement for Shell Trenches is to demonstrate that groundwater elevations are below the estimated disposal trench-bottom elevations within the slurry-wall enclosure. During development of the LTMP, six RI soil bore locations were selected to represent estimated trench bottom elevations. To monitor performance of the remedy (passive dewatering), quarterly water levels are measured from existing monitoring wells within the slurry wall, and the elevation data are interpolated to estimate groundwater elevations at the six RI bore locations.

Table 6.3-14. Shell Disposal Trenches Performance Criterion Trench Bottom Elevations and Groundwater Elevations

Boring ID	Trench Bottom Elevation (feet amsl)	FY15 Groundwater Elevations	FY16 Groundwater Elevations	FY17 Groundwater Elevations	FY18 Groundwater Elevations	FY19 Groundwater Elevations [1]
3178	5242.0	5241.2	5241.4	5239.6	5239.5	5237.4
3444	5244.1	5238.7	5239.4	5239.3	5239.3	5237.5
3445	5240.5	5239.6	5239.7	5239.1	5239.0	5237.2
3446	5240.6	5239.2	5239.6	5238.6	5238.6	5236.9
3453	5237.7	5238.8	5239.75	5239.8	5239.5	5237.95
3457	5240.8	5240.6	5240.7	5239.4	5239.3	5237.45

Note:

1. Groundwater elevations for September 2019 at bore locations interpolated from Figure 6.3-42 in feet above mean sea level (amsl).

Table 6.3-14 (above) lists the bore locations, corresponding trench-bottom elevations, and interpolated groundwater elevations for each year. Figure 6.3-42 shows the soil bore locations and SDT monitoring well network.

The performance goal was met at five of the bore locations. With the exception of several months in FY13, the performance goal has not been met at location 3453. Nonattainment of the groundwater elevation goal at this location was identified as an issue in the 2015 FYRR with a recommendation to assess the current system conditions and evaluate whether active dewatering is warranted.

The *Shell Disposal Trenches Dewatering Evaluation* was completed in March 2019 (Navarro 2019x), recommending that active dewatering was not warranted; however, there was not consensus on the conclusions of the evaluation report. As part of the evaluation, it was noted that bore location 3453 was likely not located within a disposal trench. Bore logs, chemical data, employee depositions, historical aerial photographs, and geophysical surveys of the area all provide evidence that bore location 3453 is located outside of the area used for disposal trenches, resulting in significant uncertainty in the trench-bottom elevation adopted by the LTMP. Subsequent discussion led to an agreement to conduct a site investigation to attempt to identify the bottom elevation of a disposal trench in the western portion of the site.

An investigation plan was finalized in March 2020 to complete investigative borings within the suspected disposal trench area and the installation of a monitoring well, 36258, in the western portion of the site. The investigation was completed in June 2020 and a trench bottom elevation was successfully identified. As a result, the LTMP was modified to incorporate a performance goal for the newly identified trench bottom elevation to replace location 3453 (OCN-LTMP-2020-005).

In addition, the Army installed a monitoring well, 36255, in the southeast corner of the site to provide better well coverage inside the slurry wall for interpolation of groundwater elevations. Groundwater elevations within the slurry wall enclosure reached a high in October 2016 but have been falling steadily since that time. Figure 6.3-42 provides the groundwater elevations measured for FY19 compared to the existing performance monitoring locations.

6.3.2.3 Section 36 Lime Basins Slurry/Barrier Wall (Dewatering) (#47)

Quarterly water level monitoring is conducted in six well pairs to monitor the hydraulic gradient across the slurry wall and assess progress toward meeting the dewatering goals. Monitoring well locations are shown on Figure 6.3-43. Baseline water levels for the slurry-wall project wells were measured on March 25, 2009, and the system started up on March 30, 2009. Groundwater levels decreased between 2009 and 2014, but the performance goals had not yet been achieved. Therefore, nonattainment of the performance goals was identified as in issue in the 2015 FYRR.

The first performance criterion requires that positive inward hydraulic gradient be maintained across the slurry wall. During monitoring in FY09 through FY12, an outward gradient was present for all six well pairs with a reverse gradient observed in southern wells in FY13. As observed during FY14 through FY19, an inward gradient was present in all well pairs on the southern side while an outward gradient was still present for all the well pairs on the northern side. Groundwater elevations inside and outside of the slurry wall have been steadily decreasing, with a greater change observed in wells located within the slurry wall. Figures 6.3-44 and 6.4-46 show the reverse gradient plots for the northern and southern wells measured in FY19. Based on a non-routine action plan (NRAP-LTMP-2016-003), and a corresponding OCN to the LTMP (OCN-LTMP-2016-001), the projected date for achieving an inward gradient for all well pairs was revised to April 30, 2021. However, due to declining water levels outside the slurry wall, the inward gradient goal will not be achieved by this date. A revised goal of September 2024 was set as a projected date to track progress in achieving the goal. Monitoring of progress toward meeting this goal will continue annually and will be evaluated in the next FYR period.

The second performance criterion requires water levels inside the slurry wall to be below the elevation of the bottom of the waste (5,242 feet amsl). Figure 6.3-46 presents the water level trends for the wells inside the slurry-wall enclosure and the total flow rate for the six dewatering wells between March 2009 and September 2019. FY15 marked the first year in which water levels in all northern wells were below the bottom of the waste, while water levels in the southern wells fell below the bottom of waste in FY16. This goal has been maintained at all performance locations since June 2016 and water levels continue to decline.

6.3.2.4 Section 36 Lime Basins DNAPL Remediation (O&M) (#47)

Figure 6.3-43 provides the well map for the Lime Basins area. Lime Basins DNAPL Remediation Project monitoring consists of measuring DNAPL thickness and water levels, and sampling monitoring and dewatering wells.

Water level and water quality data collection specified in the DNAPL Design Analysis Report (TtEC and URS 2012) began in FY13. Quarterly water level measurements, DNAPL measurements and water quality samples are collected from the six dewatering wells installed as part of the Lime Basins dewatering system and the three monitoring well pairs located along the north slurry wall boundary. Semiannual water level measurements, DNAPL measurements and water quality samples are collected from the three well pairs located along the south slurry wall boundary and four additional well pairs located along the eastern and western slurry wall boundaries that were installed in FY12 after the discovery of DNAPL.

DNAPL Thickness and Water Levels

Based on interpolated data, groundwater flows to the north-northwest inside the slurry wall area. The hydraulic gradient is relatively flat inside the slurry wall, ranging from 0.002 to 0.003 feet per foot in FY19, which is less than the range in previous years. The maximum head differential from the southeast corner to the northwest corner has continued to decrease compared to previous water level measurements from a high of 1.86 feet in April 2009 to 0.82 feet in February 2019. There is no apparent deviation of water levels in the wells adjacent to the slurry wall that would indicate an impact to the performance of the slurry wall.

The water level data and DNAPL measurements indicate that the slurry wall has not been adversely impacted by DNAPL according to criteria in the DAR (TtEC and URS 2012). Consistent head differentials across the slurry wall have been maintained for all the well pairs showing that the DNAPL remediation system is functioning as intended. During the five-year reporting period the volume of DNAPL recovered from wells at the Lime Basins has decreased, as presented in Table 6.3-15. While volumes recovered from individual wells may have fluctuated, the overall volume decreased from 9.0 gallons recovered from three wells in FY15 to 4.77 gallons recovered from two wells in FY19. No DNAPL was detected outside of and/or adjacent to the slurry wall.

Table 6.3-15. Summary of PRAS and Measurable DNAPL in Lime Basins Wells, FY15 – FY19

Well	Total PRAS (%) and Volume of Recovered DNAPL				
	FY15	FY16	FY17	FY18	FY19
Monitoring Wells					
36054	0.47		3.3	2.4	2.9
36212			NS	NS	NS
36231	**88.9**	25.5	55.6	**89.6**	**96**
36232	62.3	**91.7**	**134.9**	**98.5**	**101**
36233	39.5	26.6	48.5	41	49
36234	16.9	17.9	27.2	13.2	26
36235	48.4	34.8	57.4	46	68
36236	30	22.5	39.2	38.5	63
36237	23.6	32.4	25.9	29.7	44
36238			12.8	11.4	12
36239			6.6	6.8	36
36240			28.5	7.5	23
36241	6	1	6.4	4.3	5.7
36242	**102.1**	**120**	**134.4**	**124.7**	**95**
36243	**129.3**	**140.4**	**162.6**	**160.9**	**116**
36244	66.4	**78.8**	**80.6**	55.6	61
36245	53.1	68.8	70.4	50.4	41
36246	35.9	32.6	54.5	15.1	36
36247	5.4	12.4	10.1	15	11
36248	6.5	4.8, 0.65 gallons	35, 1.5 gallons	29.2, 0.037 gallons	23, 0.48 gallons
36249			10.5	9.6	8.4
Extraction Wells					
36315	56	42.4	37.6	66.7	50
36316		0.14	2.1	2.9	2.2
36317		0.29	2.4	3.1	2.6
36318		5.8	6.4	5.1	5.2
36319	41.9, 4.0 gallons	49.3, 5.1 gallons	72, 3.5 gallons	63.4, 5.1 gallons	**82**, 4.29 gallons
36320	65.5, 5.0 gallons	61.6, 1.84 gallons	64.1, 2.5 gallons	**87**, 1.47 gallons	**92**
Total DNAPL	9.0 gallons	7.59 gallons	7.5 gallons	6.61 gallons	4.77 gallons

Notes:
Calculated Total PRAS greater than 75% presented in **bold**.
Highlighting indicates measurable DNAPL was present during the noted year.

Monitoring Well and Dewatering Well Sampling

In the Lime Basins DNAPL RI Summary Report (TtEC 2010a), the percent of relative aqueous solubility (PRAS) of the DNAPL compounds was used as a screening tool to assess the potential presence of DNAPL source zones using water quality data. The PRAS is calculated by dividing the dissolved concentration of an analyte by the aqueous solubility of the analyte. As presented in the DNAPL RI Summary Report PRAS greater than or equal to 75 percent, either for an individual analyte or for the sum of the five analytes, was considered the threshold for potential DNAPL source zone presence. This threshold was selected based on the calculated average PRAS for wells where DNAPL was present during the RI. The results for FY19 are provided in Table 6.3-15.

For FY19, PRAS was calculated as a function of all analytes detected in groundwater, including the five DNAPL compounds identified in the RI Summary Report. The observed presence of DNAPL, PRAS greater than 75 percent for individual compounds, and summed PRAS greater than 75 percent in the wells are generally consistent with previous data as presented in Table 6.3-15.

PRAS calculated for each of the wells at the Lime Basins ranged from a low of 0.47% in well 36054 in FY15 to a high of 162.6% in well 36243 in FY17. Neither of these two wells yielded measurable or recoverable DNAPL. There appears to be no correlation of higher PRAS and the presence of DNAPL at the Lime Basins. Of the three wells that have yielded recoverable DNAPL, only extraction wells 36219 and 36320 have had PRAS values exceeding 75 percent.

PRAS values continue to indicate that suspected DNAPL source zones are present on the west side of the Lime Basins in the vicinity of wells 36231, 36232, 36242, 36243, and 36244. Since FY13, the PRAS in wells 36244 and 36245 has generally been lower than the PRAS for wells 36242 and 36243, which has remained greater than 75 percent. Although the total PRAS for wells on the west side of the slurry wall have exceeded 75 percent, no DNAPL has been detected in these wells. In FY19, DNAPL was detected in well 36248, which is located inside of the east slurry-wall segment, although the calculated total PRAS was only 23 percent. Current data indicate that no additional DNAPL sources zones appear to exist within the Lime Basins slurry wall and that the extent of DNAPL is actually decreasing compared to previous data.

Based on the evaluation of PRAS and the presence of DNAPL in groundwater during this reporting period, PRAS does not appear to be a reliable predictor of the presence or recoverability of DNAPL at the Lime Basins. Continued monitoring of DNAPL in Lime Basins wells provides more reliable information, especially considering that the volume of recoverable DNAPL has been decreasing over time. The elimination of PRAS as an LTMP requirement should be evaluated.

6.3.2.5 North Plants LNAPL Pilot Removal Action

An LNAPL pilot removal system was implemented in 2008 to remove LNAPL due to an historical release of fuel oil in the North Plants and to gather operating data for the potential design of a full-scale LNAPL removal action. The design of the pilot removal action is presented in the North Plants LNAPL Removal System Action Plan (TtEC and URS 2009). A separate evaluation report was issued for the LNAPL Removal Action prior to FY12 (URS 2012b). As discussed in the report, over two years of monitoring was conducted in the North Plants LNAPL recovery and monitoring wells without detection of sufficient quantities of LNAPL in these wells to support the removal of LNAPL. Quarterly monitoring was conducted for the remainder of the previous five-year reporting period and was reduced to annual monitoring in FY15. Data for the North Plants Pilot LNAPL Removal Program have been presented in the Annual Summary Reports since FY12 (URS 2012b).

Figure 6.3-47 shows the well locations and March 2019 water elevations. Except for an LNAPL thickness of 0.24 inches (0.02 feet) measured in well 25125 in October 2013, no measurable LNAPL has been detected in the North Plants wells since FY14. Since LNAPL has not been detected since FY14, the LNAPL extent during previous years is no longer shown. The groundwater flow direction and hydraulic gradient in Figure 6.3-47 are consistent with previous years.

The thickness of LNAPL remaining in the formation (if any) is probably insufficient to overcome the capillary pressure of the wells. A falling water table may cause the apparent thickness of LNAPL in the wells to increase if sufficient potentially mobile LNAPL is still present in the formation; however, that has not been observed during the past five years of decreasing water elevations. Due to the lack of observed LNAPL in North Plants wells, it is recommended that the LNAPL monitoring program be discontinued.

6.3.3 Groundwater Monitoring Programs

On-post and off-post groundwater monitoring programs not directly associated with the containment and treatment systems were evaluated by comparing site-wide monitoring results during the period FY15 through FY19 with previous data collected. During this fifth FYR period, monitoring and data evaluation was conducted in accordance with the criteria and definitions established in the 2010 LTMP (TtEC and URS 2010). Implementation of the revised monitoring programs presented in the 2010 LTMP started in FY10.

A summary data evaluation is presented in this section for each of the monitoring categories. A more detailed evaluation and data presentation is provided in the FY19 Annual Summary Report and FYSR (Navarro 2020b). The monitoring categories are the following:

- **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 level tracking wells will be used to monitor water levels and track flowpaths between individual on-post remedies and the RMA boundary as well as off post. Water level tracking will be performed annually.
- **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. Water quality tracking is conducted either once or twice during each FYR period to track plume migration upgradient from the groundwater containment and intercept systems. These data are collected to evaluate long-term trends in the FYRR.

- **Confined Flow System (CFS) Monitoring**: Monitoring as required by the On-Post ROD to monitor water quality in the confined aquifer in three areas—Basin A, South Plants, and Basin F. CFS monitoring will be performed twice in five years.
- **Off-Post 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 ICs. Exceedance monitoring will be performed twice in five years.
- **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. Water level monitoring will be performed annually. *(Separated from "Water Level Tracking" because it serves a different purpose.)*

The review was conducted in accordance with the following criteria outlined in the 2010 LTMP:

- Water level tracking will be conducted annually, and the corresponding site-wide water elevation map is provided in the ASRs. The data are evaluated in the FYSR and summarized in the FYRR. The main purpose of the long-term monitoring program is to track changes in water levels and flow paths. The evaluation in the FYSR includes comparisons of new water level maps with baseline water level maps for each FYR period.
- Exceedance monitoring has separate reporting requirements in addition to its inclusion in the FYSR. Summaries of trends based on the exceedance mapping and the most recent exceedance maps will be presented in the FYRR.
- Confined flow system monitoring will be reported in the FYSR and summarized in the FYRR, which will include an evaluation of any potential contaminant trends during that FYR period.

Conclusions from the site-wide data for these monitoring categories were used to evaluate project-specific impacts on groundwater. The conclusions of the on-post and off-post groundwater monitoring programs are summarized below.

6.3.3.1 Water Level Tracking

Under the water level tracking program, water level monitoring is used to track the effects of the source area remedies and boundary containment systems in the On-Post and Off-Post OUs. Water level data from water level tracking wells are used to develop groundwater flow paths between individual on-post remedies and the RMA boundary and support the evaluation of flow paths. By evaluating on-post flow paths over the course of the reporting period, the effects of remedies implemented across the facility can be assessed and used to support optimization of the monitoring program in the future.

Water levels are measured annually in wells completed within the UFS across RMA. Water level data are used to develop site-wide groundwater contour maps. Comparison of these maps year to year provides insight into the groundwater flow paths and whether any changes have occurred over time that could affect contaminant plume migration.

There were deviations in the Site-Wide On-Post Water Level Tracking program established by the 2010 LTMP and subsequent Well Network Update revisions during this reporting period as summarized below:

- Well 22075 – Well 22005 was used as an interim performance well for 22075 due to a well obstruction. The well was permanently replaced by well 22083 in September 2017 (OCN-LTMP-2017-001).
- Well 24109 – No water level was measured in FY18 because there was an obstruction present within the well casing. The obstruction was later identified as soft bentonite clay and it was removed. A water level was measured in FY19.
- Wells 37497, 37498, 37499, and 08060 – These new wells replaced wells 37348, 37351, 37429, and 08027 that were damaged or destroyed during construction activities along 104th and 56th Avenues (OCN-LTMP-2017-003).

Each year Army and Shell collect water level data to construct a site-wide water level map of the RMA, which is used to determine groundwater flow paths and identify changes in groundwater flow directions within the UFS that could affect contaminant plume migration. Water level maps and evaluation of potential changes that could affect remedy effectiveness are provided in the ASRs. A summary of the annual evaluations is provided below.

As expected, remediation activities—such as the installation of groundwater extraction and recharge systems, engineered caps and covers, and slurry walls—have had an effect on water levels in localized areas across the RMA. Precipitation events also affect water levels and are an important source of recharge to the shallow UFS at RMA. Precipitation data are collected on-post from two locations in Section 36, one at the Shell Disposal Trenches and one at the Lime Basins.

The average annual water-year precipitation at RMA, measured at on-site rain gauge stations, was 11.95 inches between FY15 and FY19. The historic average annual precipitation at RMA is 15.48 inches. Annual precipitation data from FY15 through FY19 showed a variable trend ranging from a low of approximately 8.35 inches in FY18 to a high of approximately 18.62 inches in FY15.

Precipitation (inches)	
FY15	18.62
FY16	11.40
FY17	10.94
FY18	8.35
FY19	10.39

Precipitation events and remediation activities have caused some changes in groundwater levels at RMA over the past five years, especially the higher-than-average precipitation in 2015. The effect of this precipitation caused water levels to rise in non-cover areas. Precipitation events at RMA generally result in increases in water level elevations while remedies—including groundwater extraction and infiltration-limiting soil covers—have caused water levels to decrease over time. Overall, based on a year-to-year water level comparison for 2015 through 2019, groundwater flow directions and associated migration of contaminant plumes have not changed significantly.

Review of these maps indicates that while water levels remained steady or increased from FY15 to FY16, there has been a steady decline in water levels over the past three years. Although water levels have declined, groundwater flow paths have remained relatively unchanged year to year with the coverage of unsaturated alluvium increasing across the central portion of RMA. As precipitation has declined during the reporting period, water levels show a corresponding decrease across the site. In particular, a significant decrease in water levels is apparent in the central part of RMA which can be attributed by a decrease in annual precipitation enhanced by the limited infiltration associated with the soil cover systems.

The year-to-year comparison indicates that there were elevated groundwater elevations in 2015, with a gradual decrease through the reporting period in areas of the UFS where saturated alluvium is present across the site. Historically, higher water levels at the NWBCS may have mobilized some residual contamination downgradient of the slurry wall that caused concentrations of dieldrin to increase in downgradient performance wells. In the vicinity of the NWBCS, water levels showed minimal change or decreased by 2 to 4 feet due to the regional effect of lower precipitation during the reporting period. Only directly upgradient of the NWBCS Northeast Extension did water levels increase, but these changes did not change the flow paths towards the system in this area. In the earlier part of the reporting period, higher water levels at NBCS required continual observation and operational adjustments of recharge trench flow rates to maintain the reverse hydraulic gradient in the central part of the system. No changes in the associated flow patterns occurred in the areas upgradient of the NWBCS and NBCS that could have affected the effectiveness of the systems during the reporting period.

Water levels in the South Plants area continue to show an overall decline. This observed decline has been present since 2001 and is attributable to decreased fluctuations within the soil cover areas because of the reduced infiltration and recharge. Water levels decreased within the cover areas by more than 2 feet in the central portion of the ICS in the vicinity of the former South Plants, Lime Basins and the Shell Disposal Trenches. The groundwater mound present in the former South Plants area in Section 1 is still present, but not as pronounced as historically documented. Localized flow paths from the remnant mound show the primary groundwater flow to the north from the South Plants area has remained consistent with historical flow paths. The groundwater divide that separates the northern flow from the southern flow—to the south and southwest—has remained in the same position. All flow paths exiting the South Plants area continue to extend to either the NWBCS or through Basin A Neck.

Implementation of the remedy has caused localized changes in water levels and localized flow directions. During the previous five-year reporting period, increased recharge occurred due to the storm event and associated flooding in September 2013. With cover construction completed and vegetation being established during the last five-year reporting period, annual water level maps for this reporting period show a relative decrease in water elevations in the cover areas. All major flow paths originating north of the South Plants area and from Basin A continue to pass through or adjacent to Basin A and exit the area to the northwest through the Basin A Neck. Comparison of the 2015 and 2019 water-level maps shows that flow paths remained consistent with historical conditions for the major flow paths upgradient and downgradient of the remedy areas.

Within the Railyard area, water levels decreased 6 to 8 feet during the reporting period, but corresponding flow paths remain stable with only minor variations shown by the annual potentiometric surfaces mapped for 2015 through 2019. In general, groundwater elevations decreased from 2015 through 2019 in the entire Western Tier area.

6.3.3.2 Water Quality Tracking

The Water Quality Tracking program focuses on tracking long-term trends in indicator analyte concentrations in plume source areas, along the edges of plumes, and across transects of major plumes. As such, the data evaluation includes monitoring data generated during this FYR period as well as previous monitoring data. Water quality data collected for these areas are used to confirm that groundwater conditions remain consistent with the initial assumptions used at the time of remedy selection. Water quality data collected in areas upgradient from the containment systems are used in combination with more extensive water level monitoring data to track the effects of the remedies on groundwater. The evaluation of water level and water quality conditions is intended to answer the following questions related to remedy performance:

- Have conditions changed since remedy selection?
- Is there new information about conditions that could affect remedy performance?
- Is any change needed in the monitoring program used to track these conditions?

The water quality tracking well network established for the 2010 LTMP is intended to monitor changes in water quality and assess the influence of the soil remedies on groundwater contaminant levels and plume migration. A map of the water quality tracking well network is presented in Figure 6.3-48. Specific indicator analytes are identified in the LTMP for each well based on historical data for the area being monitored.

Several changes to the LTMP Water Quality Tracking Network were implemented during the reporting period as summarized below:

- Well 01600 – Well 01600 was added to the water quality tracking network to continue monitoring downgradient of the Groundwater Mass Removal Project (GWMRP) area at the former South Tank Farm (STF). Sampling will be conducted on a twice-in-5-year schedule and will be analyzed for VOCs, with benzene and chloroform as indicator analytes (OCN-LTMP-2018-001).
- Wells 01044, 01047, 01101 and 01528 – Indicator analytes for these South Plants Ditch SPSA-2d water quality tracking wells were revised to include CCL4, chloroform, and DBCP with monitoring to be conducted once every five years (OCN-LTMP-2018-002).

- Wells 25004 and 36112 – These wells were added to the water quality tracking network to monitor the dieldrin pathway emanating from the north of Basin A (OCN-LTMP-2018-002). Sampling will be conducted twice every five years and analytes will include dieldrin, arsenic, DIMP, and dithiane.

The water quality tracking network monitored during this reporting period included 64 wells located within source areas, the paths of historical contaminant plumes, and upgradient of the treatment and intercept systems. As required by the 2010 LTMP, sampling was conducted in FY17 and FY19. Water quality tracking data were used to assess potential changes in water quality related to source areas and associated remedies within the on-post plume areas by using indicator compounds identified in the 2010 LTMP. Data collected prior to and during the remedy were also used in statistical trend analysis as part of the data quality assurance process.

Data for wells within the water quality tracking network were statistically evaluated for trends utilizing the Mann-Kendall trend analysis in ProUCL as part of the data quality assurance review (Navarro 2020b). Because water quality tracking relies on long-term trend analysis, data from the FYR period and previous historical data are used to evaluate trends. For the most part, the concentrations of indicator analytes are remaining stable or decreasing. Table 6.3-16 provides a summary of the wells and analytes where increasing trends were noted based on the evaluation. And additional discussion is provided below.

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Table 6.3-16. Water Quality Tracking Wells and Analytes Demonstrating Increasing Statistical Trends

Well	Indicator Analyte	Location and Monitoring Justification	Number Samples/ Number Detections	Historical Range of Detections (µg/L)	Comments
Northwest Boundary Containment System					
27037	Chloroform	Upgradient of Original System, downgradient from South Plants source	6/6	1.8-20.6	Long-term concentrations appear to be increasing based on visual observation. Increased from 4.6 in FY17 to 9.53 µg/L in FY19.
27037	Dieldrin	Upgradient of Original System, downgradient from South Plants source	6/6	0.201-2.05	Long-term concentrations appear to be increasing based on visual observation. Increased from 1.04 µg/L in FY17 to 2.05 µg/L in FY19.
27079	Chloroform	Upgradient of Original System, downgradient from Basin F source	4/6	0.432-0.774	Long-term concentrations appear to be increasing based on visual observation. Increased from 0.59 µg/L in FY17 to 0.774 µg/L in FY19.
27091	Dieldrin	Upgradient of Original System, downgradient from South Plants source	18/27	0.0103-0.419	Visually observed long-term concentrations showing a decreasing trend since 2016. Decreased from 0.173 µg/L in FY17 to 0.124 µg/L in FY19.
34015	Dieldrin	Upgradient of SWE, downgradient from South Plants source	4/4	0.0273-0.098	Long-term concentrations appear to be increasing based on visual observation. Increased from 0.0305 µg/L in FY17 to 0.0415 µg/L in FY19.
34508	Chloroform	Upgradient of Original System, downgradient from Sand Creek Lateral source	4/4	11.5-18.1	Long-term concentrations appear to be increasing based on visual observation. Increased from 13.7 µg/L in FY17 to 16.9 µg/L in FY19.
North Boundary Containment System					
23096	Fluoride	Upgradient of NBCS, downgradient from Basins C and F sources	6/6	1,800-3,690	Lowest concentration detected in FY19 at a level less than the CSRG. Visually observed long-term concentrations show a stable trend.
23142	Fluoride	Upgradient of NBCS, downgradient from Basins C and F sources	6/6	2,110-8,000	Visually observed long-term concentrations showing a stable or potentially decreasing trend. Decreased from 161,000 µg/L in FY17 to 153,000 µg/L in FY19.
24081	Chloride	Upgradient of NBCS, downgradient from North Plants source	4/4	116,000-200,000	Visually observed long-term concentrations show a stable or potentially decreasing trend. Decreased from 161,000 µg/L in FY17 to 153,000 µg/L in FY19.

Table 6.3-16. Water Quality Tracking Wells and Analytes Demonstrating Increasing Statistical Trends

Well	Indicator Analyte	Location and Monitoring Justification	Number Samples/ Number Detections	Historical Range of Detections (µg/L)	Comments
24094	Chloride	Upgradient of NBCS	5/5	93,000-179,000	Long-term concentrations appear to be stable to potentially increasing based on visual observation.
Basin A Neck System, Basin A, and Related Section 36 Source Areas					
35065	Arsenic	Upgradient of BANS, downgradient of Basin A source	4/4	7.83-96.4	Long-term concentrations appear to be increasing based on visual observation. Increased from 79.5 µg/L in FY17 to 96.4 µg/L in FY19.
35065	Trichloroethylene	Upgradient of BANS, downgradient of Basin A source	6/7	0.591-12.3	Long-term concentrations appear to be increasing based on visual observation. Increased from 1.02 µg/L in FY17 to 1.26 µg/L in FY19.

Northwest Boundary Containment System

The area upgradient of the NWBCS includes the Basin A Neck Plume, Sand Creek Lateral Plumes, and the South Plants area plume. These plumes are in the Northwest Boundary Plume Group as shown in the On-Post ROD. Nineteen wells were monitored upgradient of the NWBCS where most indicator analytes show decreasing or stable trends since 2009. Chloroform and dieldrin concentrations trends presented in Figures 6.3-49 and 6.3-50, respectively, demonstrated possibly increasing trends as described below.

- Chloroform in well 27079, downgradient of the Basin F source area, indicates a long-term statistical trend that may be increasing since 2009 based on visual observation (Figure 6.3-49).
- Chloroform in well 34508, downgradient of the Sand Creek Lateral source area, indicates a long-term statistical trend that may be increasing since 2012 based on visual observation (Figure 6.3-49).
- Chloroform in well 27037, downgradient of the South Plants area, indicates a long-term statistical trend that may be increasing since 2009 based on visual observation (Figure 6.3-49).
- Dieldrin in well 27037, downgradient of the South Plants area, appears to indicate an increasing trend since 2009 (Figure 6-3-50).
- Well 27091 indicated an increasing trend for dieldrin from 2014 to 2017, however, the trend appears decreasing from 2017 to 2019.
- For the South Plants source area, wells 27037, 27091, and 34015 demonstrated increasing statistical trends for chloroform and/or dieldrin. Visual observation of these trends indicated that while increasing trends are notable for chloroform and dieldrin in well 27037 and dieldrin in 34015, a visual decreasing trend for dieldrin in well 27091 is apparent since 2016.

North Boundary Containment System

While long-term trends visually appear to be stable or potentially decreasing for contaminants upgradient of the NBCS, fluoride in wells 23096 and 23142, and chloride in well 24081 appear to be stable, while chloride concentrations appear to be increasing since 2013 in well 24094 (Figures 6.3-51 and 63-52). Statistically, fluoride and chloride were the only analytes that demonstrated increasing trends in wells 23096, 23142, 24081, and 24094 upgradient of the NBCS.

Basin A Neck System, Basin A, and Related Section 36 Source Areas

Arsenic and trichloroethylene in well 35065, located downgradient of the former Basin A and upgradient of BANS, show long-term concentration that are increasing with levels increasing from FY12 to FY19 based on visual observation (Figures 6.3-53 and 6.3-54). The former Basin A is the source of this contamination, which is being intercepted by the BANS downgradient of wells 35065.

Figure 6.3-49 Chloroform Concentrations in NWBCS Water Quality Tracking Wells 27037, 27079, and 34508

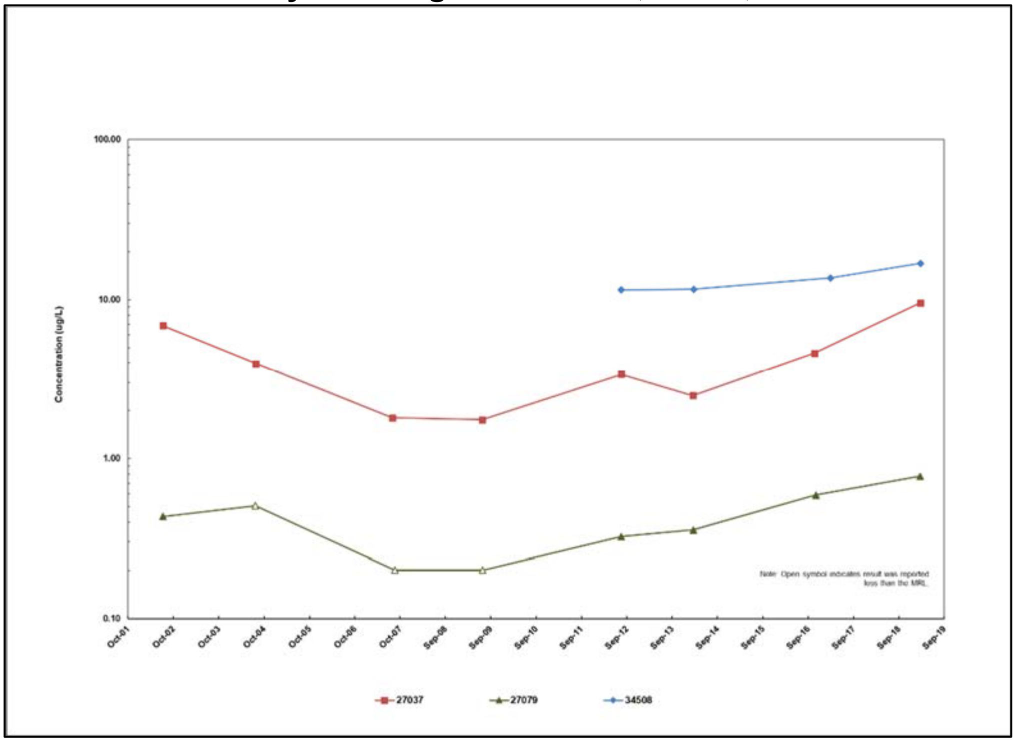


Figure 6.3-50 Dieldrin Concentrations in NWBCS Water Quality Tracking Wells 27037, 27091, and 34015

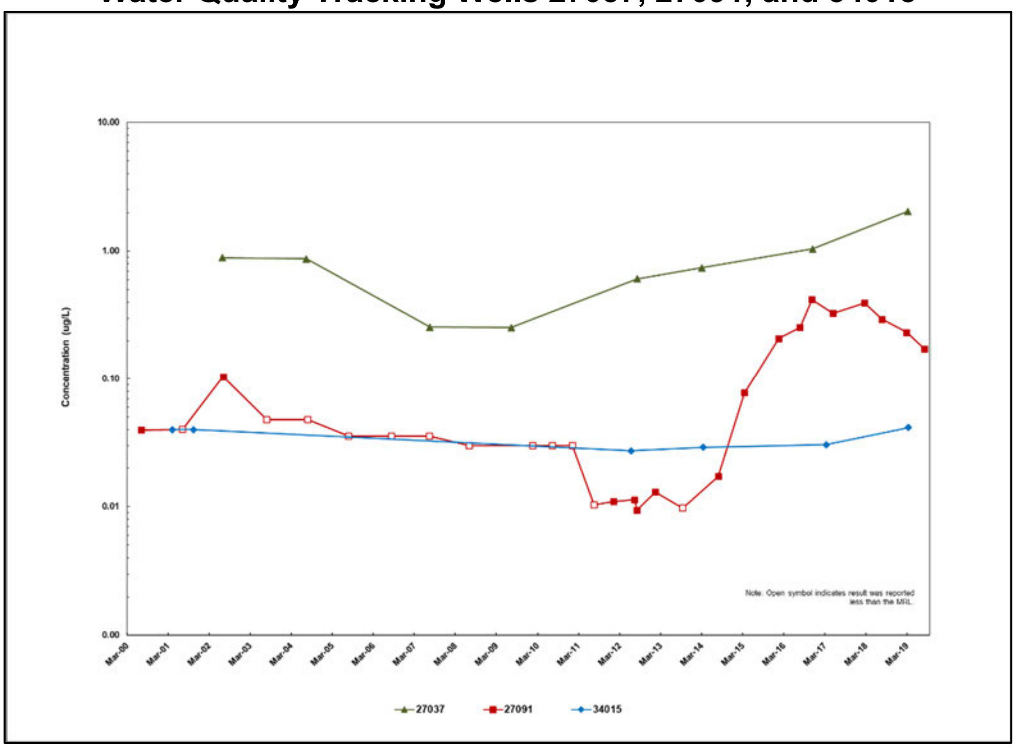


Figure 6.3-51 Fluoride Concentrations in NBCS Water Quality Tracking Wells 23096 and 23142

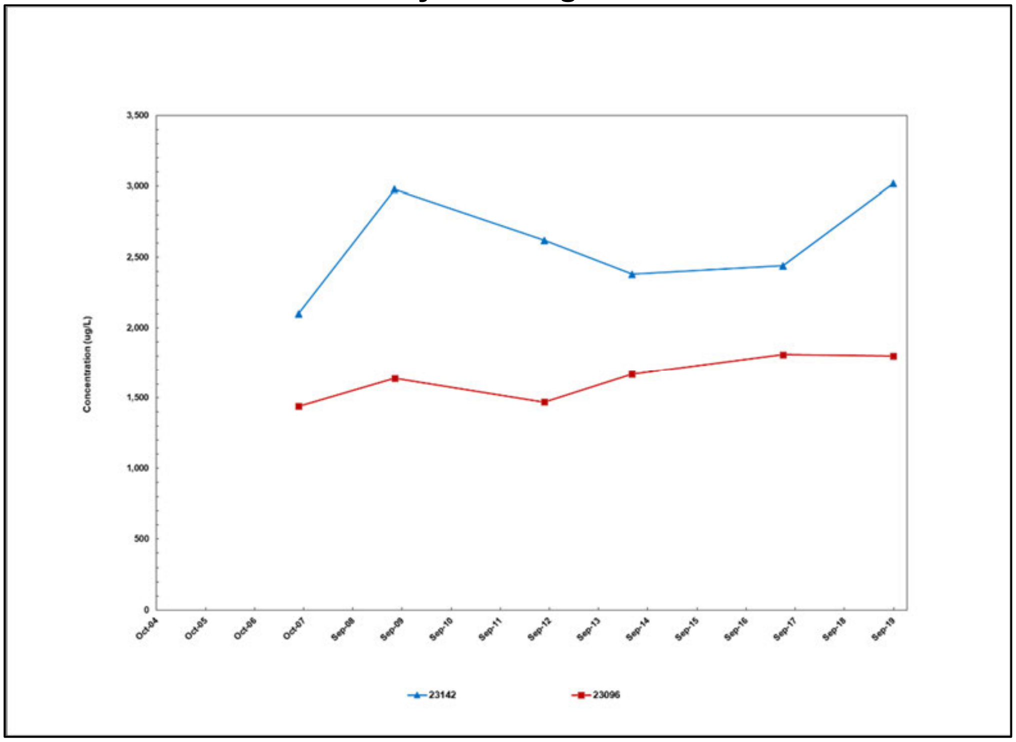


Figure 6.3-52 Chloride Concentrations in NBCS Water Quality Tracking Wells 24081 and 24094

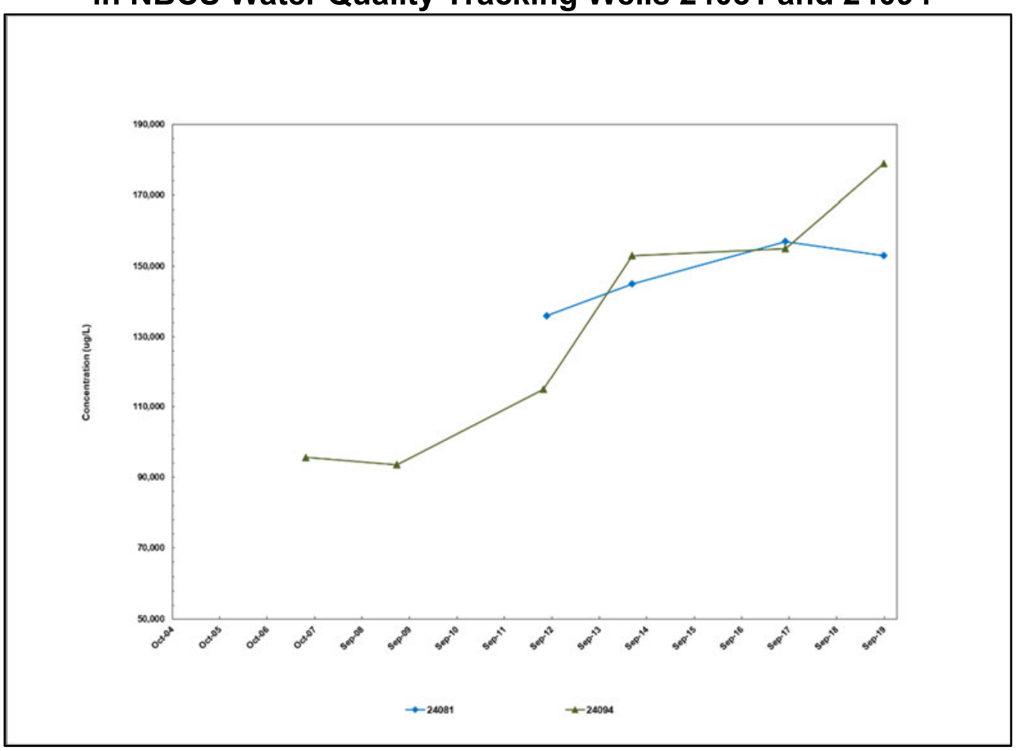


Figure 6.3-53 Arsenic Concentrations In BANS Water Quality Tracking Well 35065

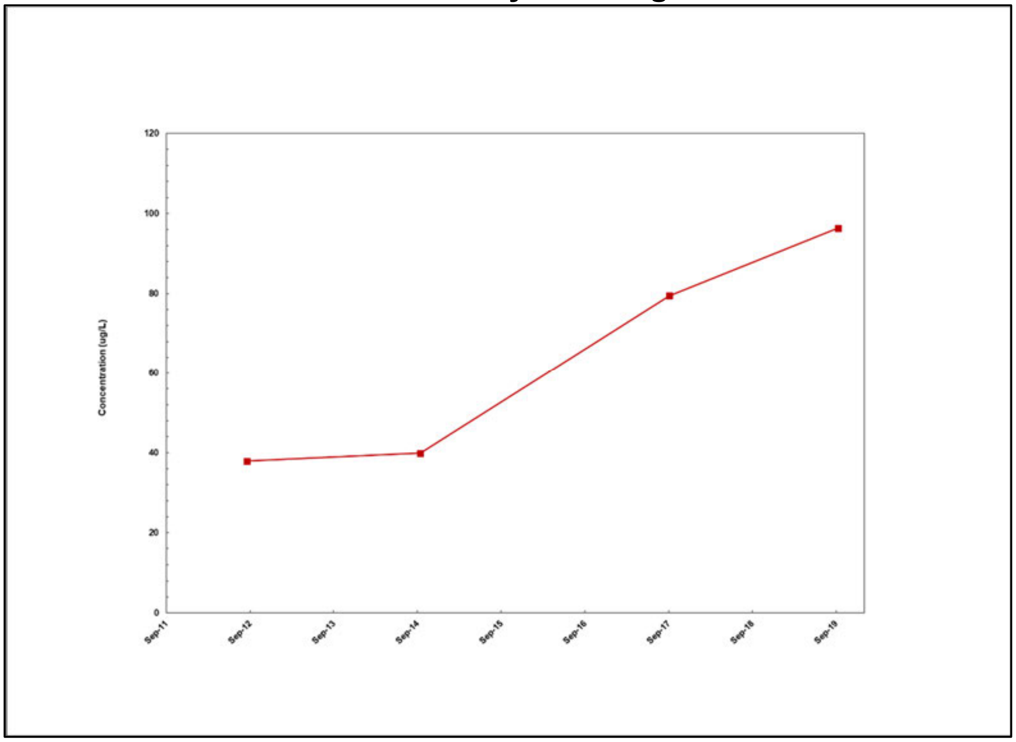
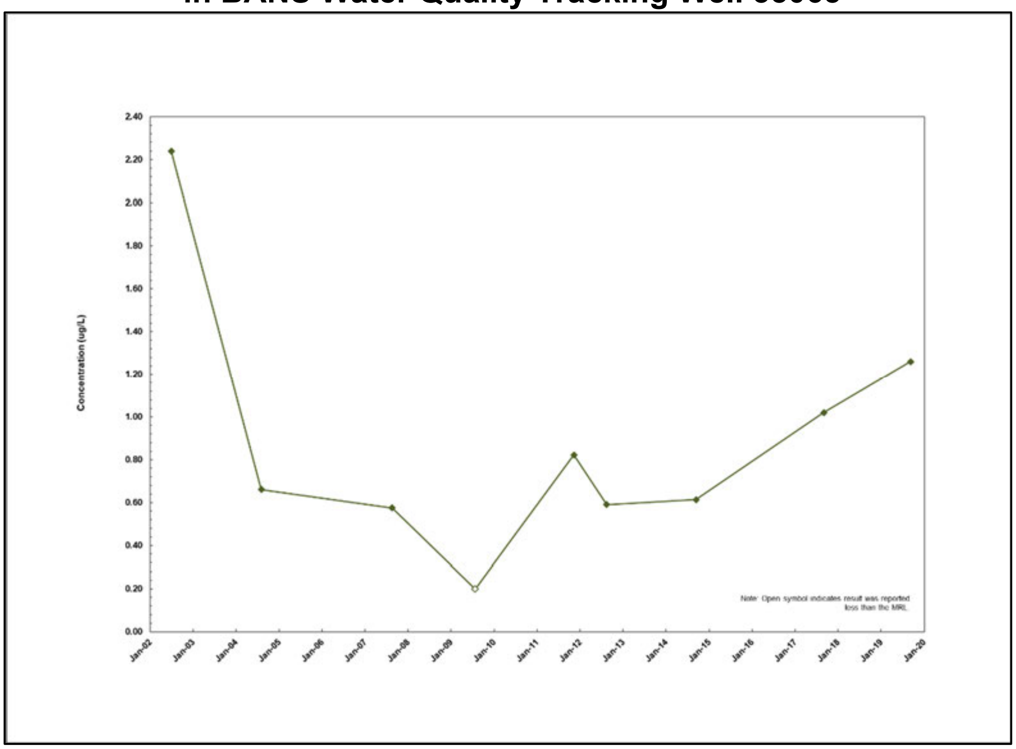


Figure 6.3-54 Trichloroethylene Concentrations in BANS Water Quality Tracking Well 35065



1,4-Dioxane and NDPA in Site-Wide Groundwater

In FY19, 1,4-dioxane and NDPA were included for the first time under the LTMP water quality tracking. Previously, these analytes were investigated under the *Emerging Contaminants Sampling and Analysis Plan* (Navarro 2017h). In accordance with OCN-LTMP-2018-001 and OCN-LTMP-2018-002, NDPA and 1,4-dioxane were added to the analyte lists for wells monitored within the water quality tracking network with the first sampling round conducted in FY19. Table 6.3-17 presents a summary of data for 1,4-dioxane and NDPA collected in FY19 for each of the flow paths monitored under the LTMP. Based on the data, the highest concentrations of 1,4-dioxane and NDPA are present in groundwater within or downgradient of the South Plants and Section 36 including Basin A and the Lime Basins.

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Table 6.3-17. Summary of FY19 Water Quality Tracking Data for Emerging Contaminants

Analyte [1]	Number of Wells	Number of Samples	Number of Detections	Range of Concentrations (µg/L)	Average Concentration (µg/L)	Location of Maximum Concentration
1,4-Dioxane						
South Plants	10	10	9	LT 0.1 – 427	44.4	Well 01078 located within the former South Plants area
Basin A/BANS	7	7	6	LT 0.1 – 29.1	6.43	Well 36210 located north and downgradient of the Lime Basins
NWBCS	15	15	9	LT 0.1 – 1.8	7.14	Well 35065 located upgradient of BANS and downgradient of Basin A source
NBCS	7	7	7	LT 0.1 – 2.88	1.05	Well 23548 located upgradient of the NBCS and downgradient of the Basin F Principal Threat area
NDPA						
Basin A/BANS	5	5	2	LT 0.003 – 16.4	3.33	Well 36210 located north and downgradient of the Lime Basins
NWBCS	8	9	6	LT 0.003 – 3.21	0.62	Well 35065 located upgradient of BANS and downgradient of Basin A source
NBCS	3	3	3	LT 0.003 – 1.98	0.785	Well 23095 located upgradient of NBCS and downgradient of Basins C and F source areas

Note:
1. NDPA and 1,4-Dioxane were added to the LTMP Water Quality Tracking network for select wells in FY19 under OCN-LTMP-2019-001 and OCN-LTMP-2019-002, respectively.

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6.3.3.3 Confined Flow System Monitoring

The On-Post ROD provides the following specific component of the selected groundwater remedy for the confined flow system:

> *Confined aquifer wells are monitored in the South Plants, Basin A, and Basin F areas. Specific monitoring wells will be selected during remedial design.*

CFS monitoring is required by the On-Post ROD to identify vertical or lateral migration of contaminants to or within the CFS in the Basin A, Basin F, and South Plants areas. The CFS well network is specified in the 2010 LTMP (TtEC and URS 2010); and the well locations are shown on Figure 6.3-55.

Evaluations conducted for data collected during this five-year reporting period included comparisons of CFS and UFS water level data and water quality data to assess the potential for downward contaminant migration. Comparisons of water level data are used to determine whether downward gradients, which indicate the potential for downward contaminant migration, are present.

There were deviations in the Site-Wide CFS Water Level and Water Quality Tracking programs established by the 2010 LTMP and subsequent Well Network Update revisions during this reporting period as summarized below:

- Wells 02047 and 02048 – Wells were added to the CFS monitoring network to be sampled twice in five years (OCN-LTMP-2016-002) with sampling scheduled for FY17 and FY19. Sampling wells 02047 and 02028 may help characterize the source of chloride in the Denver Formation A Sand or 1U Sand near well 35083.
- Well 02048 – Well 02048 could not be sampled due to an obstruction preventing the pump from being lowered deeper than approximately 10 feet below the top of casing (TOC). Because well 02048 could not be sampled, review of data for shallower CFS well 02047 was proposed to determine the necessity of a deeper well to evaluate the water-bearing zone in the Denver Formation 1U sand approximately 130-140 feet below TOC. Well 02047 was sampled to support the characterization.
- Well 23193 – Well 23193 was added to the CFS monitoring network to be sampled twice in five years (OCN-LTMP-2016-002). Well 23193 was in the 1999 LTMP. It was thought to have been damaged in 2002, but camera inspections have found no evidence of damage and a sample was obtained in 2016.

During the previous five-year reporting period, well 23193 was inspected with a downhole camera because it was earlier obstructed and could not be monitored. Since then, the obstruction was cleared, and it was determined that monitoring was possible, resulting in the collection of annual water level measurements from FY15 through FY19. Water quality samples were collected in FY17 and FY19.

Water Level Monitoring Results

Water level data and hydraulic gradients for CFS and corresponding UFS wells are presented in Table 6.3-18. Comparisons of water levels in paired UFS and CFS wells generally indicate downward hydraulic gradients throughout the CFS monitoring network.

<u>South Plants</u>

An upward hydraulic gradient has been historically present in well pair 02057/02058 because UFS water levels in South Plants have been lower than those in the CFS. In FY15 and FY16, a downward gradient was present due to increased precipitation in 2015 and 2016. This well pair is located in the former South Plants area, where the installation of low permeability engineered soil covers has decreased infiltration of precipitation and recharge to the water table. Historically, prior to cover construction, downward hydraulic gradients were typical for this well pair. An upward gradient was present in this well pair from FY17 through FY19 due to decreasing water levels in the UFS. Deceasing water levels are expected because infiltration and migration should be significantly reduced due to a limited infiltration through the cover system.

Although no other well pairs had upward gradients during this five-year reporting period, the downward gradient head differentials have decreased in several well pairs in response to the reduced infiltration of precipitation and reduced recharge of the shallow groundwater in cover areas. A reduced head differential reduces the driving force for downward migration of dissolved contaminants. Based on historical data, the vertical gradient head differentials were very consistent until about 2001, and then decreased in some of the well pairs. Table 6.3-19 provides the average head differentials prior to FY02, and the average head differentials for this five-year reporting period.

Decreased head differentials occurred in all the South Plants well pairs, with the largest decreases in UFS wells nearest the crest of the South Plants historical groundwater mound. Water levels have fallen approximately 14–15 feet in the area of the former groundwater mound. The decreases were 5–10 feet in wells on the flanks of the mound. The highest UFS contaminant concentrations in the vicinity of CFS wells occur in South Plants where the downward gradient decreased the most in well pairs 01102/01534, 01300/01078, and 36183/361981. Based on water level trends since the completion of the remedy in 2012, the South Plants soil covers continue to reduce the potential for downward migration in these historically high concentration areas.

<u>Basin A</u>

Most of the downward head differentials increased in the Basin A well pairs (Table 6.3-19). Higher water elevations have been present in UFS wells in and downgradient of Basin A after soil consolidation, re-grading, and cover construction were conducted in former Basin A. Water levels began rising in Basin A wells in 1998, when Basin A soil consolidation began, and likely was caused by a combination of: 1) increased infiltration/recharge during soil consolidation and cover construction activities; 2) irrigation of the cover to establish vegetation; and 3) loading/compaction of the underlying aquifer by the large volumes of contaminated soil, building debris, and fill placed in Basin A to facilitate re-grading and construction of the subgrade and Integrated Cover System.

Water levels in most wells within and downgradient of former Basin A have been at historical highs within the past 10 years, which is attributable to higher than normal precipitation in late 2013, 2015, and 2016. As this excess water dissipates, and the groundwater flows out of Basin A through the Basin A Neck channel, the UFS water levels should fall and the downward vertical gradient head differentials in the CFS wells would then decrease.

One exception to the increased downward vertical gradients in the Basin A wells is well pair 36159/36158. The average head differential decreased 1 foot, likely because it is unaffected by the higher water levels in Basin A. The well pair is located northeast of the CADT slurry wall and northeast of a groundwater divide. Complex Army Disposal Trenches dewatering is occurring on the southwest side of the divide and has no influence on water levels in the vicinity of wells 36158 and 36159.

Basin F

The Basin F well-pair head differentials increased with the greatest variability downgradient of former Basin A where higher UFS water levels are higher. Additionally, some well pairs are not in soil cover areas, where more infiltration of precipitation can occur resulting in groundwater recharge compared to areas beneath the soil covers.

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Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
South Plants					
01067	CFS (D)	7/27/2015	5,242.07	4.0	Downward
01068	UFS (D)	7/27/2015	5,246.05		
01067	CFS (D)	6/2/2016	5,242.17	4.6	Downward
01068	UFS (D)	6/2/2016	5,246.76		
01067	CFS (D)	5/31/2017	5,240.81	5.9	Downward
01068	UFS (D)	5/31/2017	5,246.72		
01067	CFS (D)	6/11/2018	5,239.24	6.0	Downward
01068	UFS (D)	6/11/2018	5,245.26		
01067	CFS (D)	3/5/2019	5,237.82	6.5	Downward
01068	UFS (D)	3/5/2019	5,244.32		
01102	CFS (D)	7/27/2015	5,242.46	7.6	Downward
01534	UFS (D)	7/27/2015	5,250.04		
01102	CFS (D)	6/2/2016	5,242.59	8.5	Downward
01534	UFS (D)	6/2/2016	5,251.07		
01102	CFS (D)	5/31/2017	5,241.37	8.5	Downward
01534	UFS (D)	5/31/2017	5,249.83		
01102	CFS (D)	6/11/2018	5,239.61	8.0	Downward
01534	UFS (D)	6/11/2018	5,247.60		
01102	CFS (D)	3/5/2019	5,238.18	8.1	Downward
01534	UFS (D)	3/5/2019	5,246.28		
01109	CFS (D)	7/27/2015	5,206.17	41.9	Downward
01101	UFS (D)	7/27/2015	5,248.03		
01109	CFS (D)	6/2/2016	5,206.30	42.4	Downward
01101	UFS (D)	6/2/2016	5,248.67		
01109	CFS (D)	5/31/2017	5,206.02	42.2	Downward
01101	UFS (D)	5/31/2017	5,248.20		

Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
01109	CFS (D)	6/11/2018	5,205.24	40.7	Downward
01101	UFS (D)	6/11/2018	5,245.97		
01109	CFS (D)	3/5/2019	5,204.89	39.6	Downward
01101	UFS (D)	3/5/2019	5,244.54		
01300	CFS (D)	7/27/2015	5,251.23	3.1	Downward
01078	UFS (D)	7/27/2015	5,254.36		
01300	CFS (D)	6/2/2016	5,241.69	5.1	Downward
01078	UFS (D)	6/2/2016	5,246.77		
01300	CFS (D)	5/31/2017	5,241.91	5.3	Downward
01078	UFS (D)	6/1/2017	5,247.16		
01300	CFS (D)	6/11/2018	5,240.91	5.2	Downward
01078	UFS (D)	6/11/2018	5,246.06		
01300	CFS (D)	3/5/2019	5,239.88	5.2	Downward
01078	UFS (D)	3/5/2019	5,245.04		
02057	CFS (D)	7/27/2015	5,242.06	0.9	Downward
02058	UFS (A/D)	7/27/2015	5,242.85		
02057	CFS (D)	5/19/2016	5,242.18	1.6	Downward
02058	UFS (A/D)	5/19/2016	5,243.65		
02057	CFS (D)	6/1/2017	5,240.91	-0.8	Upward
02058	UFS (A/D)	6/1/2017	5,239.94		
02057	CFS (D)	6/11/2018	5,239.16	-3.3	Upward
02058	UFS (A/D)	6/11/2018	5,235.73		
02057	CFS (D)	2/27/2019	5,237.96	-4.0	Upward
02058	UFS (A/D)	2/27/2019	5,233.84		
35083	CFS (D)	7/23/2015	5,199.98	51.6	Downward
35013	UFS (D)	7/23/2015	5,251.62		
35083	CFS (D)	6/1/2016	5,200.31	51.9	Downward

Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
35013	UFS (D)	6/1/2016	5,252.21		
35083	CFS (D)	5/22/2017	5,199.82	47.5	Downward
35013	UFS (D)	5/22/2017	5,247.30		
35083	CFS (D)	5/31/2018	5,199.04	45.6	Downward
35013	UFS (D)	5/31/2018	5,244.63		
35083	CFS (D)	2/14/2019	5,198.72	44.9	Downward
35013	UFS (D)	2/14/2019	5,243.62		
36183	CFS (D)	8/3/2015	5,234.39	10.0	Downward
36181	UFS (A/D)	8/3/2015	5,244.41		
36183	CFS (D)	6/6/2016	5,234.82	10.3	Downward
36181	UFS (A/D)	6/6/2016	5,245.07		
36183	CFS (D)	5/31/2017	5,234.61	10.6	Downward
36181	UFS (A/D)	5/31/2017	5,245.21		
36183	CFS (D)	6/4/2018	5,233.70	10.7	Downward
36181	UFS (A/D)	6/4/2018	5,244.39		
36183	CFS (D)	4/18/2019	5,233.19	10.5	Downward
36181	UFS (A/D)	4/18/2019	5,243.66		
Basin F					
23187	CFS (D)	7/15/2015	5,116.18	24.0	Downward
23185	UFS (D)	7/15/2015	5,140.22		
23187	CFS (D)	5/25/2016	5,116.57	23.1	Downward
23185	UFS (D)	5/25/2016	5,139.71		
23187	CFS (D)	4/26/2017	5,116.38	23.0	Downward
23185	UFS (D)	4/26/2017	5,139.35		
23187	CFS (D)	5/29/2018	5,116.49	22.3	Downward
23185	UFS (D)	5/29/2018	5,138.80		
23187	CFS (D)	2/13/2019	5,116.73	22.0	Downward

Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
23185	UFS (D)	2/13/2019	5,138.76		
23193	CFS (D)	7/15/2015	5,127.95	10.6	Downward
23191	UFS (A/D)	7/15/2015	5,138.50		
23193	CFS (D)	5/25/2016	5,128.25	10.6	Downward
23191	UFS (A/D)	5/25/2016	5,138.90		
23193	CFS (D)	4/26/2017	5,127.37	12.2	Downward
23191	UFS (A/D)	4/26/2017	5,139.56		
23193	CFS (D)	5/29/2018	5,128.34	11.1	Downward
23191	UFS (A/D)	5/29/2018	5,139.47		
23193	CFS (D)	2/13/2019	5,126.33	13.0	Downward
23191	UFS (A/D)	2/13/2019	5,139.29		
26147	CFS (D)	7/28/2015	5,143.10	1.4	Downward
26146	UFS (D)	7/28/2015	5,144.52		
26147	CFS (D)	5/19/2016	5,143.85	2.4	Downward
26146	UFS (D)	5/19/2016	5,146.21		
26147	CFS (D)	5/8/2017	5,145.23	2.0	Downward
26146	UFS (D)	5/8/2017	5,147.22		
26147 [2]	CFS (D)	4/11/2018	5,145.87	1.4	Downward
26146	UFS (D)	5/31/2018	5,147.26		
26147	CFS (D)	4/17/2019	5,145.27	2.0	Downward
26146	UFS (D)	4/17/2019	5,147.29		
26150	CFS (D)	7/28/2015	5,173.80	6.9	Downward
26158	UFS (D)	7/28/2015	5,180.66		
26150	CFS (D)	7/21/2016	5,174.37	7.5	Downward
26158	UFS (D)	7/21/2016	5,181.88		
26150	CFS (D)	7/12/2017	5,174.17	7.5	Downward
26158	UFS (D)	7/12/2017	5,181.69		

Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
26150	CFS (D)	7/23/2018	5,173.52	7.6	Downward
26158	UFS (D)	7/23/2018	5,181.08		
26150	CFS (D)	8/1/2019	5,172.83	7.8	Downward
26158	UFS (D)	8/1/2019	5,180.59		
26152	CFS (D)	7/27/2015	5,154.36	20.0	Downward
26154	UFS (A)	7/27/2015	5,174.38		
26152	CFS (D)	5/19/2016	5,154.85	19.6	Downward
26154	UFS (A)	5/19/2016	5,174.44		
26152	CFS (D)	5/8/2017	5,154.45	19.1	Downward
26154	UFS (A)	5/8/2017	5,173.50		
26152	CFS (D)	5/31/2018	5,153.03	18.9	Downward
26154	UFS (A)	5/31/2018	5,171.91		
26152	CFS (D)	2/14/2019	5,153.19	18.2	Downward
26154	UFS (A)	2/14/2019	5,171.37		
26153	CFS (D)	4/17/2019	5,139.67	5.1	Downward
26015	UFS (A/D)	4/17/2019	5,144.82		
26153	CFS (D)	5/31/2018	5,139.45	5.4	Downward
26015	UFS (A/D)	4/11/2018	5,144.90		
26153	CFS (D)	5/8/2017	5,139.52	5.6	Downward
26015	UFS (A/D)	4/5/2017	5,145.11		
26153	CFS (D)	5/19/2016	5,139.77	5.2	Downward
26015	UFS (A/D)	4/13/2016	5,144.93		
26153	CFS (D)	7/28/2015	5,139.48	5.4	Downward
26015	UFS (A/D)	7/28/2015	5,144.87		
Basin A					
35063	CFS (D)	7/27/2015	5,198.57	27.5	Downward
35061	UFS (A/D)	7/27/2015	5,226.09		

Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
35063	CFS (D)	6/1/2016	5,198.82	27.8	Downward
35061	UFS (A/D)	6/1/2016	5,226.61		
35063	CFS (D)	5/22/2017	5,197.81	26.6	Downward
35061	UFS (A/D)	5/22/2017	5,224.42		
35063	CFS (D)	5/31/2018	5,196.58	25.6	Downward
35061	UFS (A/D)	5/31/2018	5,222.14		
35063	CFS (D)	2/14/2019	5,196.09	24.7	Downward
35061	UFS (A/D)	2/14/2019	5,220.82		
35067	CFS (D)	7/27/2015	5,205.76	18.6	Downward
35065	UFS (A/D)	7/27/2015	5,224.34		
35067	CFS (D)	6/1/2016	5,205.87	18.9	Downward
35065	UFS (A/D)	6/1/2016	5,224.79		
35067	CFS (D)	5/22/2017	5,206.12	16.6	Downward
35065	UFS (A/D)	5/22/2017	5,222.69		
35067	CFS (D)	5/31/2018	5,204.69	16.6	Downward
35065	UFS (A/D)	5/31/2018	5,221.29		
35067	CFS (D)	2/14/2019	5,204.75	15.7	Downward
35065	UFS (A/D)	2/14/2019	5,220.48		
35068	CFS (D)	7/27/2015	5,193.61	30.7	Downward
35065	UFS (A/D)	7/27/2015	5,224.34		
35068	CFS (D)	6/1/2016	5,193.88	30.9	Downward
35065	UFS (A/D)	6/1/2016	5,224.79		
35068	CFS (D)	5/22/2017	5,193.73	29.0	Downward
35065	UFS (A/D)	5/22/2017	5,222.69		
35068	CFS (D)	5/31/2018	5,193.19	28.1	Downward
35065	UFS (A/D)	5/31/2018	5,221.29		
35068	CFS (D)	2/14/2019	5,193.09	27.4	Downward

Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
35065	UFS (A/D)	2/14/2019	5,220.48		
36113	CFS (D)	7/23/2015	5,218.96	6.7	Downward
36112	UFS (D)	7/23/2015	5,225.66		
36113	CFS (D)	6/1/2016	5,219.42	6.3	Downward
36112	UFS (D)	6/1/2016	5,225.68		
36113	CFS (D)	5/31/2017	5,219.47	4.7	Downward
36112	UFS (D)	5/31/2017	5,224.14		
36113	CFS (D)	5/30/2018	5,218.73	3.7	Downward
36112	UFS (D)	5/30/2018	5,222.44		
36113	CFS (D)	2/20/2019	5,218.18	3.6	Downward
36112	UFS (D)	2/20/2019	5,221.76		
36114	CFS (D)	7/23/2015	5,193.37	32.3	Downward
36112	UFS (D)	7/23/2015	5,225.66		
36114	CFS (D)	6/1/2016	5,193.64	32.0	Downward
36112	UFS (D)	6/1/2016	5,225.68		
36114	CFS (D)	5/31/2017	5,193.56	30.6	Downward
36112	UFS (D)	5/31/2017	5,224.14		
36114	CFS (D)	5/30/2018	5,193.01	29.4	Downward
36112	UFS (D)	5/30/2018	5,222.44		
36114	CFS (D)	2/20/2019	5,192.99	28.8	Downward
36112	UFS (D)	2/20/2019	5,221.76		
36159	CFS (D)	7/23/2015	5,200.05	20.2	Downward
36158	UFS (D)	7/23/2015	5,220.24		
36159	CFS (D)	6/2/2016	5,200.16	20.6	Downward
36158	UFS (D)	6/2/2016	5,220.78		
36159	CFS (D)	5/31/2017	5,199.89	21.5	Downward
36158	UFS (D)	5/31/2017	5,221.39		

Table 6.3-18. Water Level Data and Hydraulic Gradients for Confined Flow System and Unconfined Flow System Well Pairs

Well	Flow System [1]	Date	Water Elevation (feet amsl)	Head Differential (feet)	Vertical Hydraulic Gradient (feet)
36159	CFS (D)	5/30/2018	5,198.42	22.7	Downward
36158	UFS (D)	5/30/2018	5,221.11		
36159	CFS (D)	2/20/2019	5,199.49	21.5	Downward
36158	UFS (D)	2/20/2019	5,221.02		
36171	CFS (D)	7/27/2015	5,198.26	37.8	Downward
36169	UFS (A)	7/27/2015	5,236.09		
36171	CFS (D)	6/2/2016	5,198.54	37.6	Downward
36169	UFS (A)	6/2/2016	5,236.19		
36171	CFS (D)	5/31/2017	5,198.28	36.1	Downward
36169	UFS (A)	5/31/2017	5,234.41		
36171	CFS (D)	5/30/2018	5,197.84	35.3	Downward
36169	UFS (A)	5/30/2018	5,233.15		
36171	CFS (D)	2/20/2019	5,197.82	34.6	Downward
36169	UFS (A)	2/20/2019	5,232.42		

Notes:

1. Flow System designations:
   A – Alluvial
   D – Denver Formation
   CFS – Confined flow system
   UFS – Unconfined flow system
2. Water level revised from the value listed in RMAED based on likely field transcription error for the depth of water in UFS well 26146 in April 2018.

Table 6.3-19. CFS and UFS Vertical Gradient Head Differentials

Well Pair		Prior to FY02		FY15–FY19	
CFS Well	UFS Well	Average Head Differential (feet)	Vertical Gradient Direction	Average Head Differential (feet)	Vertical Gradient Direction
South Plants					
01067	01068	14.4	Downward	5.4	Downward
01102	01534	12.3	Downward	8.1	Downward
01109	01101	42.2	Downward	41.4	Downward
01300	01078	13.1	Downward	4.8	Downward
02057	02058	3.8	Downward	-1.0	Upward
35083	35013	51.4	Downward	48.3	Downward
36183	36181	17.4	Downward	10.4	Downward
Basin F					
23187	23185	21.3	Downward	22.9	Downward
23193	23191	10.7	Downward	11.5	Downward
26147	26146	2.2	Downward	1.8	Downward
26150	26158	9.3	Downward	7.4	Downward
26152	26154	16.7	Downward	19.1	Downward
26153	26015	5.0	Downward	5.3	Downward
Basin A					
35063	35061	24.3	Downward	26.4	Downward
35067	35065	15.9	Downward	17.3	Downward
35068	35065	25.6	Downward	29.2	Downward
36113	36112	4.3	Downward	5.0	Downward
36114	36112	27.3	Downward	30.6	Downward
36159	36158	22.3	Downward	21.3	Downward
36171	36169	32.9	Downward	36.3	Downward

Water-Quality Monitoring Results

Chemical data are used to determine whether contaminant concentrations in the CFS are changing or are indicating significant migration over time. Only chloride, chlorobenzene, and dieldrin were detected in CFS wells during the five-year reporting period. Water quality trends for each well are summarized in Table 6.3-20.

Chloride

Chloride is naturally occurring and generally occurs at higher concentrations in the UFS compared to the underlying CFS. The chloride concentrations in the CFS wells were compared to corresponding data for adjacent UFS wells to evaluate water quality trends.

South Plants

Concentrations during this reporting period for all wells except 35083 were less than or comparable to the previous five-year period and occurred within the historical range of detections.

Chloride levels in CFS well 35083 have shown a general increasing trend from 1993 to 2012 where the historical high concentration was 1,620,000 µg/L. Since FY12, levels appear to have stabilized. During this reporting period chloride concentrations decreased in FY17 and FY19 to 1,440,000 µg/L and 1,390,000 µg/L respectively. These concentrations are higher than in nearby UFS wells by one to two orders of magnitude.

Paired UFS well 35013 was sampled in FY14 when chloride was measured at 89,500 µg/L. The vertical gradient between the UFS and CFS in this area is downward. UFS well 35013 has been contaminated by a variety of VOCs that have not been detected in CFS well 35083. Because organic analytes detected in UFS well 35013 have not been detected in CFS well 35083, and the UFS chloride concentrations are much lower, the source of higher chloride concentrations in the CFS is not directly apparent.

CFS wells 02047 and 02048 were added to the CFS well network in order to evaluate chloride migration upgradient of well 35083. Well 02047 is screened shallower within the CFS than well 02048, which is screened within the same zone as 35083. Well 02048 could not be sampled during the reporting period due to an obstruction, but a sample was collected from well 02047 showing the chloride level in FY19 was between one and two orders of magnitude less than the concentrations in well 35083.

Well 35083 is screened in the Denver Formation 1U Sand/Lignite A, which underlies the A Sand. Well completion information for well 35083 indicates there is no bentonite well seal installed on top of the filter pack, and that fine sand was used to prevent grout from entering the filter pack and well screen. During the previous reporting period it was noted that it was possible that groundwater with elevated concentrations of chloride may have been migrating laterally from South Plants through Lignite A or the A Sand, and then “leaking” into well 35083. Based on the potentiometric surface map of the A Sand, groundwater flow towards well 35083 may originate to the east in the direction of the Lime Basins. Elevated chloride in the CFS appears to be localized in the southeast portion of Section 35 and based on known groundwater flow directions within the Denver Formation, downgradient migration has not impacted other CFS wells on site.

Further evaluation of chloride in the vicinity of well 35083 related to lateral flow from the southeast and east, as well as vertical flow from the UFS immediately adjacent to well 35083, should be conducted to determine the source of elevated chloride in the CFS. This recommendation is included under Other Findings in Section 9.1.

Basin F

Chloride concentrations showed stable or decreasing trends in CFS wells 23187, 23193, 26147, 26150, 26152, and 26153 within former Basin F. In the Basin F area, CFS well 26147 historically has had a higher chloride concentration than was detected in its companion UFS well 26146.

Basin A

Chloride concentrations showed stable or decreasing trends in CFS wells 35063, 35068, 36113, 36159, 36114 and 36171 in the vicinity of Basin A. In the Basin A area, CFS well 36159 historically has had a higher chloride concentration than was detected in its companion UFS well 36158.

Chloride concentrations in well 35067 demonstrate an increasing trend over the past 30 years. Concentrations appear to have remained stable from FY09 to FY19, with a decrease in FY17 and a subsequent increase in FY19—to a level consistent with the previous five-year reporting period (Table 6.3-20). Adjacent UFS well 35065 has had a similar increasing trend and the concentrations are an order-of-magnitude greater. Similar increasing concentration trends in these wells is corroborated by the downward vertical gradient (Table 6.3-18), thus indicating vertical migration from the UFS to the CFS accounts for cross-contamination at depth. However, the aquitard in the location of well 35067 is questionable, and flow within the CFS may be semi-confined (HLA 1994).

Chlorobenzene

Chlorobenzene concentrations in Basin A well 02057 decreased from 1989 to 2007 but increased slightly from FY09 to FY14. Concentrations in FY17 and FY19 demonstrate a decreasing trend over the past five years. As previously stated, the integrity of the aquitard is questionable in well 02057 and the well was constructed without an outer casing, which would have sealed off the UFS within the alluvium. The top of the well filter pack is within the weathered bedrock, with the well possibly screened in semi-confined conditions. The well construction and screen placement might explain the presence of historical contamination that likely migrated vertically into the well when a downward gradient was present between the UFS and CFS.

Dieldrin

Dieldrin was detected during this reporting period in CFS wells 23187, 23193, 26147, and 26153 downgradient of Basin F.

Previously, dieldrin had only been detected in well 26153, and the concentration increased from near the MRL in FY12 to 0.0569 µg/L in FY17. In FY19, dieldrin decreased by an order of magnitude in well 26153 to a concentration of 0.00621 µg/L. Dieldrin has been detected previously in well 26153 (in 1992 and 1997) and the levels detected in FY17 and FY19 are within the historical range. Historically, dieldrin has been detected in nearby UFS well 26015, located almost 400 feet upgradient of well 26153, and the concentrations have increased since FY14.

Dieldrin was detected for the first time in CFS wells 23187, 23193, and 26147 during this five-year reporting period.

In well 23187, dieldrin was detected for the first time in FY17 and again in FY19. Paired UFS well 23185 has not been sampled since 1994, where dieldrin had not been historically detected. It is possible that the UFS is a source due to a strong downward gradient present within the well pair (Table 6.3-19).

In well 23193, dieldrin was detected during this reporting period for the first time since June 2002. Concentrations in FY17 and FY19 were 0.00845 and 0.0207 µg/L, respectively. Well 23191 is a UFS well co-located with 23193 and is utilized in the sitewide water level monitoring network. An average downward gradient of 11.5 feet exists between wells 23193 and 23191, which could account for vertical migration from the UFS to the CFS. Water quality data do not exist for UFS well 23191, but dieldrin has been present in UFS well 23142 since 1994. Well 23142—located approximately 400 feet from 23193—shows a similar vertical gradient between the two flow systems. While 23191 is not monitored for water quality, historical water quality data show that dieldrin has been present in this UFS well at levels exceeding the PQL.

In well 26147, dieldrin was detected for the first time in FY19 at a concentration of 0.00476 µg/L. Well 26146 is a UFS well co-located with 25147 and is utilized in the sitewide water level monitoring network. An average downward gradient of 1.8 feet exists between wells 26146 and 26147, which could account for vertical migration from the UFS to the CFS. The vertical gradients, while downward, range from 1.4 to 2.4 feet during the reporting period and indicate a possible lack of integrity in CFS well 26147. When well specifications are evaluated for 26147 and 26146, it appears that groundwater from the UFS may be in direct connection with the CFS as presented below:

	26147 (CFS)	26146 (UFS)
Screened Interval (feet amsl)	5092.2–5072.2	5110.5–5125.5
Bottom of Casing (feet amsl)	5069.7	5108.00
FY19 Groundwater Elevation (feet amsl)	5145.27	5147.29
Vertical Gradient	2.02 feet	

Further evaluation of dieldrin in the vicinity of Basin F, as well as vertical flow from the UFS, should be conducted to determine the source of elevated dieldrin in the CFS. This recommendation is included under Other Findings in Section 9.1.

Table 6.3-20. Confined Flow System Water Quality Evaluation

Well	Observations
South Plants	
01067	Chloride – Concentrations during this reporting period were less than the previous five-year period and occurred within the historical range of detections. 1,1-Dichloroethane – Not detected during the reporting period despite being detected in FY14.
01102	Chloride – Concentrations during this reporting period were less than the previous five-year period and occurred within the historical range of detections. No other indicator analytes were detected.
01109	Chloride – Concentrations are stable and within typical historical range. No other indicator analytes were detected.
01300	Chloride – Concentrations during this reporting period were less than the previous five-year period and occurred within the historical range of detections. No other indicator analytes were detected.
02047	Chloride – Well added to the CFS network in 2018 and sampled for the first time in FY19. Chloride concentration was within the range of historical concentrations in CFS groundwater within South Plants at a concentration of 31,000 µg/L. No other indicator analytes were detected.
02057	Chloride – Chloride concentration increased in FY17, with a subsequent decrease in FY19 to a concentration consistent with historical concentrations. Chlorobenzene – Concentrations remain less than 1 µg/L and a decreasing trend is evident since 2014. An upward gradient between this well and unconfined well 02058 existed from FY17 to FY19. No other indicator analytes detected.
35083	Chloride – Concentrations show steady increasing trend with historical high of 1,620,000 µg/L in FY12 but decreased to 1,390,000 µg/L in FY19. No other indicator analytes were detected. As previously noted, this well did not have a bentonite seal installed above the filter pack, which has likely affected its integrity.
36183	Chloride – Stable to decreasing chloride trend from 320,000 µg/L in 2007 to 74,200 µg/L in FY19, and within historical range for this well. No other indicator analytes were detected.
Basin F	
23187	Chloride – Concentrations show stable trend with increases in concentrations in FY17 and FY19. Dieldrin – Detected for the first time in FY17 and again in FY19. Paired UFS well 23185 has not been sampled since 1994, and it is possible that the UFS is a source due to the downward gradient present within the well pair.
23193	Chloride – Well could not be sampled in FY17 due to an obstruction, but sampling was conducted in FY19 as the obstruction cleared. Chloride concentrations have been stable since 1993. Dieldrin – Detected during this reporting period for the first time since June 2002. Concentrations in FY17 and FY19 were 0.00845 and 0.0207 µg/L, respectively.

Table 6.3-20. Confined Flow System Water Quality Evaluation

Well	Observations
26147	Chloride – Concentrations show a stable trend at elevated concentrations when compared to historical data. Dieldrin – Detected for the first time in FY19 at a concentration of 0.00476 µg/L.
26150	Chloride – Concentrations show a stable trend at elevated concentrations when compared to historical data and a decreasing trend since 2012. Dieldrin – Not detected in this well since sampling began in 1988.
26152	Chloride – Concentrations show a stable trend since 1993 with current levels consistent with historical data. Dieldrin – Not detected in this well since sampling began in 1988.
26153	Chloride – Concentration in FY17 decreased to 7650 µg/L compared to FY14 (193,000 µg/L). In FY19, the concentration increased to 211,000 µg/L and is consistent with historical data prior to 2002 for this well. Dieldrin – Detected in FY17 at a concentration of 0.0569 µg/L with a significant—order of magnitude—decrease in FY19 to 0.00621 µg/L.
Basin A	
35063	Chloride – Concentrations show a stable trend since 2002 with levels generally less than historical data prior to remedy implementation.
35067	Chloride – Chloride concentrations continue an upward trend since 1989 with an increase during this reporting period. Chloride concentrations decrease in FY17 with an increase in FY19 to a level comparable to the concentration in FY14. Chloride in the paired UFS well 35065 has ranged from 2,000,000 to more than 4,000,000 µg/L since 2012. There is a significant downward gradient in this location, and as previously reported, the aquitard is questionable and well may be semi-confined.
35068	Chloride – Concentrations have been decreasing since 2009 from 80,800 µg/L to 38,900 µg/L in FY17. The concentration increased in FY19 to 48,600 µg/L, which is comparable to level detected in FY14 (48,900 µg/L).
36113	Chloride – Concentrations show a stable trend since 1987 with current levels consistent with historical data.
36114	Chloride – Concentrations indicate a stable or potentially decreasing trend, with levels in FY17 and FY19 less than the historical high concentration detected in 1986 and 2009 of 198,000 µg/L.
36159	Chloride – Concentrations indicate a stable or potentially decreasing trend, with levels in FY17 and FY19 less than the historical high concentration detected in 2009 of 697,000 µg/L.
36171	Chloride – Concentrations are generally lower than in other CFS wells within the Basin A area and demonstrated a decreasing trend FY09 through FY14. There was an increase in FY17 to 27,600 µg/L, but the concentration decreased in FY19 to 23,900 µg/L.

6.3.3.4 Off-Post Exceedance Monitoring

As stated in the Off-Post ROD, 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 (HLA 1995):

> *[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 Remediation Scope and Schedule (HLA 1996) added that the purpose of the off-post regional monitoring program is to provide data to assess the effectiveness of the remedy, contaminant concentration reduction, and groundwater flow direction and hydraulic gradient. In addition, these monitoring data are used to prepare maps depicting the extent of groundwater maps where contaminant concentrations exceed CSRGs.

Originally, the data were provided through regional monitoring of a network comprising off-post monitoring wells and private wells. Regional monitoring is now conducted under the 2010 LTMP as exceedance monitoring, and monitoring wells are sampled twice every five years. Water levels within the exceedance network are monitored annually. To support regional evaluation of DIMP in groundwater, private wells sampled by TCHD are included in the CSRG exceedance data mapped twice every five years.

Exceedance monitoring is also conducted in support of the institutional control component of the off-post remedy. The purpose of the institutional control is to restrict the use of contaminated groundwater—in particular by restricting the installation of new wells—within identified plume areas. This restriction is implemented in areas with contaminant concentrations that potentially exceed CSRGs. The Army provides results of the CSRG monitoring events to the Office of the State Engineer, city of Commerce City, city of Brighton, and Adams County officials for their use in issuing notifications to well permit applicants and for controlling inappropriate use of off-post water with contaminant concentrations exceeding CSRGs.

The off-post CSRG exceedance data are also used to monitor the extent and concentration trends of plumes upgradient and downgradient of the OGITS. These data are used to evaluate the OGITS monitoring networks and inform decisions regarding treatment system shutdown.

During the five-year reporting period, exceedance monitoring was conducted in FY17 and FY19. Table 6.3-21 provides a summary of the off-post wells included in the exceedance monitoring program and Figure 6.3-56 depicts the exceedance monitoring network. Monitoring wells 37351 and 37429 were replaced by wells 37498 and 37499, respectively. The former wells were destroyed during construction along 104th Avenue in November 2016.

Table 6.3-21. CSRG Exceedance Off-Post Monitoring Wells

Well ID	Location	Analytes [1]
23198	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate, 1,4-dioxane
24162	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate, 1,4-dioxane
24166	North Boundary	DIMP, dieldrin, fluoride, chloride, sulfate, 1,4-dioxane
37008	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37009	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37010	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37011	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37012	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37013	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37027	Northern Pathway	Chloroform, tetrachloroethylene, DIMP, fluoride, chloride, sulfate, NDPA, 1,4-dioxane
37039	Northern Pathway	Carbon tetrachloride, DIMP, 1,4-dioxane
37041	First Creek Pathway	DIMP, chloride
37065	First Creek Pathway	OGITS CSRG analyte list, 1,4-dioxane
37070	First Creek Pathway	DIMP, fluoride
37074	First Creek Pathway	DIMP, fluoride, chloride, sulfate
37076	First Creek Pathway	DIMP, 1,2-dichloroethane, fluoride, chloride, sulfate, NDPA, 1,4-dioxane
37080	Northern Pathway	DIMP, chloride, 1,4-dioxane
37081	First Creek Pathway	Fluoride, chloride, sulfate, dieldrin, DIMP, VOCs, NDPA, 1,4-dioxane
37083	First Creek Pathway	DCPD, DIMP, 1,2-dichloroethane, fluoride, chloride, sulfate, NDPA, 1,4-dioxane
37084	First Creek Pathway	OGITS CSRG analyte list, 1,4-dioxane
37094	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37095	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37097	Off-Post Plume	DIMP, 1,4-dioxane
37108	Off-Post Plume	DIMP
37110	First Creek Pathway	OGITS CSRG analyte list, 1,4-dioxane
37126	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride, 1,4-dioxane
37150	Off-Post Plume	Carbon tetrachloride, DIMP, chloride, 1,4-dioxane
37151	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride, 1,4-dioxane
37320	Off-Post Plume	DIMP, dieldrin, chloride, 1,4-dioxane
37328	Off-Post Plume	DIMP, dieldrin, fluoride, chloride, sulfate, VOCs, NDPA, 1,4-dioxane
37338	North Boundary	DIMP, dieldrin, fluoride, chloride

Table 6.3-21. CSRG Exceedance Off-Post Monitoring Wells

Well ID	Location	Analytes [1]
37339	North Boundary	DIMP, fluoride, chloride, sulfate, 1,4-dioxane
37342	First Creek Pathway	Chloride, sulfate, DIMP, VOCs
37343	First Creek Pathway	OGITS CSRG analyte list, 1,4-dioxane
37347	Off-Post Plume	DIMP
37349	Off-Post Plume	DIMP
37498	Off-Post Plume	DIMP
37353	Off-Post Plume	DIMP
37367	Off-Post Plume	DIMP, chloroform, tetrachloroethylene, fluoride, chloride, NDPA, 1,4-dioxane
37368	Northern Pathway	DIMP, chloroform, tetrachloroethylene, chloride, sulfate, NDPA, 1,4-dioxane
37369	First Creek Pathway	DIMP, dieldrin, fluoride, chloride, VOCs, 1,4-dioxane
37370	First Creek Pathway	OGITS CSRG analyte list, 1,4-dioxane
37374	Off-Post Plume	Fluoride, chloride, sulfate, DIMP, dieldrin
37377	Off-Post Plume	DIMP, fluoride, chloride, sulfate, VOCs, 1,4-dioxane
37378	Off-Post Plume	Carbon tetrachloride, DIMP, dieldrin, chloride, 1,4-dioxane
37379	Off-Post Plume	DIMP, chloride, sulfate
37389	Off-Post Plume	DIMP, dieldrin, tetrachloroethylene, chloride, NDPA, 1,4-dioxane
37391	Off-Post Plume	DIMP, dieldrin, tetrachloroethylene, chloride, sulfate, NDPA, 1,4-dioxane
37392	Off-Post Plume	DIMP, dieldrin, chloride, 1,4-dioxane
37395	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37396	First Creek Pathway	DIMP, chloride, sulfate, 1,4-dioxane
37397	Off-Post Plume	DIMP, chloroform, fluoride, chloride, sulfate
37404	Northern Pathway	OGITS CSRG analyte list, 1,4-dioxane
37405	Off-Post Plume	VOCs, 1,4-dioxane
37407	First Creek Pathway	DIMP, fluoride, sulfate
37428	Off-Post Plume	DIMP
37499	Off-Post Plume	DIMP
37452	Northern Pathway	DIMP, carbon tetrachloride, chloride

Notes:

OGITS CSRG Analyte List: DIMP, aldrin, chlordane, PPDDE, PPDDT, dieldrin, endrin, hexachlorocyclopentadiene, isodrin, atrazine, malathion, 1,4-oxathiane, CPMS, CPMSO, CPMSO2, dithiane, benzene, ethylbenzene, toluene, xylenes, 12DCLE, 1,3-dichlorobenzene, CCL4, chlorobenzene, chloroform, tetrachloroethylene, trichloroethylene, DCPD, DBCP, NDMA, NDPA. arsenic, chloride, fluoride, and sulfate.

VOCs include benzene, ethylbenzene, toluene, xylenes, 12DCLE, 1,3-dichlorobenzene, CCL4, chlorobenzene, chloroform, tetrachloroethylene, trichloroethylene, DCPD.

The exceedance monitoring program includes contaminants identified in the CSRG lists for the NWBCS, NBCS, and OGITS near the groundwater systems and a reduced analyte list for other wells based on sampling history and contaminant concentration trends. Water quality data from monitoring wells and private wells were used to construct exceedance maps presented in Figures 6.3-57 through 6.3-66. It should be noted that private well monitoring is conducted by TCHD and is discussed in Section 6.3.3.5.

The Army and Shell mapped exceedance areas for the following analytes through the course of the five-year reporting period:

1,2-Dichloroethane	DIMP
1,4-Dioxane	Dieldrin
Arsenic	Fluoride
Carbon tetrachloride	NDPA
Chloride	Sulfate

In accordance with OCN-LTMP-2019-001 and OCN-LTMP-2019-002, NDPA and 1,4-dioxane were added to the analyte list for many of the wells within the exceedance monitoring network in FY19 due to their presence in groundwater as determined during the emerging contaminants sampling program (see Section 6.3.3.9 for more discussion). Since these two analytes were not added to the program until 2019, plume maps are only provided for FY19. These two analytes will continue to be monitored twice every five years under the exceedance monitoring program moving forward.

For comparison, exceedance maps for 2014 and 2019 generally show contaminant distributions consistent with the previously mapped exceedance areas in most locations, with some decreases in the exceedance areas for several analytes. While water-level fluctuations occurred off post during the period, flow direction and contaminant migration pathways were generally not affected.

CSRG exceedance maps are shown for 2014 and 2019 in Figures 6.3-57 through 6.3-66, while maps for 1,4-dioxane and NDPA are presented in Figures 6.3-67 and 6.3-68 respectively. Concentrations of these analytes that exceed CSRGs/PQLs are portrayed in plume configurations—if the coverage of data warrants such an interpretation—or highlighted individual well locations. A summary of the off-post exceedance monitoring is provided below.

12DCLE

Concentrations of 12DCLE exceeded the CSRG of 0.4 µg/L in three wells at concentrations ranging from 0.811 to 1 µg/L. These wells are all located within the FCS capture zone, with no detections above the CSRG in wells downgradient of the extraction wells. Figure 6.3-57 shows the 12DCLE exceedance areas for 2014 and 2019.

Arsenic

Arsenic concentrations exceeded the CSRG of 2.35 µg/L in six wells in FY19 at concentrations ranging from 2.5 to 3.95 µg/L, an increase from two wells in FY14. Five wells were all within the area of the NPS, and one well is directly north of the NBCS. Figure 6.3-58 shows the arsenic exceedance areas for 2014 and 2019. Monitoring well 37464 and extraction well 37809 both had arsenic concentrations exceeding the CSRG in 2014 and 2019. In 2019, three additional wells (extraction well 37809 and monitoring wells 37008 and 37011—both located downgradient of 37809) contained arsenic at levels exceeding the CSRG.

Carbon Tetrachloride

CCL4 concentrations exceeded the CSRG of 0.3 µg/L in four wells in FY19 at concentrations ranging from 0.245 to 1.1 µg/L, an increase from one well in FY14. All four wells were within the area of the NPS. Figure 6.3-59 shows the CCL4 exceedance areas for 2014 and 2019. The concentration of CCL4 in well 37471 exceeded the CSRG in 2014 but was below the CSRG in 2019. In 2019, four wells (extraction well 37819 and monitoring wells 37037, 37469, and 37473) had CCL4 at concentrations exceeding the CSRG. These four wells are located side-gradient of well 37471, which contained CCL4 at a level exceeding the CSRG in 2014, but not in 2019.

Chloride

Chloride exceeded the CSRG of 250,000 µg/L in 29 wells in FY19 at concentrations ranging from 268,000 to 1,430,000 µg/L immediately downgradient of the NBCS with plumes extending into the FCS and NPS as presented in Figure 6.3-60. In accordance with the On-Post ROD for the NBCS, chloride is expected to attenuate naturally to the CSRG.

DIMP

Concentrations of DIMP exceeded the CSRG of 8 µg/L in 11 wells in FY19, compared with 12 wells in FY14. All wells with detections above the CSRG were located within the area of the FCS, as shown on Figure 6.3-61. There were no exceedances detected in wells downgradient of the extraction wells in FY19. To the southwest of the FCS, the exceedance area continues to be based on results for unconfined Denver Formation well 37379. The DIMP concentrations in adjacent alluvial well 37374 have been below the CSRG since 1994. The underlying unconfined Denver Formation has lower permeability and has a slower groundwater flow rate compared to the overlying alluvium. In 2014 and 2019, DIMP in well 37379 was shown as an isolated exceedance instead of connecting the exceedance areas with upgradient alluvial wells.

Dieldrin

Dieldrin concentrations exceeded the PQL of 0.013 µg/L in 36 wells in FY19, compared to 40 wells in FY14. Dieldrin was detected above the PQL in wells within both the area of the FCS system and the NPS system, and an area downgradient of the NWBCS. General observations of the dieldrin plume include:

- Downgradient of the NWBCS, exceedances of dieldrin occur delineating a narrow plume that extends to the northwest. Off-post wells were sampled in 2019 under a supplemental program (OCN-LTMP-2019-005) to better define the extent of dieldrin downgradient of the NWBCS (Figure 5.2-1). The results of the monitoring program were used to delineate the dieldrin plume depicted in Figure 6.3-62.

- Downgradient of the NBCS, a plume has been delineated extending from the western end of the NBCS northwest to well 37374 (see Figure 6.3-62). Dieldrin has been detected intermittently in well 37374 since 1988 with no discernible trend. While there is no well coverage between the NBCS and well 37374, dieldrin concentrations immediately downgradient of the system are greater than in well 37374 and have been consistently present since being identified in 1986 during the off-post RI.
- Directly north and downgradient of the NBCS the dieldrin plume is split by a groundwater divide with flow paths towards the FCS and the NPS. The number of wells with detections above the PQL in the FCS portion of the plume increased from 9 in 2014 to 13 in 2019. Within the NPS area, the number of wells with detections above the PQL decreased from 13 in FY14 to 11 in FY19.

Considering the presence of dieldrin exceeding the PQL in wells downgradient of the NWBCS, and the limited number of suitable downgradient wells, additional wells should be considered to support a comprehensive characterization of the off-post dieldrin plume in this area. This is identified as an issue in Section 8.0.

1,4-Dioxane

While 1,4-dioxane has been sampled under the emerging contaminants program since FY12, it was formally added to the list of analytes to be monitored under the exceedance monitoring program for off-post wells in FY19. 1,4-dioxane concentrations exceeded the CBSG of 0.35 µg/L in 4 wells in FY19 within the area of the FCS system (Figure 6.3-65). Samples from wells 37076, 37083, 37369, and 37389 contained 1,4-dioxane at concentrations exceeding the CBSG. These wells are located downgradient of the NBCS and upgradient of the extraction wells within the FCS.

Fluoride

Fluoride exceeded the CSRG of 2,000 µg/L in 18 wells in FY19 at concentrations ranging from 2,040 to 3,640 µg/L immediately downgradient of the NBCS with plumes extending into the FCS and NPS as presented in Figure 6.3-63. The CSRG for fluoride is represented by the agricultural CBSG rather than the human health standard of 4,000 µg/L.

NDPA

NDPA was also sampled under the emerging contaminants program before being formally added to the list of analytes to be monitored under the exceedance monitoring program for off-post wells in FY19. Concentrations of NDPA exceeded the CSRG of 0.005 µg/L in 11 wells in FY19 (Figure 6.3-66). NDPA was detected at concentrations exceeding the CSRG of 0.005 µg/L within localized plumes downgradient of the NBCS. Immediately downgradient of the NBCS, NDPA was detected in two wells at concentrations greater than the CSRG in a linear configuration that terminates approximately two-thirds of a mile north of the RMA boundary. Three wells within the FCS area contained NDPA at concentrations exceeding the CSRG upgradient of the extraction wells. NDPA exceeded the CSRG in six wells within the southern portion of the NPS including extraction wells 37815 and 37816 located downgradient of the primary line of extraction wells and recharge trenches parallel to Highway 2. The NDPA plume is well defined at the downgradient edge since it was not detected in performance wells further downgradient.

Sulfate

Sulfate exceeded the CSRG of 540,000 µg/L in 19 wells in FY19 at concentrations ranging from 348,000 to 2,020,000 µg/L immediately downgradient of the NBCS with plumes extending into the FCS and NPS as presented in Figure 6.3-64. In accordance with the On-post ROD for the NBCS, sulfate is expected to attenuate naturally to the CSRG.

6.3.3.5 Private Well Network (#96)

In accordance with the 1997 Memorandum of Agreement between TCHD and the Army (PMRMA 1997), TCHD conducts sampling of private wells in the Off-Post OU. Samples are collected from off-post private wells to determine the water quality of new off-post wells as required by the Off-Post ROD, to respond to citizen requests, and to determine whether CFS wells are acting as conduits for contaminant transport from the UFS to the CFS. In addition, data collected from off-post private wells are used to assist in refining the off-post CSRG exceedance map. Execution of the program depends on cooperation from the private well owners, and access to the wells is therefore not consistent.

Figure 6.3-67 shows the locations of the private wells sampled during this reporting period. Thirty wells were sampled at least once including 15 alluvial wells and 15 Arapahoe aquifer wells. Table 6.3-22 presents the analytical results for private well sampling for DIMP and the emerging contaminant 1,4-dioxane during the five-year reporting period. The monitoring results for the private wells sampled during the FYR period showed that DIMP concentrations were below the CSRG with one exception.

In FY15 and FY16, well 359A had DIMP detections exceeding the CSRG. Bottled water was provided to the residents to minimize exposure. After evaluation of possible alternate water sources, the well was closed and replaced by a new well, 359D, in November 2016. The initial sample collected had a DIMP concentration of 2.97 µg/L. However subsequent sampling in FY17-FY19 has shown DIMP concentrations exceeding the CSRG in some samples. Bottled water is currently being provided to the residents and evaluation of the presence of DIMP in this location and options for alternate water supply are ongoing. This is identified as an issue in Section 8.0.

During the FYR period, 1,4-dioxane was not detected in wells located within the Arapahoe aquifer. Three alluvial wells had intermittent detections above the CBSG, but all results have been below the CBSG since FY18.

During the period, two surface water samples were collected each year within storage impoundments northwest of RMA owned by Denver Water. The surface water discharges into the South Platte River and DIMP results were below the reporting limit.

Table 6.3-22. Water Quality Data for the Off-Post Private Monitoring Wells, FY15 – FY19

Private Well ID	Aquifer	Sample Date	Analyte Concentrations (µg/L)	
			DIMP	1,4-Dioxane
359A (Abandoned in November 2016)	Arapahoe	2/9/2015	6.13 (pre-purge) 8.14 (post-purge)	NA
		7/27/2015	8.64	< 0.1
		6/13/2016	9.53	< 0.137
359C	Alluvial	7/27/2015	1.19	0.12
		6/13/2016	1.52	< 0.137
		7/10/2017	1.14	< 0.137
		7/12/2018	0.709	< 0.1
		7/11/19	0.79	< 0.1
359D	Arapahoe	11/21/2016	2.97	< 0.137
		7/10/2017	7.72	< 0.137
		8/21/2017	10.5	NA
		5/22/2018	5.99	NA
		9/18/2018	6.08	< 0.1
		7/11/19	1.52 (pre-purge) 7.72 (post-purge)	< 0.1
		8/27/19	2.07 (pre-purge) 11 (post-purge)	NA
361A	Arapahoe	7/17/2018	< 0.5	< 0.1
365C	Arapahoe	8/8/2017	< 0.5	< 0.137
486A	Arapahoe	8/2/2018	< 0.5	< 0.1
494B	Alluvial	10/8/2015	< 0.5	< 0.137
494C	Alluvial	10/8/2015	0.899	< 0.137
		7/25/2016	3.67	< 0.137
		7/18/2017	3.0	< 0.137
		8/22/2018	1.99	0.132
		8/13/2019	2.71	0.115
538A	Alluvial	7/29/2015	< 0.5	0.13
541A	Alluvial	7/282015	0.927	0.19
		7/7/2016	0.975	0.29
		7/25/2017	1.24	0.444
		7/10/2018	1.56	0.302
		7/24/2019	1.55	0.28
550A	Alluvial	7/282015	< 0.5	0.75
		7/7/2016	< 0.5	1.33
		7/25/2017	< 0.5	0.307
		7/10/2018	< 0.5	0.348
		8/13/2019	< 0.5	0.188
611A	Arapahoe	8/4/2015	< 0.5	< 0.1

Table 6.3-22. Water Quality Data for the Off-Post Private Monitoring Wells, FY15 – FY19

Private Well ID	Aquifer	Sample Date	Analyte Concentrations (µg/L)	
			DIMP	1,4-Dioxane
611F	Alluvial	8/4/2015	< 0.5	< 0.1
843A	Arapahoe	7/29/2015	< 0.5	< 0.1
		7/14/2016	< 0.5	< 0.137
901B	Arapahoe	7/17/2019	< 0.5	< 0.1
917A	Arapahoe	7/31/2019	< 0.5	< 0.1
985B	Alluvial	7/16/2015	5.08	0.1
		7/14/2016	4.61	< 0.137
		8/1/2017	2.51	< 0.137
986A	Alluvial	8/25/2015	2.28	0.18
		7/20/2016	3.67	0.341
		7/19/2017	1.82	0.375
		7/5/2018	1.66	0.22
		7/30/2019	1.38	0.223
986B	Arapahoe	7/5/2018	< 0.5	< 0.1
989A	Alluvial	7/31/2017	< 0.5	0.256
		8/6/2018	< 0.5	0.182
		7/30/2019	< 0.5	0.148
992A	Alluvial	6/30/2016	1.48	< 0.137
993A	Alluvial	7/13/2015	1.29	0.1
		8/10/2017	1.76	< 0.137
		9/6/2018	2.43	0.128
		7/25/2019	0.868	0.136
1190A	Arapahoe	7/11/2018	< 0.5	< 0.1
1190B	Alluvial	8/10/2015	1.66	< 0.1
		6/23/2016	2.96	< 0.137
1324A	Arapahoe	6/30/2016	< 0.5	< 0.137
1324C	Alluvial	7/30/2015	< 0.5	0.15
1334H	Arapahoe	7/27/2015	1.09	< 0.1
		6/23/2016	1.03	< 0.1
		7/13/2017	0.937	< 0.137
		7/12/2018	0.785	< 0.1
		7/15/2019	0.768	< 0.1
1402B	Alluvial	8/23/2016	< 0.5	0.341
		7/31/2017	0.0209	0.307
		8/1/2019	< 0.5	0.215
1556A	Arapahoe	8/2/2018	< 0.5	< 0.1
1731A	Arapahoe	7/8/2017	< 0.5	< 0.137

Notes: < – Analyte not detected and reported as a value less than the reporting limit. NA – Not Analyzed

6.3.3.6 Hazardous Waste Landfill Post-Closure Groundwater Monitoring

Groundwater beneath the HWL is currently monitored under the requirements of the HWL Post-Closure Groundwater Monitoring Plan (PCGMP), provided in Appendix B of the HWL Post-Closure Plan (Navarro 2019d) as modified by approved HWL O&M OCNs.

Closure groundwater monitoring of the HWL was initiated in October 2006, following the last waste load into the HWL and continued until May 2009. The July 2009 sampling event was the first HWL post-closure groundwater monitoring event following the final inspection of the HWL cap by the Regulatory Agencies. This section presents the results of the HWL post-closure groundwater monitoring program between 2015 and 2019.

HWL Water Level Monitoring

Water levels were measured in 68 wells quarterly to evaluate the UFS and CFS flow conditions in the area of the Corrective Management Unit (CAMU) and to identify any significant changes in flow direction in the area of the CAMU. Wells used in HWL post-closure groundwater monitoring are shown on Figure 6.3-68. The potentiometric surface of the UFS in the vicinity of the HWL shows that across the entire CAMU, groundwater flow is generally to the north and northwest (Figure 6.3-68). No significant variations in groundwater flow directions have been identified during post-closure monitoring.

Figure 6.3-68 shows a more pronounced groundwater high along the west side of the HWL similar to the observed water table in 2018. This configuration of the water table is consistent with recharge from the grass-line perimeter channel located along the west side of the HWL. This interpretation is further supported by the increasing trend in water elevations in other monitoring wells located on the west side of the HWL.

The potentiometric surface of the Denver Formation lower sandstone unit indicates flow from the CFS into UFS downgradient of the HWL and illustrates the water table across the area and the interaction between the two flow systems. Groundwater flow in the lower sandstone unit of the CFS merges with the UFS on the north and east sides of the HWL and ELF and the southeastern portion of the former Landfill Wastewater Treatment System. Currently, the zone where the UFS and CFS merge is illustrated by a dashed line for the approximate boundary indicating the lower sandstone unit in Figure 6.3-69. South of the line, the flow is confined to semi-confined, while north of the line the flow is unconfined where the confining unit is not present (TtFW 2004).

The post-closure groundwater monitoring reports from 2011 and 2012 indicated that the water level data from well 25194 were considered unacceptable for use in contouring the UFS. Based on surrounding wells, water levels from well 25194 did not appear indicative of the actual water table elevation in the UFS because it appeared to be a perched zone. These reports stated that well 25194 would continue to be monitored as part of the downgradient HWL water-quality well network in accordance with the HWL PCGMP (Navarro 2019d).

However, while preparing the 2013 annual post-closure groundwater monitoring report, the site hydrogeology, water level, and water quality data for well 25194 (and its predecessor well

25094) were re-evaluated. Well 25094 was dry from 1999 until 2003, and then had a foot or less of water in the screen until water levels rose in 2007/2008. Well 25094 was closed in 2008. Since then, water levels have been relatively stable in replacement well 25194, and two to three feet above the initial water elevations in well 25094. The relatively small rise in water levels likely is in response to recharge from the grass-lined perimeter channel that runs along the west side of the HWL that was constructed in 2008. The 2013 water elevation in well 25194 is similar to those in the upgradient wells located south of the HWL. Thus, the previous interpretation of well 25194 being in a perched zone was questioned.

With inclusion of well 25194 in the UFS, a more pronounced groundwater high became evident along the west side of the HWL (Figure 6.3-68). This configuration of the water table is consistent with recharge from the perimeter ditch located along the west side of the HWL. This interpretation is further supported by the increasing trend in water elevations in monitoring wells 25027, 25194, and 25203 located along the west side of the HWL since 2008.

The Army notified the Regulatory Agencies of these conditions, but the parties have not come to consensus on the ramifications of the change. The Army and Regulatory Agencies met in August 2015 to discuss how the issue would be resolved. The Army agreed to install another well downgradient of the HWL and to sample that well in accordance with the HWL PCGMP (Navarro 2019d). Well 25184 was installed in 2016, but it has been dry since. The Army and Regulatory Agencies will continue to use the consultative process to come to agreement on potential changes to the monitoring plan.

HWL Post-Closure Groundwater Quality

The HWL water quality network wells and supplemental operational monitoring wells are shown on Figure 6-3-68. Samples were analyzed for 16 indicator compounds (ICs) each quarter, and for the full suite of analytes during the annual sampling event. As presented below, 16 ICs were selected for the HWL to establish baseline contaminant trends and calculate upper prediction limits (UPLs).

Arsenic	1,1-Dichloroethane	Dieldrin
Benzene	1,2-Dichloroethane	Lead
Bicycloheptadiene	Dichlorodifluoromethane	Mercury
Carbon tetrachloride	1,1-Dichloroethene	1,1,1-Trichloroethane
Chloroform	DCPD	
Chromium	DIMP	

The list of ICs and the full analyte suite is available in the HWL PCGMP (Navarro 2019d).

As noted in the HWL PCGMP (Navarro 2019d), wells 25086 and 25088 were installed under dry conditions. These two wells are sampled only if groundwater levels are within the well screen and adequate groundwater is available. Both wells were dry for all sampling events between 2015 and 2019.

Statistical Evaluation of 2015-2019 Analytical Data

The upper limits of the prediction interval—represented as UPLs—are statistical values used to compare upgradient background to downgradient compliance water quality to determine potential impacts on groundwater and the effectiveness of the HWL remedy. The general approach for determining and evaluating UPLs for the HWL is consistent with EPA guidance document, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA 2009). UPLs were calculated using upgradient water quality data collected during the preoperational, operational, closure, and post-closure groundwater monitoring periods for the HWL.

Table 6.3-23 provides a summary of the findings presented in the annual HWL Post-Closure Groundwater Monitoring Reports for 2015 through 2019 (Navarro 2016j, 2017g, 2018h, 2019q, 2020b). With the exception of dieldrin in 2016, none of the ICs were detected at concentrations that exceeded UPLs during the five-year reporting period (Table 6.3-23). Due to the elevated level of dieldrin in groundwater in 2016, its presence in the vicinity of the HWL was investigated as discussed below.

In accordance with the HWL PCGMP, groundwater samples have been collected at the HWL since 2011. Dieldrin has been detected downgradient of the HWL in well 25194, exceeding the UPL (0.051 µg/L) for three quarters in 2016. Since 2016, dieldrin concentrations have been below the UPL. Elevated dieldrin in well 25194 is likely due to sources of pre-existing soil contamination in the vicinity of the HWL. The presence of pre-existing contamination was investigated in accordance with NRAP-2016-004 and the *Hazardous Waste Landfill Groundwater Monitoring Wells 25194 and 25184 Subsurface Soil and Landfill Stormwater Runoff Sampling and Analysis Plan* (Navarro 2016d). Results of the investigation were documented in the *Hazardous Waste Landfill Groundwater Monitoring Wells 25194 and 25184 Subsurface Soil and Landfill Stormwater Runoff Data Summary Report* (Navarro 2019g). A summary of the Data Summary Report conclusions is provided below.

The primary objective of the subsurface soil and stormwater runoff sampling program was to evaluate the source of the dieldrin in well 25194. However, dieldrin was not detected in any of the subsurface soil samples and the stormwater runoff sample collected during the program. Therefore, the source of the dieldrin detected in well 25194 could not be identified.

There is no evidence that the dieldrin contamination at well 25194 is connected with the waste contained within the HWL. The most likely explanation for the dieldrin detections is remobilization of residual contamination in soil that pre-dates the construction of the landfill. The remobilization of residual contamination may have been caused by the change in the hydrogeology in this area when the grass-lined perimeter channel was constructed west of the HWL in 2008 and increasing groundwater levels associated with heavy precipitation from late 2013 through spring 2016. The perimeter channel conveys stormwater runoff from the HWL and ELF and allows for infiltration within the grass-lined portions of the drainage, including the area east of well 25194 (Navarro 2019g). The detection limit for dieldrin is higher in soil than it is in water, so it is possible that residual levels of dieldrin in the soil may exist below the detection limit, but still of sufficient concentration to appear in the quarterly groundwater monitoring samples collected from well 25194.

Furthermore, a Mann-Kendall analysis of dieldrin in groundwater at the HWL shows a decreasing concentration trend for dieldrin in well 25194 for the five-year reporting period, strengthening the position that the HWL is not a source of dieldrin in groundwater in this area.

Based on review of previous investigations, hydrogeologic information, statistical evaluations, and trend analysis, the groundwater quality in the vicinity of the HWL has not been affected by post-closure O&M of the landfill.

Table 6.3-23. Hazardous Waste Landfill (HWL) Groundwater Statistical Analysis Summary

Year	Indicator Compounds Exceeding Upper Prediction Limits	Well 25194 Trend Analysis	FYSR Conclusion
2015	None	Neither the dieldrin concentrations nor the CUSUM exceeded the control limits. A revised UPL for dieldrin of 0.051 was applied. Therefore, indicating there were no sudden or gradual changes in dieldrin concentrations.	Groundwater quality in the vicinity of the HWL has not been affected by operations, closure and post-closure O&M of the HWL.
2016	Dieldrin	The dieldrin concentrations did not exceed the control limit or the UPL, but the CUSUM did exceed the control limit, indicating a change in dieldrin concentrations. NRAP-2016-004 and *HWL Groundwater Monitoring Wells 25194 and 25184 Subsurface Soil and Landfill Stormwater Runoff SAP* (Navarro 2016d) were finalized to investigate the source of dieldrin that has been detected in well 25194 since July of 2011.	Groundwater quality in the vicinity of the HWL has not been affected by operations, closure and post-closure O&M of the HWL.
2017	None	Dieldrin concentrations did not exceed the control limit, but the CUSUM did exceed the control limit, indicating the presence of dieldrin prior to HWL construction. Further evaluation of dieldrin concentrations using Mann-Kendall trend analysis showed a decreasing trend in dieldrin concentrations.	Groundwater quality in the vicinity of the HWL has not been affected by operations, closure and post-closure O&M of the HWL.

Table 6.3-23. Hazardous Waste Landfill (HWL) Groundwater Statistical Analysis Summary

Year	Indicator Compounds Exceeding Upper Prediction Limits	Well 25194 Trend Analysis	FYSR Conclusion
2018	None	Dieldrin concentrations did not exceed the control limit, but the CUSUM did exceed the control limit, indicating the presence of dieldrin prior to HWL construction. Further evaluation of dieldrin concentrations using Mann-Kendall trend analysis showed a decreasing trend in dieldrin concentrations.	Groundwater quality in the vicinity of the HWL has not been affected by operations, closure and post-closure O&M of the HWL.
2019	None	The dieldrin concentrations did not exceed the control limit or the UPL, and the CUSUM did not exceed the control limit; thus, indicating a general decreasing trend in dieldrin concentrations. Further evaluation of dieldrin concentrations using Mann-Kendall trend analysis showed a decreasing trend in dieldrin concentrations.	Groundwater quality in the vicinity of the HWL has not been affected by operations, closure and post-closure O&M of the HWL.

Note: The Mann-Kendall statistical analysis and the cumulative sum control chart (CUSUM) are available on the data CD in the Hazardous Waste Landfill subfolder.

6.3.3.7 Enhanced Hazardous Waste Landfill Post-Closure Groundwater Monitoring

Groundwater beneath the ELF is currently monitored under the requirements of the ELF PCGMP, provided as Appendix B of the ELF Post-Closure Plan (Navarro 2020f) as modified by approved OCNs. Preoperational groundwater monitoring for the ELF was completed in April 2006, followed by operational monitoring from April 2006 through July 2008. Closure monitoring was completed in the spring of 2010 and post-closure monitoring began in the summer of 2010. The July 2010 sampling event was the first ELF post-closure monitoring event following final inspection of the ELF cap by the Regulatory Agencies. Sampling procedures and frequencies and analytes evaluated remained the same throughout the pre-operational, operations, closure, and post-closure (to date) periods. This section presents the results of the ELF post-closure groundwater monitoring program between 2015 and 2019.

ELF Water Level Monitoring

Water levels were measured in 68 wells quarterly to evaluate the UFS and CFS flow conditions in the area of the CAMU and to identify any significant changes in flow direction in the area of the CAMU. Wells used in ELF post-closure groundwater monitoring are shown on Figure 6.3-68. Across the entire CAMU, groundwater flow is generally to the north and northwest. No significant variations in groundwater flow directions have been identified during post-closure monitoring.

Due to the proximity of the ELF to the HWL, refer to Section 6.3.3.6 for a detailed discussion on water levels and groundwater flow in the vicinity of the landfills.

ELF Post-Closure Groundwater Quality

The ELF water quality network wells are shown on Figure G-1. Groundwater samples were analyzed for 13 ICs each quarter, and the expanded analyte suite of 70 compounds annually (Navarro 2020f). As presented below, 13 ICs were selected for the ELF to establish baseline contaminant trends and calculate UPLs.

Arsenic	Benzene	Chromium
1,1,1-Trichloroethane	Carbon tetrachloride	Lead
1,1-Dichloroethane	Chloroform	Mercury
1,1-Dichloroethene	Dieldrin	
1,2-Dichloroethane	DIMP	

The list of ICs and the full analyte suite is available in the ELF PCGMP (Navarro 2020f).

Statistical Evaluation of 2015-2019 Analytical Data

Prediction limits are statistical values used to compare upgradient water quality to concentrations in the downgradient compliance wells and are used to evaluate potential impacts on the groundwater and effectiveness of the ELF remedy. The general approach for determining and evaluating UPLs for the ELF is consistent with EPA guidance document, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA 2009). UPLs were calculated from data collected during the ELF preoperational, operational, closure, and post-closure groundwater monitoring period for upgradient wells.

Comparison of downgradient water quality data to UPLs should provide an indication whether groundwater has been impacted by the ELF. Table 6.3-24 provides a summary of the findings presented in the annual ELF Post-Closure Groundwater Monitoring Reports for 2015 through 2019 (Navarro 2016j, 2017g, 2018h, 2019q, 2020b). None of the ICs were detected at concentrations that exceeded UPLs during the five-year reporting period.

Based on review of hydrogeologic information, statistical evaluations, and trend analysis, the groundwater quality in the vicinity of the ELF has not been affected by post-closure O&M of the landfill.

Table 6.3-24. Enhanced Hazardous Waste Landfill (ELF) Groundwater Statistical Analysis

Year	Indicator Compounds Exceeding Upper Prediction Limits	Additional Information	FYSR Conclusion
2015	None	Historically, lead was detected in downgradient wells prior to waste being placed in the ELF in April 2006 (TtEC 2011a). Concentrations of lead did not exceed the UPL.	Groundwater quality in the vicinity of the ELF has not been affected by operations, closure and post-closure O&M of the ELF.
2016			
2017			
2018			
2019			

6.3.3.8 Basin F Post-Closure Groundwater Monitoring

The Basin F post-closure groundwater monitoring program is intended to demonstrate that post-closure care of the Basin F Surface Impoundment and the Basin F Wastepile satisfy RCRA closure performance standards, which includes the requirement to control, minimize or eliminate post-closure escape of hazardous contaminants to groundwater (6 Code of Colorado Regulations 1007-3, Section 265, Subpart G).

The analytical results for the ICs were evaluated for samples collected annually at the start of post-closure monitoring in October 2010 through April 2019. This section presents the results of the Basin F post-closure groundwater monitoring program during the five-year reporting period.

Basin F Water Level Monitoring

Water levels were measured annually in 27 Basin F network wells to evaluate UFS conditions in the area of Basin F. This information is used to evaluate groundwater flow for significant changes in flow direction over time. Wells used in Basin F post-closure groundwater monitoring are shown on Figure 6.3-70. The flow direction and groundwater elevations in the UFS are consistent with historical flow and elevations prior to closure and post-closure activities. Groundwater in the vicinity of Basin F flows primarily to the north with flow components to the northwest and northeast at the northern end of Basin F. In 2019, groundwater elevations continued a decreasing trend in wells downgradient and upgradient of Basin F. Groundwater in well 26128 showed an increasing trend between 2014 and 2018 but decreased approximately 3 feet in 2019. The CFS in the Basin F area is addressed as part of the LTMP (TtEC and URS 2010), and results of CFS monitoring during this five-year reporting period are presented in Section 6.3.3.3.

Basin F Post-Closure Groundwater Quality

The Basin F Wastepile (WP) and Principal Threat (PT) well networks are shown on Figure 6.3-70. In 2006, the Basin F water quality well network was divided into a Basin F WP component—comprising wells 26015, 26017, 26028—and Basin F PT component—comprising wells 26015, 26073, 26128, 26133, 26157, 26163, and 26173. The two networks were established based on the locations of wells relative to a contaminant source and its corresponding groundwater flow path. Downgradient well 26015 is included in both networks due to comingled groundwater flow paths at that location. Groundwater samples are collected annually from the Basin F well networks and are analyzed for the 11 indicator compounds presented below and in the Basin F PCGMP (TtEC 2011c).

Arsenic	Copper	NNDMEA
Chloroform	DCPD	Sulfate
Chloride	DIMP	Tetrachloroethylene
CPMSO2	Dieldrin	

As detailed in the Basin F PCGMP (TtEC 2011a), elevated concentrations of some contaminants in downgradient wells—including chloroform, CPMSO2, DCPD, DIMP and tetrachloroethylene—were identified during baseline monitoring and may be the result of residual contamination present in the unsaturated and saturated zones that was mobilized by rising water levels and/or continuing migration from the vadose zone to the saturated zone. Basin F was constructed in 1956, and before the basin was drained in 1988, significant contamination migrated from leaks in the basin liner through the 40- to 45-foot thick unsaturated zone to the water table. Thus, residual contamination present in the soil above and below the water table will serve as continuing contaminant source to groundwater. Leaking in the Basin F liner occurred on the east side of Basin F, specifically in the area where PT excavation took place during the remedy, which accounts for the higher concentrations of indicator compounds in downgradient PT wells.

Statistical Evaluation of 2015-2019 Analytical Data
Prediction limits are statistical values used to compare upgradient water quality to concentrations in the downgradient compliance wells and are used to evaluate potential impacts on the groundwater and effectiveness of the Basin F remedy. Eleven indicator compounds were selected for Basin F to establish baseline contaminant trends and calculate UPLs.

Since pre-existing groundwater contamination is present under Basin F, baseline sample results from both upgradient and downgradient wells adjacent to Basin F were used to calculate baseline UPLs. As described in the Basin F PCGMP (TtEC 2011), this approach deviates from the approach described in the EPA guidance document, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA 2009) which provides for calculation of UPLs using data from upgradient groundwater samples for comparison to future downgradient groundwater sample analytical results. For Basin F, UPLs were initially calculated using the baseline data consisting of upgradient and downgradient data, as required by the PCGWMP. Since the initial baseline UPLs were calculated, a sufficient number of upgradient water quality samples now exist to calculate updated UPLs for comparison to downgradient data. Considering the data available since post-closure monitoring began, the statistical approach for evaluating data is being re-assessed to provide for a more robust analysis of water quality at Basin F. Statistical methods including UPLs, control charts, and trend analyses will be evaluated for use in the post-closure monitoring program moving forward. Figures 6.3-70a through 6.3-70k display analytical results for the post-closure period and results are discussed below.

Basin F Wastepile
Table 6.3-25 provides a summary of the findings associated with the Basin F WP presented in the annual Basin F Post-Closure Groundwater Monitoring Reports issued during the five-year reporting period (Navarro 2015f, 2016c, 2017b, 2018c, 2019h).

Concentrations for some indicator compounds have increased during post-closure monitoring compared to baseline data for the Basin F WP wells. Concentrations of arsenic, chloride, and DIMP appear to be increasing upgradient of Basin F. Arsenic and chloroform appear to be increasing in downgradient well 26015, while sulfate and tetrachloroethylene appear to be increasing in downgradient well 26017.

The statistical evaluations conducted during the period conclude that that groundwater quality downgradient of the Basin F WP area has potentially been affected in the vicinity of wells 26015 and 26017.

Table 6.3-25. Basin F Wastepile Groundwater Statistical Analysis Summary

Year	Indicator Compounds which exceeded Upper Prediction Limits[1]	Additional Information	FYSR Conclusion[2]
2015	Chloroform	The 2015 chloroform concentration in well 26015 was within the historical range of chloroform values for the well.	Groundwater quality downgradient of the Basin F WP has not been significantly affected.
2016	Chloroform	The 2016 chloroform concentrations in wells 26015 and 26017 were within the historical range of chloroform values for the wells.	Groundwater quality downgradient of the Basin F WP has not been significantly affected.
2017	Chloroform	The 2017 chloroform concentrations in wells 26015 and 26017 were within the historical range of chloroform values for the wells. Since the 2017 chloroform concentrations were only slightly above the prediction limit and likely caused by higher water levels mobilizing residual chloroform, the potential effect on the groundwater quality was extremely small.	Groundwater quality downgradient of the Basin F WP area has potentially been affected in the vicinity of wells 26015 and 26017.
2018	Chloroform	The 2018 chloroform concentrations in wells 26015 and 26017 were within the historical range of chloroform values for the wells. Since the 2018 chloroform concentrations were only slightly above the prediction limit and likely were caused by higher water levels mobilizing residual chloroform, the potential effect on the groundwater quality was extremely small.	Groundwater quality downgradient of the Basin F WP area has potentially been affected in the vicinity of wells 26015 and 26017.
2019	Chloroform, copper	The 2019 chloroform concentrations in wells 26015 and 26017 were within the historical range of chloroform values for the wells. The copper concentration in well 26015 was also within the historical range of copper for the well.	Groundwater quality downgradient of the Basin F WP area has potentially been affected in the vicinity of wells 26015 and 26017.

Note:

1. Upper prediction limits are statistical values used to compare upgradient water quality to concentrations in the downgradient compliance wells and are used to evaluate potential impacts on the groundwater and effectiveness of the Basin F remedy. These are not groundwater standards.
2. As of 2019, concentrations of arsenic, chloride, and DIMP appear to be increasing upgradient of Basin F. Arsenic and chloride appear to be increasing in downgradient well 26015, while sulfate and tetrachloroethylene appear to be increasing in downgradient well 26017.

Basin F Principal Threat

Table 6.3-26 provides a summary of the findings associated with the Basin F PT area presented in the annual Basin F Post-Closure Groundwater Monitoring Reports (Navarro 2015f, 2016c, 2017b, 2018c, 2019h).

During the period, groundwater along the PT flow path appears to have been impacted, with observed increases of select ICs in PT downgradient wells. During post-closure monitoring, chloroform, DIMP, sulfate, and tetrachloroethylene appear to be increasing upgradient of Basin F compared to baseline data for the Basin F PT wells. Several indicator compounds—including, chloroform, CPMSO2, DCPD, DIMP, sulfate, and tetrachloroethylene—appear to be increasing in more than one downgradient well. The exceedances likely are caused by residual contamination and are consistent with pre-existing contamination that was present before the Basin F post-closure period.

The statistical evaluations and trend analysis conducted during the period, conclude that groundwater quality downgradient of the Basin F PT area has potentially been affected in the vicinity of wells 26133, 26157, 26163, and 26173.

Table 6.3-26. Basin F Principal Threat Groundwater Statistical Analysis Summary

Year	Indicator Compounds which exceeded Upper Prediction Limits[1]	Additional Information	FYSR Conclusion[2]
2015	Chloroform, DCPD, CPMSO2, and tetrachloroethylene	Groundwater concentrations in the Basin F wells can be affected by rising water levels, which may mobilize the residual contamination present above previous water table elevations.	Increases in concentrations or high concentrations in downgradient PT wells may be the result of residual contamination that is present in the saturated zone or may be continuing to migrate from the vadose zone to the saturated zone.
2016	Chloroform, DCPD, CPMSO2, and tetrachloroethylene	The 2016 concentrations in wells 26163 and 26173 were within the historical ranges of Chloroform, CPMSO2, DCPD, and tetrachloroethylene values for the wells.	
2017	Arsenic, chloroform, CPMSO2, copper, DCPD, DIMP, NDMA, and tetrachloroethylene	The 2017 concentrations of most of these analytes were within their historical ranges. CU, dieldrin, and tetrachloroethylene concentrations exceeded their respective historical ranges in wells 26163 and/or 26173.	Groundwater quality downgradient of the Basin F PT area has been potentially affected by residual subsurface contamination in the vicinity of wells 26133, 26163, and 26173. The increase in concentrations and exceedance of the prediction limits in downgradient PT wells is caused by rising water levels and mobilization of pre-existing residual contamination from former Basin F. In accordance with the Post Closure Groundwater Monitoring
2018	Chloroform, DCPD, CPMSO2, and tetrachloroethylene	The 2018 concentrations of most of these analytes were within their historical ranges. The tetrachloroethylene concentration exceeded the historical range in well 26173.	

Table 6.3-26. Basin F Principal Threat Groundwater Statistical Analysis Summary

Year	Indicator Compounds which exceeded Upper Prediction Limits[1]	Additional Information	FYSR Conclusion[2]
2019	Chloroform, CPMSO2, copper, DCPD, DIMP, and tetrachloroethylene	The 2019 concentrations of most of these analytes were within their historical ranges. CU and tetrachloroethylene concentrations exceeded their respective historical ranges in wells 26163 and/or 26173.	Plan, there are no chemical-specific standards that apply to Basin F groundwater since the RMA remedy addresses contaminated groundwater downgradient at the NBCS and NWBCS, where it is extracted and treated. Further evaluation is planned for FY21 to consider the source of increasing concentrations in groundwater downgradient of Basin F.

Note:

1. Upper prediction limits are statistical values used to compare upgradient water quality to concentrations in the downgradient compliance wells and are used to evaluate potential impacts on the groundwater and effectiveness of the Basin F remedy. These are not groundwater standards.
2. As of 2019, concentrations of arsenic, chloride, and DIMP appear to be increasing upgradient of Basin F. Arsenic and chloride appear to be increasing in downgradient well 26015, while sulfate and tetrachloroethylene appear to be increasing in downgradient well 26017.

Basin F Post-Closure Monitoring Summary

Upgradient and downgradient groundwater data collected during post-closure monitoring of WP and PT wells were evaluated to demonstrate post-closure operations and maintenance of the Basin F surface impoundment and that the Basin F WP meets the RCRA closure performance standards. Concentration trends are presented in Figures 6.3-70a through 6.3-70k (located under the Tables Tab). The following conclusions are based on the groundwater monitoring results for Basin F post-closure groundwater monitoring as presented in the 2019 annual groundwater monitoring report as they relate to the five-year reporting period. Table 6.3-27 presents a summary of the results for the evaluation of water quality in WP and PT wells.

- Groundwater elevations have generally decreased in all downgradient and upgradient monitoring wells since late 2015. Groundwater in well 26128 showed a greater decrease than other upgradient wells with a decrease of approximately 3 feet in 2019—likely due to a deeper screened interval within the Denver Formation than other wells monitored for Basin F.
- Impacts to groundwater along the WP flow path appear to have fewer exceedances of UPLs in downgradient WP wells in 2019 as compared to previous years. Concentrations for some ICs have increased during post-closure monitoring compared to baseline data for the Basin F WP wells.
- Groundwater along the PT flow path appears to have been impacted, with observed increases of select ICs in PT downgradient wells. During post-closure monitoring, chloroform, DIMP, sulfate, and tetrachloroethylene appear to be increasing

upgradient of Basin F compared to baseline data for the Basin F PT wells, and several ICs appear to be increasing in more than one downgradient well.

Based on the distribution of the analyte concentrations and water quality trends, it appears that the PT groundwater flow path is having a greater impact on water quality downgradient of the former Basin F compared to the WP flow path. Further evaluation of Basin F groundwater data should be conducted to determine the source of elevated concentrations downgradient from Basin F. This recommendation is included under Other Findings in Section 9.1

Table 6.3-27. Summary of Basin F Post-Closure Groundwater Quality Trends

Wastepile Wells	Principal Threat Wells
Arsenic	
Downgradient wells show increasing (26015) or stable (26017) trends.	Three of five downgradient wells showed an increase in concentration in 2019, while arsenic decreased to a nondetect level in well 26133. Concentrations of arsenic were less than the UPL in all downgradient wells.
Chloroform	
Downgradient wells show decrease in concentrations.	Increasing trend noted for upgradient and downgradient wells. Statistical trends are decreasing or not observed some downgradient wells.
Chloride	
Potential increasing trend observed in the upgradient well, while downgradient wells show decreasing (26015) or generally increasing (26017) trends.	Stable or decreasing trends observed in all upgradient downgradient wells, with chloride concentrations in well 26133 potentially increasing.
CPMSO2	
Not detected in upgradient or downgradient wells.	Apparent stable trend for upgradient well 26128. CPMSO2 was not detected in downgradient well 26015 and shows stable or decreasing trends in downgradient wells 26133, 26163, and 26157.
Copper	
Not detected in upgradient well. Not detected downgradient, and only detected once in well 26015 during five-year reporting period.	Not detected in upgradient wells. Detected in four of five downgradient wells. Downgradient well 26163 is the only well with a history of consistent detections.
DCPD	
Not detected in upgradient or downgradient wells.	DCPD was not detected in upgradient wells and one downgradient well. Downgradient wells show stable trends, while two wells show increasing trends.

Table 6.3-27. Summary of Basin F Post-Closure Groundwater Quality Trends

Wastepile Wells	Principal Threat Wells
DIMP	
Increasing trend observed in upgradient well and is likely due to residual upgradient contamination migrating towards Basin F. Downgradient wells show stable or decreasing trends.	Upgradient well 26073 appears to have an increasing trend since 2014, while well 26128 concentrations have been variable. Concentrations in downgradient wells appear to be relatively stable over time with an increase in concentrations in well 26173 since 2018.
Dieldrin	
Decreasing trend observed in upgradient well. Downgradient wells show no apparent or stable trends.	Concentrations in upgradient wells appear to be relatively stable. Concentrations in downgradient wells 26015, 26133, 26157, and 26173 have been relatively stable, with well 26015 having lower concentrations. Downgradient well 26163 shows no apparent trend through post-closure, but concentrations have increased during the past four years.
NDMA	
Variable concentrations in upgradient and downgradient wells since 2006.	NNDMEA has intermittently been detected in upgradient well 26073 and the concentrations in upgradient well 26128 appear to be relatively stable with an increase in 2019. Downgradient wells show stable or decreasing trends in wells 26015, 26157 and 26163. Apparent increasing trends observed in downgradient wells 26133 and 26173.
Sulfate	
Consistent trend observed in upgradient well and is likely due to residual upgradient contamination migrating towards Basin F. Increasing trend observed in both downgradient wells through 2015 with a decrease in concentrations through 2019.	Upgradient wells 26073 and 26128 show a potential increasing trend since 2013. Downgradient wells 26015, 26157, and 26163, show decreasing trends, while wells 26133 and 26173 shows increasing trends.
Tetrachloroethylene	
Not detected in upgradient well or downgradient well 26015. Increasing trend observed in downgradient well 26017.	Tetrachloroethylene concentrations are decreasing in upgradient well 26073, while well 26128 shows an increasing trend since 2013. Tetrachloroethylene was not detected in downgradient well 26015. Downgradient wells 26133, 26163, and 26173 show increasing trends. Downgradient well 26157 shows a decreasing trend with concentrations less than the PL.

6.3.3.9 Emerging Contaminants

Three emerging contaminants have been identified for evaluation in RMA groundwater: 1,4-dioxane, NDPA, and PFOA/PFOS. An emerging contaminant is defined as a contaminant that has a reasonably possible pathway to enter the environment; presents a potential unacceptable human health or environmental risk; and does not have a regulatory standard based on peer-reviewed science, or the regulatory standards are evolving due to new science, detection capabilities, or pathways (Army 2018).

During the 2010 and 2015 Five-Year Reviews, 1,4-dioxane and NDPA were identified as potential new groundwater contaminants at RMA. Consistent with 2016 Army guidance, PFOA/PFOS were included in emerging contaminants monitoring since the EPA developed a health advisory level in drinking water.

The *Emerging Contaminants Sampling and Analysis Plan* (Navarro 2017h) was prepared in FY17 to investigate NDPA and PFOA/PFOS in groundwater and provide for continued monitoring of 1,4-dioxane. Sampling under this SAP was conducted in FY17 and FY18. A data summary report was prepared in 2019 presenting the results of the Emerging Contaminant monitoring program (Navarro 2019aa).

The FY19 Perfluorinated Compounds SAP included PFOA/PFOS sampling from a limited group of wells and the treatment plant influents/effluents to verify the 2017/2018 PFOA/PFOS results and determine the extent of potential releases at RMA (Navarro 2019v).

1,4-Dioxane

Groundwater monitoring was conducted in several phases between 2011 and 2018. The objective of the sampling program was to characterize the horizontal and vertical extent of 1,4-dioxane in groundwater at the RMA and assess the concentrations in the influent and effluent at the treatment plants. Investigative samples were collected from both on-post and off-post groundwater monitoring wells. Figure 6.3-71 presents the site-wide distribution of 1,4-dioxane in 2018.

1,4-Dioxane was detected in the majority of monitoring wells within and downgradient of RMA source areas (Navarro 2017i, 2019aa). The 1,4-dioxane concentration was above the CBSG in the Basin A, South Plants, Complex Army Trenches, and Basin F source areas with contaminant plumes extending to the NBCS and NWBCS (Figure 6.3-71). Several wells off post in the First Creek and Northern Pathway areas also exceeded the CBSG. 1,4-Dioxane was not detected in surface water sample locations collected from Lake Ladora in 2015 and 2017.

N-Nitrosodi-n-propylamine

During the 2015 Five-Year Review, NDPA was identified in groundwater above the CBSG of 0.005 µg/L; however, because NDPA was not part of the standard analytical reporting, further evaluation was required. The CBSG for NDPA was promulgated after the On-Post and Off-Post RODs were completed and no CSRG for NDPA was identified in the RODs. Groundwater and treatment plant sampling were conducted in 2017/2018 (Navarro 2017h) to determine whether NDPA should be added to the treatment plants' CSRG lists. Figure 6.3-72 presents the location of wells sampled for NDPA and the analytical results for each well where NDPA was detected.

NDPA was detected in multiple monitoring wells within and downgradient of RMA source areas (Figure 6.3-72). The NDPA concentration was above the CBSG in the Basin A, South Plants, Complex Army Trenches, and Basin F source areas with contaminant plumes extending to the NBCS and NWBCS, indicating that RMA is a source of NDPA contamination in groundwater (Navarro 2019aa). The NDPA concentration was also above the CBSG upgradient of FCS and NPS and in some NPS extraction wells. Review of treatment plant data shows that NDPA is present above the CBSG in all plant influent samples at concentrations above the CBSG. Effluent concentrations at all plants are below the CBSG, indicating effective treatment from the existing systems. Based on the monitoring data collected, NDPA was added to the CSRG list for NBCS, NWBCS and OGITS (OCN-LTMP-2019-001). Review of the analytical method has determined that the CBSG of 0.005 µg/L can be used as the CSRG.

Per- and Polyfluoroalkyl Substances

Per- and polyfluoroalkyl substances have been classified as emerging contaminants by the EPA. Although there is no current standard, EPA has developed a health advisory level for perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) in drinking water of 0.070 µg/L, either individually or combined when both are present. Site documents generated during the FYR period also refer to PFAS as perfluorinated compounds, or PFCs.

In 2016, the Army issued guidance for evaluating restoration sites for potential PAFS contamination to determine the presence/absence of PFAS and evaluate whether response actions are necessary (Army 2016a). The two PFAS of interest are PFOA and PFOS, which are typically associated with fire-fighting aqueous film-forming foams (AFFF). RMA facilities included a fire station located in the southwest corner of Section 36, which was in operation from 1942 to 2005. On-site fire-fighting engines housed at the station were equipped with tanks that contained AFFF; however, there is no record of the use or discharge of foam at the fire station. A review of RMA records revealed only one documented use of AFFF on site. In 1979, 25 gallons of AFFF were applied to an acetone spill in South Plants north of Building 514 (RMA 1979). The foam was used as a vapor suppressant while the spill was cleaned up. Other applications and chemicals have been related to PFAS contamination, including metal plating and other industrial manufacturing, which do not pertain to RMA. PFAS have also been associated with the manufacturing of some pesticides, although there is no record of their use at RMA.

Per- and polyfluorinated substances had not been evaluated previously in RMA groundwater; therefore, no historical PFAS groundwater data exist. The Army conducted an investigation from July 2017 to August 2018 to assess the potential for PFOA/PFOS groundwater contamination at the RMA (Navarro 2017h). The results of the investigation indicated detectable levels of PFOA/PFOS in RMA groundwater, although only one location near the South Plants spill area (near well 01525) was above the EPA health advisory level. The initial investigation concluded that further characterization of the PFOA/PFOS contamination was necessary. Figure 6.3-73 presents the location of wells sampled for PFOA/PFOS and the analytical results for each well where PFOA/PFOS were detected.

The FY19 Perfluorinated Compounds SAP included PFOA/PFOS sampling from a limited group of wells and the treatment plant influents/effluents to verify the 2017/2018 PFOA/PFOS results and determine the extent of potential releases at RMA.

As detailed in the FY19 Perfluorinated Compounds Data Summary Report (Navarro 2020i), RMA does not appear to be a significant source of PFOA/PFOS contamination in groundwater. Although PFOA/PFOS were detected in 19 of the 25 wells sampled, there were only five wells that exceeded the health advisory level. The sampling program did not establish a PFOA/PFOS background concentration since the compounds are not naturally occurring.

All of the wells exceeding the health advisory level are located in the vicinity of the South Plants source area associated with the documented use (Figure 6.3-73). Recommended actions included adding PFOA/PFOS analysis to select wells in the LTMP site-wide water quality tracking network and continued monitoring at the treatment plants in accordance with a future OCN to the LTMP. This OCN was completed in October 2020 (OCN-LTMP-2020-004).

6.3.3.10 Post-Shut-Off and Shut-Off Monitoring

Motor Pool System/Irondale Containment System Post-Shut Off Monitoring Results (#58)

The goals of the MPS/ICS Post-Shut-Off Monitoring SAP (URS 2011) are to monitor groundwater to evaluate concentrations relative to CSRGs in order to substantiate shutdown of the system. During the five-year monitoring period, the concentrations of DBCP and trichloroethylene measured in wells were below the CSRGs of 0.2 µg/L and 5 µg/L, respectively. The concentration of trichloroethylene increased to 4.6 µg/L in well 04535 in FY17, approaching the CSRG. However, the concentration decreased in FY18 and FY19 to around 1 µg/L. DBCP was not detected in the wells sampled. Table 6.3-28 provides monitoring data for the MP/ICS post-shut-off monitoring.

Table 6.3-28. Motor Pool System/Irondale Containment System Post-Shut-Off Monitoring Results

Well	Fiscal Year	Analyte Concentrations (µg/L)	
		DBCP	Trichloroethylene
04021	2017	NA	0.406
	2019	NA	0.446
04535	2015	LT 0.0194	0.977
	2016	NA	1.47
	2017	NA	4.6
	2018	NA	1.19
	2019	NA	0.891
33081	2015	LT 0.192	LT 0.2
	2016	LT 0.0192	NA

Note:
NA – Not analyzed

Water levels in the vicinity of the MPS/ICS have decreased by more than 5 feet during the five-year reporting period. Review of water level data presented in annual regional water level maps (Figure 6.3-74) indicates that the groundwater flow direction in the area appears unchanged. Post-shut-off monitoring will continue in accordance with the MPS/ICS SAP (URS 2011). The SAP does not specify a duration for post-shut-off monitoring. Trichloroethylene and DBCP concentrations have been below their respective CSRGs since post-shut-off monitoring started in FY12 and continuation of post-shut-off monitoring will be evaluated in the next five-year review period.

Groundwater Mass Removal Project Post-Shut-Off Monitoring Results (#60a)

The GWMRP post-shut-off monitoring period began in FY12 and was scheduled for five years as outlined in the SAP. One additional year of monitoring was completed in FY17 (URS 2012c). The GWMRP post-shut-off monitoring network included wells in the vicinity of and downgradient from the STF, as shown on Figure 6.3-75. Benzene was detected above the historical high concentration in well 01687 during the first year of monitoring in 2012 but was not detected in any of the downgradient post-shut-off wells in subsequent years (Table 6.3-29). Well 01049 was added to the monitoring program for sampling in FY13 and FY14 to monitor the area downgradient of well 01687, but benzene was not detected. Benzene was sampled twice in five years in well 01312, which was in the high concentration portion of the benzene plume, and the concentrations were within the historical range (Navarro 2018j).

The post-shut-off monitoring results confirmed that the benzene plume continues to be stable or is receding and is not migrating toward the lakes. Following completion of the post-shut-off monitoring period, an MCR was submitted to the Regulatory Agencies on June 12, 2018 (Navarro 2018j). The MCR was approved in January 2020.

Table 6.3-29. GWMRP Post-Shut-Off Monitoring Results

Well	Fiscal Year	Analyte Concentrations (µg/L)	
		Benzene	Chloroform
01049	2013	< 0.2	< 0.2
	2014	< 0.2	< 0.2
01600	2012	< 0.2	< 0.2
	2013	< 0.2	< 0.2
	2014	< 0.2	< 0.2
	2015	< 0.2	< 0.2
	2016	< 0.2	< 0.2
	2017	< 0.2	< 0.2
	2019	< 0.2	< 0.2
01670	2012	< 0.2	< 0.2
	2013	< 0.2	< 0.2
	2014	< 0.2	< 0.2
	2015	< 0.2	< 0.2
	2016	< 0.2	< 0.2
	2017	< 0.2	< 0.2
01687	2012	1,170	< 5
	2013	< 5	< 5
	2014	< 0.2	< 0.2
	2105	< 0.2	< 0.2

Table 6.3-29. GWMRP Post-Shut-Off Monitoring Results

Well	Fiscal Year	Analyte Concentrations (µg/L)	
		Benzene	Chloroform
	2016	< 0.2	< 0.2
	2017	< 0.2	< 0.2

Note: Well 01049 added due to benzene detection in well 01687.

Long-term monitoring is required in the STF area to continue monitoring of the benzene plume. The following wells in the vicinity of the STF were incorporated into the site-wide water quality tracking program (discussed in Section 6.3.3.2 of this report) for monitoring on a twice-in-five-year frequency:

01312	02505	02524
01600	02512	02525
02034	02523	02597

Water levels are also monitored as part of the annual site-wide water level tracking network. Water quality tracking results from FY19 were below reporting limits for all wells except well 02034, which had a benzene concentration of 0.223 µg/L. This was the first detection in well 02034 since 2004, but the concentration is well below the CSRG of 5 µg/L.

Railyard Containment System Shut Off Monitoring Results

The RYCS was designed to capture the Railyard DBCP plume. When the MPS/ICS extraction systems were shut down, 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 RYCS.

A RYCS pre-shut-off monitoring program was conducted during FY14. The results of the pre-shut-off program met the criteria for continuation of the shut-off process. The *Railyard Containment System Shut-Off Sampling and Analysis Plan*, and associated Decision Document DD-34, were prepared for review and approval by the Regulatory Agencies in 2016 (Navarro 2016k). The shut-off water quality monitoring network consists of eight wells, which are shown on Figure 6.3-76:

03501	03529
03502	03530
03503	03534
03528	03538

The wells are sampled for the ICS CSRG analytes DBCP and trichloroethylene. The RYCS met shut-off criteria and was shut down on May 25, 2016. RYCS shut-off monitoring took place on a quarterly basis for a one-year period beginning during the second quarter of FY17 through the first quarter of FY18, with detections below the CSRGs for DBCP (0.2 µg/L) and trichloroethylene (5 µg/L). Monitoring results are provided on Table 6.3-30. In accordance with the LTMP, the shut-off monitoring frequency was reduced to annual starting in FY19 following four quarters with results below the CSRGs. FY19 monitoring results indicate that trichloroethylene was not detected in any wells. DBCP was detected in well 03534 at a concentration of 0.0236 µg/L, which is below the CSRG of 0.2 µg/L.

Table 6.3-30. RYCS Shut-Off Monitoring Results for FY16 – FY19

Well	Sample Date	Analyte Concentrations (µg/L)	
		DBCP	Trichloroethylene
03501	6/8/16	LT 0.019	LT 0.2
	8/8/16	LT 0.0192	LT 0.2
	11/1/16	LT 0.0194	LT 0.2
	1/30/17	LT 0.0192	LT 0.2
	5/15/17	LT 0.0192	LT 0.2
	7/20/17	LT 0.0198	LT 0.2
	11/29/17	LT 0.0196	LT 0.2
	12/3/18	LT 0.0194	LT 0.2
03502 [1]	6/8/16	LT 0.0188	LT 0.2
	1/30/17	LT 0.0196	LT 0.2
	11/29/17	LT 0.0192	LT 0.2
03503	6/8/16	0.0729	LT 0.2
	8/8/16	0.124	LT 0.2
	11/1/16	0.119	LT 0.2
	1/30/17	0.0586	LT 0.2
	5/15/17	LT 0.0192	LT 0.2
	7/20/17	LT 0.0194	LT 0.2
	11/29/17	LT 0.0194	LT 0.2
	12/3/18	LT 0.0194	LT 0.2
03528	6/8/16	LT 0.0190	LT 0.2
	8/4/16	LT 0.0194	LT 0.2
	10/31/16	LT 0.0196	LT 0.2
	1/30/17	LT 0.0196	LT 0.2
	5/15/17	LT 0.0192	LT 0.2
	7/19/17	LT 0.0194	LT 0.2
	11/30/17	LT 0.0194	LT 0.2
	12/4/18	LT 0.0196	LT 0.2
03529	6/8/16	LT 0.0188	LT 0.2
	8/4/16	LT 0.0196	LT 0.2
	10/31/16	0.0258	LT 0.2
	1/31/17	0.0184	LT 0.2

Table 6.3-30. RYCS Shut-Off Monitoring Results for FY16 – FY19

Well	Sample Date	Analyte Concentrations (µg/L)	
		DBCP	Trichloroethylene
	5/16/17	LT 0.0196	LT 0.2
	7/19/17	LT 0.0196	LT 0.2
	11/30/17	LT 0.0192	LT 0.2
	12/4/18	LT 0.0194	LT 0.2
03530	6/8/16	LT 0.019	LT 0.2
	8/4/16	LT 0.0194	LT 0.2
	10/31/16	0.0411	LT 0.2
	1/31/17	LT 0.0192	LT 0.2
	5/16/17	LT 0.0194	LT 0.2
	7/19/17	LT 0.0194	LT 0.2
	11/30/17	LT 0.0192	LT 0.2
	12/4/18	LT 0.0194	LT 0.2
03534	6/8/16	LT 0.019	LT 0.2
	8/4/16	0.101	LT 0.2
	10/31/16	**0.297**	LT 0.2
	1/31/17	0.205	LT 0.2
	5/16/17	0.12	LT 0.2
	7/19/17	0.0551	LT 0.2
	11/30/17	0.025	LT 0.2
	12/3/18	0.0236	LT 0.2
03538	6/8/16	LT 0.0188	LT 0.2
	8/8/16	LT 0.0194	LT 0.2
	11/1/16	0.0443	LT 0.2
	1/31/17	0.0426	LT 0.2
	5/16/17	LT 0.0192	LT 0.2
	7/20/17	LT 0.0194	LT 0.2
	11/29/17	0.0197	LT 0.2
	12/3/18	LT 0.0192	LT 0.2

Notes:

1. Well 03502 is nested with well 03503. It was sampled during the first and fourth quarters of the first year to confirm
historical data that have shown the DBCP plume is located in the upper part of the aquifer.
2. DBCP concentrations in **bold** exceeded CSRG of 0.2 µg/L.

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6.3.3.11 Off-Post Water Level Monitoring

Off-post water level monitoring was conducted annually in in conjunction with on-post water level tracking. Water level data from on-post and off-post wells are used to map the potentiometric surface of the UFS across the region to determine groundwater flow paths for mapping contaminant plumes within the off-post CSRG exceedance monitoring area. Annual water-level maps are provided in the ASRs. There have been no significant changes in flow directions upgradient of the OGITS FCS and NPS over the past five years.

Groundwater levels were higher in much of the off-post area in FY15 subsequent to high precipitation in spring 2014 and 2015. Water levels were higher in the vicinity of O'Brian Canal where it is unlined, but not north of the NPS where a portion of the canal is lined. Seepage from unlined portions of the irrigation canals recharge the groundwater and affect the groundwater elevations near the canals. A portion of O'Brian Canal near the NPS in Section 12 was relocated and lined in 2008. The flow in the canal is seasonal and varies from year to year. Within the FCS, there was little or no change in water levels during the reporting period, which is not unexpected since shallow groundwater in the area is affected by First Creek surface water ponding on the west and east sides of Highway 2. Surface water is typically present in this area for much of the year.

6.3.4 Surface Water Monitoring

6.3.4.1 On-Post Surface Water Quality Monitoring (#50a)

An On-Post Short-Term Surface Water Sampling program was implemented starting in 2012 (URS 2012a) and continued through FY17. The objective of the on-post Surface Water Monitoring Program is to ensure that there are no unacceptable effects on biota from surface water contamination. Surface water data have been evaluated to confirm whether surface water quality has been adversely impacted due to the construction of the soil cover systems and the establishment of vegetation during remedy. Sampling was also conducted to evaluate whether surface water quality has been adversely affected due to hydraulic connections between migrating contaminated groundwater and the lakes.

Sampling was conducted during the reporting period under the Short-Term Surface Water Sampling and Analysis Plan (URS 2012a). Due to the lack of surface water in some of the locations, the sampling required in the SAP was not completed until FY15. The surface water locations sampled on post during the five-year reporting period are shown on Figure 6.3-78 and include the following:

- Lake Ladora – Location SW020009
- Borrow Area 5 Pond – Location SW24005
- North Plants – Location SW25101
- Former Basin E Pond – Location SW26002

The analyte list for on-post surface water includes organochlorine pesticides, metals, VOCs for SW020009 and SW24005, and DIMP for SW24005. Due to detections of metals at location

SW26002 in FY13 and FY15, Addendum 1 to the SAP was completed to provide for additional monitoring (Navarro 2016i), which was not completed until FY17 due to lack of surface water at this location. During the reporting period one sample was collected at each location from Lake Ladora, the Borrow Area 5 Pond Outlet, and North Plants. Five samples were collected from the Former Basin E Pond. Table 6.3-31 presents the analytical results for surface water samples collected at on-post locations during the five-year reporting period.

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Table 6.3-31. Summary of Analytes Detected in Short-Term Monitoring of On-Post Surface Water, FY15–FY19

Analyte	Analyte Concentrations by Location and Sample Date (µg/L)							
	SW020009 Lake Ladora	SW24005 Borrow Area 5	SW25101 North Plants	SW26002 Former Basin E Pond				
	6/24/15	5/5/15	5/5/15	4/23/15	10/22/15	5/9/17	6/12/17	9/26/18
Organochlorine Pesticides								
alpha-Chlordane	LT 0.00281	0.00648	0.012	OCPs were not analyzed in SW26002 samples during the five-year reporting period.				
alpha-Endosulfan	0.0193	0.00393	0.00326					
Aldrin	0.00704	LT 0.00499	0.00856					
Dieldrin	0.00987	LT 0.00361	**0.0224**					
Endrin	0.0134	0.011	0.0176					
Endrin ketone	LT 0.0025	0.00476	0.0471					
gamma-Chlordane	0.0154	LT 0.00656	LT 0.00656					
HPCL	0.0138	LT 0.005	0.0071					
HPCLE	0.0133	LT 0.00423	LT 0.00423					
Isodrin	0.00908	LT 0.00554	LT 0.00554					
Metals (dissolved unless otherwise noted)								
Aluminum	LT 100	41,700	325,000	1,670	13,100	23,200	24,000	500
Antimony	LT 6	LT 30	LT 30	LT 30	LT 30	LT 30	LT 30	LT 30
Arsenic	LT 1	21	95.7	24.2	11.1	5.01	21.9	18.4
Arsenic (total)	NA	22.7	187	22.7	30	6.07	55.4	17.6
Barium	60.2	523	2,230	41.5	3,060	179	281	108
Beryllium	LT 2	LT 2	14.8	LT 2	8.3	LT 2	LT 2	LT 2
Boron	95.5	NA	NA	NA	NA	NA	NA	NA
Cadmium	LT 4	LT 4	9	LT 4	6.9	31	LT 4	LT 4
Calcium	42,100	104,000	366,000	11,700	85,000	14,800	40,900	45,100
Chromium	LT 10	39.7	265	LT 10	LT 10	18.5	18.2	LT 10
Cobalt	LT 10	LT 10	82.5	LT 10	30.5	LT 10	LT 10	LT 10
Copper	LT 10	30.1	172	36.1	51.3	15.3	31.8	LT 10

Table 6.3-31. Summary of Analytes Detected in Short-Term Monitoring of On-Post Surface Water, FY15–FY19

Analyte	Analyte Concentrations by Location and Sample Date (µg/L)							
	SW020009 Lake Ladora	SW24005 Borrow Area 5	SW25101 North Plants	SW26002 Former Basin E Pond				
	6/24/15	5/5/15	5/5/15	4/23/15	10/22/15	5/9/17	6/12/17	9/26/18
Iron	LT 100	31,500	285,000	1,020	1,660	16,200	16,700	418
Lead	LT 3	18.5	145	LT 3	12	14.3	14.9	LT 3
Magnesium	16,900	20,200	78,500	1,390	9,990	5,230	10,800	8,870
Manganese	161	361	3,230	19.5	3,860	190	466	35.6
Nickel	LT 20	21.8	186	LT 20	45.4	LT 20	23.1	LT 20
Potassium	4,650	12,900	68,800	12,200	20,800	10,500	23,700	22,700
Selenium	LT 5	LT 5	17.6	LT 5	LT 5	LT 5	5.1	LT 5
Silver	LT 2.6	LT 10	LT 10	LT 10	LT 10	LT 10	LT 10	LT 10
Sodium	80,500	12,400	2,520	67,600	36,800	1,780	60,500	17,600
Thallium	LT 5	LT 5	LT 5	LT 5	LT 5	LT 5	LT 5	LT 5
Vanadium	LT 10	90.1	514	64.3	49.3	40.5	56.7	11.8
Zinc	13.9	120	1,030	LT 10	126	93.8	784	LT 10
Water Quality Parameters								
Ammonia	98	102	267	Water quality parameters were not analyzed in SW26002 samples during the five-year reporting period.				
Chloride	102,000	1,320	1,100					
Nitrite	LT 1000	LT 1000	1,480					
Phosphate (total)	157	4,960	6,200					
Sulfate	75,400	2,880	3,950					
Total organic carbon	7,500	37,000	23,000					
Dissolved organic carbon	8,100	14,000	13,000					

Notes:

Concentrations in **bold** exceed the CSRG/PQL. The only exceedance was for dieldrin detected in the sampled collected at SW25101 in May 2015.

Concentrations highlighted exceed calculated chronic and/or acute aquatic life standards (Navarro 2020c).

LT – Concentration less than the method reporting limit. NA – Not Analyzed

Table 6.3-32. Analytical Results of the FY15–FY19 Off-Post Surface Water Monitoring Program

Site	Sample Date	Analyte Concentrations (µg/L)						
		Aldrin	Arsenic	Chloride	DIMP	Dieldrin	NDMA	Sulfate
SW08003 First Creek Near Buckley Road	7/29/15	LT 0.00499	1.25	92,200	LT 0.5	LT 0.00361	LT 0.00115	172,000
	7/12/16	LT 0.00499	LT 1	102,000	LT 0.5	LT 0.00361	LT 0.0015	176,000
	8/22/17	LT 0.00499	1.14	92,800	LT 0.5	LT 0.00361	LT 0.003	153,000
	6/7/18	LT 0.00898	LT 1	77,300	LT 0.5	LT 0.00263	LT 0.003	144,000
	7/17/19	LT 0.00898	1.25	96,500	LT 0.5	LT 0.00263	LT 0.003	147,000
SW24004 First Creek Near 96th Avenue	7/29/15	LT 0.00499	1.82	115,000	LT 0.5	LT 0.00361	LT 0.00115	229,000
	7/12/16	LT 0.00499	1.14	134,000	LT 0.5	LT 0.00361	LT 0.0015	227,000
	8/22/17	LT 0.00499	1.70	127,000	LT 0.5	LT 0.00361	0.00445	222,000
	6/7/18	LT 0.00898	1.66	105,000	LT 0.5	LT 0.00263	LT 0.003	189,000
	7/17/19	LT 0.00898	**2.56**	121,000	LT 0.5	0.00327	LT 0.003	172,000
SW37001 First Creek Near Highway 2	7/29/15	LT 0.00499	**2.43**	136,000	LT 0.5	LT 0.00361	LT 0.00115	250,000
	7/12/16	LT 0.00499	**2.83**	135,000	LT 0.5	0.00908	LT 0.0015	223,000
	8/22/17	LT 0.00499	2.07	142,000	LT 0.5	LT 0.00361	0.00409	242,000
	6/7/18	LT 0.00898	**2.60**	127,000	LT 0.5	0.00659	LT 0.003	230,000
	7/17/19	LT 0.00898	**3.12**	129,000	LT 0.5	0.00535	LT 0.003	179,000
CSRG/PQL (µg/L)		0.014	2.35	250,000	8	0.013	0.009	540,000

Notes:

Concentrations in **bold** exceeded CSRG/PQL.

LT – Concentration less than the method reporting limit.

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Concentrations in the sample from Lake Ladora were below the aquatic life standards and below the CBSGs/PQLs. Thus, these data indicate that runoff from exposed surface soil from the South Plants cover did not impact surface water above surface water acute or chronic aquatic life standards and that South Plants groundwater plumes are not migrating into the lakes above CBSGs. Similarly, concentrations were below the surface water standards at Borrow Area 5 (SW24005) indicating that runoff from the landfill caps did not impact surface water at that location.

Concentrations of dissolved metals including cadmium, copper, manganese, nickel, selenium and zinc in surface water at location SW25101 exceeded the calculated aquatic life standards. In addition, concentrations of aldrin and dieldrin exceeded their respective PQLs. However, based on the local topography, contaminants at this location do not have the potential to migrate to downstream receptors at concentrations above the aquatic life standards, or have the potential to migrate off-post and exceed the off-post remediation goals in surface water.

Surface water at SW26002, former Basin E Pond, contained dissolved metals concentrations exceeding the calculated aquatic life standards in multiple samples collected. This was identified as an issue in the 2015 FYRR (Navarro 2016h). Assessment of the surface water data and existing soil data from the Remedial Investigation indicated the possibility that elevated dissolved metal concentrations in the former Basin E Pond resulted from dissolution of naturally occurring metals in soil. However, due to the continued presence of metals exceeding the calculated aquatic life standards, an addendum to the Short-Term SAP was completed to further investigate the site (Navarro 2016i). Planned sampling under the SAP addendum included two additional samples; one sample after a rain event and a second sample when it is observed that the pond was shrinking as it was drying up.

The additional sampling was not completed until 2017 due to a lack of water at the site in 2016. Concentrations of cadmium, copper, selenium and zinc exceeded their respective calculated standards in one or both samples collected. Although concentrations of all metals, except cadmium, were higher in the second sample collected, the surface water sampling proved inconclusive for determining the source of the elevated concentrations.

As a result, an investigation of surface soil in the former Basin E area was conducted to determine whether there were anthropogenic sources of metals within Basin E contributing to surface water contamination (Navarro 2018f). Statistical and geochemical evaluation of the soil data provided adequate weight-of-evidence that the presence of trace metals in the surface soil indicates natural background concentrations and there was no anthropogenic source of metals (Navarro 2019b).

Conclusion of the former Basin E investigation completed the requirements of the short-term surface water monitoring program, as documented in the MCR (Navarro 2020d). No further on-post surface water monitoring is required.

6.3.4.2 Off-Post Surface Water Monitoring (#50c)

Surface water locations SW08003, SW24004, and SW37001 (Figure 6.3-78) were sampled annually FY15–FY19. During the five-year reporting period, only arsenic was detected at concentrations above the off-post CSRG in samples collected in First Creek near at 96th Avenue (SW24004) in FY19 and Highway 2 (SW37001), downgradient of RMA, in FY15, FY16, FY18, and FY19 (Table 6.3-32).

Historically, arsenic in the First Creek sample collected at Highway 2 (SW37001) has occurred at higher concentrations compared to samples collected at the RMA boundary at 96th Avenue (SW24004). The concentration of arsenic remains higher in First Creek at off-post location SW37001 than at boundary location SW24004—consistent with the historical trend in arsenic detected within First Creek. Therefore, it is likely that the presence of arsenic in surface water at SW37001 is naturally occurring and not attributable to RMA activities.

With the continuing removal of organic contaminants from the groundwater in the area, concentrations of the target suite of organic constituents in surface water at off-post station SW37001 are expected to continue to decrease. Treatment of groundwater contaminants at the NBCS and the OGITS appear to be having a positive effect on First Creek water quality.

6.3.5 Site-Wide Biota Monitoring (#48)

The long-term BMP was developed to evaluate the effectiveness of the RMA remedy for biota as required by the ROD. Phase 1 of the BMP included collection of starling brain and kestrel egg samples between 2007 and 2013. Although the starling evaluation was completed as planned, the kestrel portion of the BMP could not be completed as outlined in the BMP.

The kestrel monitoring program was conducted over four collection seasons; however, less than half of the specified nest boxes provided at least one egg per collection season for a minimum of three seasons. Although the majority of the dieldrin concentrations in the eggs collected were below detection, there was insufficient data to evaluate the decision rule described in the BMP for all nest box locations. Dieldrin egg residues above the egg No Observable Adverse Effect Concentration (NOAEC) were detected once in each of seven different kestrel nest boxes during the four seasons that the kestrel nest boxes were monitored. In addition, for nest boxes where the mean egg concentration did exceed the NOAEC, Phase 2 tissue collection could not be implemented as described in the BMP due to a lack of nest box occupancy. Completion of the BMP was identified as an issue in the 2015 FYRR.

The Army conducted a series of meetings with the Regulatory Agencies to determine requirements for completion of the program. Due to the difficulties in obtaining sufficient kestrel samples and the desire to reduce the impact on the kestrel population, sampling requirements for program completion were revised to focus on soil sampling rather than collection of kestrel samples.

The Army completed the Data Summary Report for tissue sampling in November 2016 (Navarro 2016e) and prepared a sampling and analysis plan for the soil sampling effort (Navarro 2017d). An incremental sample methodology was selected to provide an estimate of mean surface soil concentrations across the entire sample area. The overall sample area was selected after review of the Phase 1 tissue data and supplemental data evaluation. Because Phase 2 was focused on completing the kestrel portion of the BMP, the sample area was divided into decision units approximating the kestrel foraging range of 100 acres with no modifications for remedy boundaries like soil cover boundaries. The nest boxes that required additional investigation and the corresponding 59 soil sample decision units are shown on Figure 6.3-78.

Incremental soil sampling was conducted in November 2017 throughout the area where kestrel results indicated potential exposure. Nine decision units were randomly selected to evaluate the sample approach and incremental sampling methodology. Three samples, the initial sample plus replicate and triplicate samples, were collected in these units to assess sample variability, expressed as the relative standard deviation.

The samples obtained as part of this program were analyzed for dieldrin only since dieldrin was identified as the primary risk driver in the BMP. All soil results were below the selected screening criteria of 110 μg/g indicating that the remedy effectively eliminated significant exposure pathways in the area sampled (Navarro 2018i). A summary of sample results, including the replicate and triplicate evaluation, is provided on Table 6.3-33. Sample variability exceeded the 35 percent acceptability threshold in two sample sets. However, the maximum concentrations detected were less than 20 percent of the screening criteria and the results were determined to be acceptable.

The Army completed the Data Summary Report for soil sampling in June 2018 (Navarro 2018i) and prepared a draft MCR in December 2018 to document completion of the ROD-required biomonitoring program. The MCR is awaiting final EPA review. Completion of the BMP documentation is identified under Other Findings in Section 9.0.

Table 6.3-33. Biomonitoring Program Phase 2 Soil Sampling Results

Decision Unit	Site ID	Sample Date	Dieldrin Concentration (ugg)	Replicate/ Triplicate	Average	Standard Deviation	Relative Standard Deviation
DU1	BMP2SS001	11/9/2017	LT 0.005				
DU2	BMP2SS002	11/9/2017	LT 0.005				
DU3	BMP2SS003	11/8/2017	LT 0.005				
DU4	BMP2SS004	9/26/2017	0.00694		0.0056	0.00112	19.8%
DU4	BMP2SS060	9/26/2017	LT 0.005	R			
DU4	BMP2SS061	9/26/2017	LT 0.005	T			
DU5	BMP2SS005	11/8/2017	LT 0.005				
DU6	BMP2SS006	11/9/2017	LT 0.005				
DU7	BMP2SS007	11/15/2017	LT 0.005				
DU8	BMP2SS008	11/14/2017	0.0111				
DU9	BMP2SS009	11/14/2017	0.00737				
DU10	BMP2SS010	11/14/2017	LT 0.005				

Table 6.3-33. Biomonitoring Program Phase 2 Soil Sampling Results

Decision Unit	Site ID	Sample Date	Dieldrin Concentration (ugg)	Replicate/ Triplicate	Average	Standard Deviation	Relative Standard Deviation
DU11	BMP2SS011	11/8/2017	LT 0.005				
DU12	BMP2SS012	10/17/2017	LT 0.005				
DU13	BMP2SS013	9/27/2017	LT 0.005		0.005	0	0.0%
DU13	BMP2SS062	9/27/2017	LT 0.005	R			
DU13	BMP2SS063	9/27/2017	LT 0.005	T			
DU14	BMP2SS014	11/21/2017	0.00592				
DU15	BMP2SS015	11/21/2017	0.0299				
DU16	BMP2SS016	11/14/2017	LT 0.005				
DU17	BMP2SS017	11/13/2017	LT 0.005				
DU18	BMP2SS018	10/18/2017	LT 0.005				
DU19	BMP2SS019	10/17/2017	LT 0.005				
DU20	BMP2SS020	11/15/2017	LT 0.005				
DU21	BMP2SS021	11/15/2017	LT 0.005				
DU22	BMP2SS023	11/27/2017	0.0276				
DU23	BMP2SS022	10/2/2017	LT 0.005		0.0048	0.00029	6.0%
DU23	BMP2SS064	10/2/2017	LT 0.005	R			
DU23	BMP2SS065	10/2/2017	0.0045	T			
DU24	BMP2SS024	11/13/2017	0.0116				
DU25	BMP2SS025	11/6/2017	0.00529				
DU26	BMP2SS026	10/17/2017	LT 0.005				
DU27	BMP2SS027	11/15/2017	LT 0.005				
DU28	BMP2SS028	10/4/2017	LT 0.005		0.005	0	0.0%
DU28	BMP2SS066	10/4/2017	LT 0.005	R			
DU28	BMP2SS067	10/4/2017	LT 0.005	T			
DU29	BMP2SS029	11/27/2017	LT 0.005				
DU30	BMP2SS030	11/28/2017	0.0592				
DU31	BMP2SS031	11/28/2017	0.009				
DU32	BMP2SS032	10/3/2017	LT 0.005		0.0075	0.00361	48.3%
DU32	BMP2SS068	10/3/2017	0.0116	R			
DU32	BMP2SS069	10/3/2017	0.00578	T			
DU33	BMP2SS033	10/18/2017	LT 0.005				
DU34	BMP2SS070	10/5/2017	LT 0.005				
DU34	BMP2SS071	10/5/2017	LT 0.005				
DU35	BMP2SS035	11/16/2017	LT 0.005				
DU36	BMP2SS036	11/20/2017	LT 0.005				

Table 6.3-33. Biomonitoring Program Phase 2 Soil Sampling Results

Decision Unit	Site ID	Sample Date	Dieldrin Concentration (ugg)	Replicate/ Triplicate	Average	Standard Deviation	Relative Standard Deviation
DU37	BMP2SS037	11/28/2017	0.00555				
DU38	BMP2SS038	10/12/2017	0.0147		0.0153	0.00067	4.4%
DU38	BMP2SS072	10/12/2017	0.0151	R			
DU38	BMP2SS073	10/12/2017	0.016	T			
DU39	BMP2SS039	10/31/2017	LT 0.005				
DU40	BMP2SS040	10/31/2017	LT 0.005				
DU41	BMP2SS041	10/18/2017	LT 0.005				
DU42	BMP2SS042	10/19/2017	LT 0.005				
DU43	BMP2SS043	10/23/2017	LT 0.005				
DU44	BMP2SS044	11/21/2017	0.00503				
DU45	BMP2SS045	11/20/2017	0.00694				
DU46	BMP2SS046	10/25/2017	LT 0.005				
DU47	BMP2SS047	10/25/2017	LT 0.005				
DU48	BMP2SS048	10/23/2017	LT 0.005				
DU49	BMP2SS049	11/20/2017	0.0174				
DU50	BMP2SS050	10/12/2017	0.00538		0.0121	0.00607	50.2%
DU50	BMP2SS074	10/16/2017	0.0137	R			
DU50	BMP2SS075	10/12/2017	0.0172	T			
DU51	BMP2SS051	10/24/2017	0.00512				
DU52	BMP2SS052	10/16/2017	LT 0.005		0.005	0	0.0%
DU52	BMP2SS076	10/16/2017	LT 0.005	R			
DU52	BMP2SS077	10/16/2017	LT 0.005	T			
DU53	BMP2SS053	10/25/2017	LT 0.005				
DU54	BMP2SS054	10/24/2017	LT 0.005				
DU55	BMP2SS055	11/6/2017	0.0123				
DU56	BMP2SS056	11/2/2017	LT 0.005				
DU57	BMP2SS057	11/2/2017	0.00923				
DU58	BMP2SS058	11/1/2017	LT 0.005				
DU59	BMP2SS059	11/1/2017	0.0485				

6.3.6 Caps and Covers Monitoring

6.3.6.1 Hazardous Waste Landfill Monitoring

Remediation wastes have been disposed in the Corrective Action Management Unit HWL facility. State regulations (6 Code of Colorado Regulations 1007-3, Section 264.552) require that areas within the CAMU where remediation wastes remain in place after closure be managed and contained to control, minimize, or eliminate future releases to the extent necessary to protect human health and the environment. During the HWL closure period a cap was constructed over the HWL as required by the HWL Closure Plan (TtEC 2006a). The integrity of the HWL Cap will be maintained by the U.S. Army for the duration of the post-closure period. The HWL entered post-closure following physical completion of the cap construction on May 20, 2009. Refer to Figure 6.3-80 (Sheets 1 and 2) for HWL RCRA Cap details.

Landfill Inspection and Maintenance

The procedure for inspecting the HWL soil cap conditions and infrastructure features is detailed in SOP HWL 001, presented in Appendix A of the HWL Post-Closure Plan (Navarro 2019d). This SOP includes procedures for inspections, as well as a procedure for measuring the loss of cap soil thickness. The HWL was inspected quarterly and semiannually throughout this FYR period.

Issues noted during inspections have primarily focused on the condition of the vegetation community and erosion. Since the HWL was not irrigated after construction, the perennial grasses being established in the rock-amended vegetative soil layer relied on rainfall only. This led to a relatively slow establishment of native grasses on the cap and surrounding area. Vegetation establishment continues to improve from year to year and the population of broadleaf weedy species continues to decline. Weed control was a consistent area of emphasis with special attention given to weedy species that are the most difficult to control such as bind weed, thistles, and cheat grass. The selected weed control methods were specific to the weedy species being addressed. Chemical control, either through spot-spraying or broadcast spraying, was routine. Herbicides were used to address specific species while minimizing the impact on the native perennial grasses. Ground clear herbicides were also applied to the perimeter road, access roads and around the wastewater conveyance features to prevent vegetative damage to the road surface and to provide safe work areas around the conveyance features that were free of habitat for potentially dangerous wildlife like rattlesnakes. Mowing was occasionally used on low-slope areas to control weedy species such as kochia.

Areas that could benefit from overseeding were identified during formal inspections, performance of maintenance activities, and vegetation surveys throughout the growing seasons. These areas were typically either weedy areas where the perennial grasses had not established themselves yet, or areas where soil repairs were made, leaving bare ground. Overseeding was performed by hand in small areas, but larger areas were overseeded with broadcast seeding techniques.

Erosion was significantly less pervasive during this FYR period than it was in the first years following cap construction. Erosion was limited to areas of high surface flow such as perimeter channel side slopes where vegetation was not well established and LCS/LDS manhole access roads. No erosion rills were observed on the sideslopes of the HWL itself. Erosion on channel sideslopes was repaired using rock-amended vegetative soil and hand seeding to improve vegetation establishment. In one case, erosion control logs and blankets were installed over the seeded area. Erosion on access roads was repaired by re-grading the affected road with a motor grader.

Animal trails were occasionally identified on the HWL cap. Deer were frequently seen on and around the landfill and began establishing trails on the sideslopes. Maintenance personnel alternately closed and opened gates in the HWL perimeter fence to manage animal traffic and minimize trail formation.

The HWL cap includes a network of nine erosion/settlement monuments that are surveyed and measured semiannually in accordance with SOP HWL 001. The monuments are exposed at the soil surface and extend downward through the soil portion of the cap to the biota barrier layer. The exposed length of each monument is measured semiannually and recorded during the performance of Type II inspections in accordance with SOP HWL 001. The measured soil thickness loss for all nine monuments between April 2015 and March 2020 has ranged from 0.0 to 4.25 inches, which is below the non-routine trigger level of 4.8 inches. Erosion monument EM-HWL01 measured as much as 4.25 inches of soil loss during the spring 2017 Type II inspection. Although the measurement was below the Non-Routine Action trigger level, the maintenance personnel inspected the monument and surrounding area for indications of potential issues. Inspectors noted that the monument was located within a localized depression, which had been commonly observed around the HWL and ELF erosion/settlement monuments in the past. The soil thickness loss was most likely a result of natural consolidation of loosely compacted soil around the monument and was not representative of a broader impact area. Approximately one cubic yard of rock amended soil was placed in the depression in June of 2017 to fill the area and match surrounding grades. The repair area was hand seeded.

Survey results have not indicated any significant movement of the cap either horizontally or vertically.

The cover perimeter survey monuments were surveyed in the spring of 2020. All monuments were successfully located.

Additional details regarding the inspections and maintenance performed on the HWL are available in the landfill monitoring reports issued annually in June (Navarro 2015g, 2016j, 2017g, 2018h, 2019q, 2020b).

Wastewater Management

The HWL was constructed with two cells, each cell containing two LCS sumps and two LDS sumps. Each sump is equipped with a wastewater conveyance system to individually transfer wastewater to a lift station located near the northwest corner of the landfill. Conveyance piping connects the lift station to two tanks located in the Leachate Storage/Loadout Facility (LS/LF) Building.

The Wastewater Operators inspected and maintained the HWL LCS/LDS in accordance with the HWL Post-Closure Wastewater Management Plan, contained in Appendix C of the HWL Post-Closure Plan (Navarro 2019d). The following routine maintenance and repair activities were performed on the HWL LCS/LDS.

- Performed monthly inspections on the HWL emergency lights and fire extinguishers.

- Performed monthly inspections on the lift station liner leak detection and conveyance pipelines leak detection.
- Performed quarterly inspections on the HWL LCS/LDS and Wastewater Conveyance System.
- Performed quarterly inspections for grounding and tool safety inspections and first aid kits.
- Performed weekly HWL leak detection panel readings.
- Repaired and replaced system components as necessary.
- Transferred wastewater from the HWL LCS/LDS manholes to the lift station, and then to the storage tanks in the LS/LF Building as needed.
- Wastewater from the storage tanks in the LS/LF Building was shipped off site for treatment and disposal.

The Wastewater Operators documented system inspections on inspection forms included in the HWL Post-Closure Wastewater Management Plan. Also, a system maintenance database was used to document inspections and maintenance activities. Wastewater O&M Reports were generated by the database and included log entries for inspections and maintenance activities.

The volume of wastewater generated by the HWL per year is shown in Table 6.3-34.

Table 6.3-34. HWL Wastewater Volumes

Year	Period Start	Period End	Volume (gal)
2015	May 2014	April 2015	28,037
2016	May 2015	April 2016	30,736
2017	May 2016	April 2017	28,077
2018	May 2017	April 2018	21,490
2019	May 2018	April 2019	26,116
2020	May 2019	April 2020	21,661

Action Leakage Rate Analysis

Each month the Army calculated the rate of leachate collected in each LDS sump and compared that rate to the ALR for the sump as described in the Action Leakage Rate/Response Action Plan, provided in Appendix D of the HWL Post-Closure Plan (Navarro 2019d). The average daily flow rate was calculated as the volume of liquid pumped from the sump during the month, divided by the number of days in the month; divided by the acreage of surface area served by the sump. This average value is defined as the average daily flow rate and is expressed as gallons per acre per day (gpad). This average daily flow rate was then compared to the ALR and 85 percent of the ALR to determine whether any response action is necessary. The average daily flow rate for all four LDS sumps was much lower than the ALR and the non-routine action trigger level of 85 percent of the ALR for every month in the FYR period. The maximum average daily flow rate was 2.62 gpad, measured in LDS2 in October 2019. The ALR for LDS2 is 131 gpad. The performance standards and non-routine action trigger levels for leak detection liquids were not exceeded during the five-year review period.

LCS/LDS Post-Closure Monitoring

For the majority of this FYR period water quality samples were collected quarterly from the sampling port on each LCS/LDS line when wastewater is present. For three quarters of the year (Calendar Quarters 1, 3, and 4) these samples were analyzed for the indicator compounds, and for one quarter (Calendar Quarter 2) the samples are analyzed for the complete analyte list.

In May of 2019 the sampling approach was changed to an as-needed sampling frequency triggered by the level of wastewater in the sumps. The volume of wastewater generated by the landfill had dropped off significantly since the post-closure period began, and quarterly sampling had become unnecessary. The new approach initiates sampling before wastewater is pumped out of the sump either because the wastewater reached the High Level setting defined in Section 3.1.1 of the HWL PCP Wastewater Management Plan, or for other wastewater management purposes. The first sample collected from each sump within a calendar year is analyzed for the complete list of analytes, and any subsequent samples collected with the year are analyzed for the indicator compound analytes. The Army proposed the change in OCN-HWL-2019-001, which was approved by the regulatory agencies on May 2, 2019.

The LCS results can be used to identify what specific compounds are detected in the HWL leachate. Based on the results from the LCS samples during the operational, closure, and post-closure groundwater monitoring, the indicator compounds selected for analysis and the chemical groups (VOCs, pesticides, DIMP, and metals) are consistent with wastes placed in the landfill and are within the chemical groups used in determining potential groundwater impacts. The indicator compounds detected in the HWL LCS sumps during this FYR period include arsenic, benzene, chromium, DIMP, dichlorodifluoromethane, dicyclopentadiene, dieldrin, mercury and lead.

The objective of the HWL LDS sampling is to assist in monitoring for potential leaks in the landfill liner systems and to provide data necessary for interpreting whether contamination in downgradient monitoring wells can be tied to leakage from the HWL. To meet these objectives, analyte classifications have been established which determine data review and reporting requirements for the analytes list provided in the HWL PCGMP. The analyte classifications are:

- Analytes Excluded from LDS Reporting Requirements
- Analytes Requiring Reporting If Detected
- Watch List Analytes

The analyte classifications are based on the data end use and frequency of detections in previous sampling events.

Based on results from the LDS samples collected during the operational, closure, and post-closure phases, the HWL LCS liner systems appear to be intact. LDS sample results that required evaluation and regulatory agency notification during this FYR period are presented in Table 6.3-35. There were no LDS analytical results in 2018 and 2019 that required regulatory agency notification per Table 3.0-2 of the *Hazardous Waste Landfill Post-Closure Plan* (Navarro 2019d).

Table 6.3-35. HWL Leak Detection System Analyte Detection Summary (2015 – 2019)

Analyte	NRAP Number	Classification	Sump	Sample Date	Concent. (µg/L)	Reporting Limit (µg/L)	Tigger Level (µg/L)
ACLDAN	2015-001	Watch List	LDS4	4/21/15	0.097	0.00281	0.069
Aldrin	2015-005	Watch List	LDS4	8/3/15	0.184	0.00499	0.16
MEXCLR	2016-001	Report if Detected	LDS4	10/26/15	0.0736	0.00269	N/A
TDGCL	2016-005	Report if detected	LDS2	4/20/16	11.9	5.0	N/A
ACLDAN	2016-005	Watch List	LDS4	4/20/16	0.102	0.00281	0.069
Lead	2016-005	Watch List	LDS1	4/20/16	18.2	3.0	15.0
Dieldrin	2016-007	Watch List	LDS4	10/20/16	0.0859	0.00361	0.073
Endrin	2016-007	Watch List	LDS4	10/20/16	0.157	0.00399	0.088
Endrin	2017-001	Watch List	LDS4	1/18/17	0.184	0.00399	0.088
Dieldrin	2017-002	Watch List	LDS4	7/12/17	0.0867	0.013 (PQL)	0.073

ACLDAN – alpha-Chlordane MEXCLR – methoxychlor TDGCL – thiodiglycol

It is common for analytes to be detected in HWL LDS sump samples. Typically, the detections are attributed to contaminants in the LCS clay liner material, rather than indications of leaks in the liner system. The soil used to construct the compacted clay liners of the HWL contained low levels of RMA contaminants that only became detectable after they were mobilized in water and analyzed using a method that had a much lower MRL than what can be achieved in soil analyses.

Evaluations of the LDS sample results included review of detections in borrow soil used to construct the liner, review of the historic range of detections for the LDS sump, review of concentrations of the compound in the corresponding LCS sump, history of decreasing MRLs for the subject compound, and investigation into laboratory Quality Control documentation. None of the LDS analytical result evaluations have indicated potential leaks in the landfill liner systems. Complete descriptions of the evaluation findings are contained in the NRAPs corresponding to each regulatory agency notification.

6.3.6.2 Enhanced Hazardous Waste Landfill Monitoring

Remediation wastes have been disposed in the CAMU ELF facility. State regulations (6 Code of Colorado Regulations [CCR] 1007-3, Section 264.552) require that areas within the CAMU where remediation wastes remain in place after closure be managed and contained to control, minimize, or eliminate future releases to the extent necessary to protect human health and the environment. During the ELF closure period a cap was constructed over the ELF as required by the ELF Closure Plan (TtEC 2008c). The integrity of the ELF Cap will be maintained by the U.S. Army for the duration of the post-closure period. The ELF entered post-closure following physical completion of the cap construction on May 27, 2010. Refer to Figure 6.3-80 (Sheets 1 and 2) for ELF RCRA Cap details.

Landfill Inspection and Maintenance

The procedure for inspecting the ELF soil cap conditions and infrastructure features is detailed in SOP ELF 001, presented in Appendix A of the ELF Post-Closure Plan (Navarro 2020f). This SOP includes procedures for inspections, as well as a procedure for measuring the loss of cap soil thickness. The ELF was inspected quarterly and semiannually throughout this FYR period.

Like the HWL, issues noted during inspections have primarily focused on the condition of the vegetation community and erosion. Since the ELF was not irrigated after construction, the perennial grasses being established in the rock-amended vegetative soil layer relied on rainfall only. This led to a relatively slow establishment of native grasses on the cap and surrounding area, and the persistence of weedy populations on south and west facing slopes. Perennial native grasses have become well established on the north and east faces, the top of the landfill, and surrounding areas. Vegetation establishment continues to improve from year to year and the population of broadleaf weedy species continued to decline. Weed control was a consistent area of emphasis with special attention given to species that are the most difficult to control such as bind weed, thistles, and cheat grass. The selected weed control methods were specific to the weedy species being addressed. Chemical control, either through spot-spraying or broadcast spraying, was routine. Herbicides were used to address specific species while minimizing the impact on the native perennial grasses. Ground clear herbicides were also applied to the perimeter road, access roads and around the ELF buildings to prevent vegetative damage to the road surface and to provide safe work areas around the buildings that were free of habitat for potentially dangerous wildlife like rattlesnakes. Mowing was occasionally used on low-slope areas to control weedy species such as kochia.

Areas that could benefit from overseeding were identified during formal inspections, performance of maintenance activities, and vegetation surveys throughout the growing seasons. These areas were typically either weedy areas where the perennial grasses had not established themselves yet, or areas where soil repairs were made, leaving bare ground. Overseeding was performed by hand in small areas, but larger areas were overseeded with broadcast seeding techniques. Overseeded species included purple three-awn (*Aristida purpurea*), sixweeks fescue (*Vulpia octoflora*), and needle and thread (*Hesperostipa comata*).

The area near the gas vent layer’s perimeter continued to have sparse vegetation cover by both annual and perennial vegetation. No change in this status is expected because the soil thickness in this zone above the gas vent layer’s filter fabric is too thin to support plant growth, especially in hot, dry weather. However, the oscillations in plant community composition and production on the ELF and surrounding areas have been somewhat reduced in the maturing plant community after several growing seasons. Most of the area has developed a stable and sustainable plant community.

Erosion was significantly less pervasive during this FYR period than it was in the first years following cap construction. Erosion was limited to areas of high surface flow such as perimeter channel side slopes where vegetation was not well established, places where runoff from surrounding areas was concentrated and created washouts, and perimeter access road surfaces. The Section 25 stockpile area, located directly south of the ELF, routinely drained into the southwest corner of the ELF perimeter channel, washing out the perimeter access road and the outside slope of the perimeter drainage channel. Drainage of the stockpile area was improved, and the channel side slope was armored with riprap and protected with erosion logs. Other areas of channel side slope erosion were repaired with rock-amended soil. Perimeter access roads were regraded using a motor grader and culverts were installed to allow stormwater to flow from one side of the road to the other.

Animal trails were also identified occasionally on the ELF cap. Deer were frequently seen on and around the landfill and began establishing trails on the sideslopes. Maintenance personnel alternately closed and opened gates in the ELF perimeter fence to manage animal traffic and minimize trail formation.

Invasion of burrowing animals was an issue for the eastern and southern perimeter areas of the ELF in 2017, 2018, and 2019. The landfill inspectors noted that burrows in areas surrounding the ELF were occupied by prairie dogs, cottontail rabbits, rattle snakes, and badgers at various times. Burrows were typically identified outside of the southern and eastern perimeter channels adjacent to an existing prairie dog colony that was outside of the Army maintained area. The Army used pest-control contractors to manage the burrowing animal population and backfilled the burrows after the animals were eliminated.

The ELF cap includes a network of eight erosion/settlement monuments that were surveyed and measured semiannually in accordance with SOP ELF 001. The monuments are exposed at the soil surface and extend downward through the cap. The exposed length of each monument was measured semiannually and recorded during the performance of Type II inspections in accordance with SOP ELF 001. The measured soil thickness loss for all eight monuments between April 2015 and March 2020 ranged from 0.0 to 4.0 inches, which is below the non-routine trigger level of 4.8 inches. Survey results have not indicated any significant movement of the cap either horizontally or vertically.

The cover perimeter survey monuments were surveyed in the spring of 2020. All monuments were successfully recovered.

Additional details regarding the inspections and maintenance performed on the ELF are available in the landfill monitoring reports issued annually in June (Navarro 2015g, 2016j, 2017g, 2018h, 2019q, 2020b).

Wastewater Management

The ELF is a triple-lined landfill with two cells: the LB cell and the WP cell. Each cell contains an LCS, a primary LDS, and a secondary LDS. Each sump is equipped with a separate wastewater conveyance system to individually transfer wastewater to two tanks in the LS/LF Building.

The Wastewater Operators inspected and maintained the ELF LCS/LDS and associated buildings in accordance with the ELF Post-Closure Wastewater Management Plan, contained in Appendix

C of the ELF Post-Closure Plan (Navarro 2020f). The following routine maintenance and repair activities were performed on the ELF LCS/LDS.

- Performed weekly inspections on the LB Leachate Riser Control House, the WP Leachate Riser Control House, and the LS/LF building.
- Performed quarterly inspections on the ELF LCS/LDS and Wastewater Conveyance System.
- Recorded weekly sump and tank levels for the ELF LCS/LDS and LS/LF building.
- Performed monthly inspections on emergency/exit lights in the LS/LF building, and both Leachate Riser Controls Houses buildings.
- Inspected grounding, tools, and first aid kits quarterly.
- Repaired and replaced system components as necessary.
- Transferred wastewater from the ELF LCS/LDS sumps to the tanks in the LS/LF building as needed.
- Wastewater from the storage tanks in the LS/LF Building was shipped off site for treatment and disposal.

The Wastewater Operators documented system inspections on inspection forms included in the ELF Post-Closure Wastewater Management Plan. Also, a system maintenance database was used to document inspections and maintenance activities. Wastewater O&M Reports were generated by the database and include log entries for inspections and maintenance activities.

The volume of wastewater generated by the ELF per year is shown in Table 6.3-36.

Table 6.3-36. ELF Wastewater Volumes

Year	Period Start	Period End	Volume (gal)
2015	May 2014	April 2015	3,297
2016	May 2015	April 2016	3,973
2017	May 2016	April 2017	2,714
2018	May 2017	April 2018	1,256
2019	May 2018	April 2019	2,421
2020	May 2019	April 2020	6,483

Note: Wastewater volumes generated between 2015 and 2019 were the result of quarterly sump sampling. The relatively large volume generated in 2020 came from sump WPLDS2 when the wastewater level in the sump was lowered from "High" water set point to the "Low" level.

Action Leakage Rate Analysis

Each month the Army calculated the wastewater collection rate in each LDS sump and compared that rate to the ALR for the respective sump as described in the ELF Post-Closure Action Leakage Rate/Response Action Plan, provided in Appendix D of the ELF Post-Closure Plan

(Navarro 2020f). The average daily flow rate was calculated as the volume of liquid pumped from the sump during the month, divided by the number of days in the month; divided by the acreage of surface area served by the sump. This average value is defined as the average daily flow rate and is expressed as gpad. This average daily flow rate was compared to the ALR, and 85 percent and 50 percent of the ALR to determine whether any response action was necessary. The average daily flow rate for all four LDS sumps was much lower than the ALR and the non-routine action trigger levels of 50 and 85 percent of the ALR for every month in the FYR period. The maximum average daily flow rate was 2.42 gpad, measured in LBLDS2 in April 2016. The ALR for LBLDS2 is 159 gpad. The performance standards and non-routine action trigger levels for leak detection liquids were not exceeded.

LCS/LDS Post-Closure Monitoring

For the majority of this FYR period water quality samples were collected quarterly from the sampling port on each LCS/LDS line when wastewater is present. For three quarters of the year (Calendar Quarters 1, 3, and 4) these samples were analyzed for the indicator compounds, and for one quarter (Calendar Quarter 2) the samples are analyzed for the complete analyte list.

In May of 2019 the sampling approach was changed to an as-needed sampling frequency triggered by the level of wastewater in the sumps. The volume of wastewater generated by the landfill had dropped off significantly since the post-closure period began, and quarterly sampling had become redundant. The new approach initiates sampling before wastewater is pumped out of the sump either because the wastewater reached the High-Level setting defined in Section 3.1.1 of the ELF PCP Wastewater Management Plan, or for other wastewater management purposes. The first sample collected from each sump within a calendar year is analyzed for the complete list of analytes, and any subsequent samples collected within the year are analyzed for the indicator compound analytes. The Army proposed the change in OCN-ELF-2019-002, which was approved by the regulatory agencies on May 29, 2019.

The ELF LCS analytical results are not used in any of the upper prediction limit calculations, however, the LCS results can be used to identify what specific compounds are detected in the ELF leachate. Based on the results from the LCS samples during the operational, closure, and post-closure groundwater monitoring, the indicator compounds selected for analysis and the chemical groups (VOCs, pesticides, DIMP, and metals) are consistent with wastes placed in the landfill and are within the chemical groups used in determining potential groundwater impacts. Chloroform was the only indicator compound detected in the ELF LCS sumps in 2015. From 2016 to 2019, the LCS sump levels have been too low to collect samples.

The objective of the ELF LDS sampling is to assist in monitoring for potential leaks in the landfill liner systems and to provide data necessary for interpreting whether contamination in downgradient monitoring wells can be tied to leakage from the ELF. To meet these objectives, analyte classifications have been established which determine data review and reporting requirements for the analytes list provided in the ELF PCGMP. The analyte classifications are:

- Analytes Excluded from LDS Reporting Requirements
- Analytes Requiring Reporting If Detected

- Watch List Analytes

The analyte classifications are based on the data end use and frequency of detections in previous sampling events.

Based on results from the LDS samples collected during the operational, closure, and post-closure phases, the ELF LCS liner systems appear to be intact. LDS sample results that required evaluation and regulatory agency notification during this FYR period are presented in Table 6.3-37. There were no LDS analytical results in 2017 and 2019 that required regulatory agency notification per Table 3.0-2 of the *Enhanced Hazardous Waste Landfill Post-Closure Plan* (Navarro 2020f).

Table 6.3-37. ELF Leak Detection System Analyte Detection Summary (2015 – 2019)

Analyte	NRAP Number	Classification	Sump	Sample Date	Concent. (µg/L)	Reporting Limit (µg/L)
Cyanide	2015-002	Report if detected	LBLDS2	5/7/15	91.5	10
PPDDT	2015-006	Report if detected	WPLDS1	7/30/15	0.00643	0.00608
PPDDE	2015-006	Report if detected	WPLDS2	7/30/15	0.00776	0.00518
MEXCLR	2015-006	Report if detected	WPLDS2	7/30/15	0.0107	0.00269
MEXCLR	2016-003	Report if detected	LBLDS2	10/21/15	5.53	5.00
TCLEA	2016-003	Report if detected	LBLDS2	10/21/15	0.16	0.11
PPDDT	2016-006	Report if detected	WPLDS1	4/12/16	0.0151	0.00608
Chromium	2016-006	Report if detected	LBLDS1	4/11/16	11.1	10
Mercury	2019-003	Report if detected	LBLDS2	2/7/18	0.345	0.2
ACLDAN – alpha-Chlordane MEXCLR – Methoxychlor TDGCL – Thiodiglycol						

There were LDS analytical results in 2015, 2016, and 2018 that required regulatory notification. It is common for analytes to be detected in ELF LDS sump samples. Typically, the detections are attributed to contaminants in the LCS and LDS clay liner material, rather than indications of leaks in the liner system. The soil used to construct the compacted clay liners of the ELF contained low levels of RMA contaminants that only became detectable after they were mobilized in water and analyzed using a method that had a much lower MRL than what can be achieved in soil analyses.

Evaluations of the LDS sample results included review of detections in borrow soil used to construct the liner, review of the historic range of detections for the LDS sump, review of concentrations of the compound in the corresponding LCS sump, history of decreasing MRLs for the subject compound, and investigation into laboratory quality control documentation. None of the LDS analytical result evaluations have indicated potential leaks in the landfill liner systems. Complete descriptions of the evaluation findings are contained in the NRAPs corresponding to each regulatory agency notification.

6.3.6.3 Integrated Cover System Monitoring

After ICS construction was completed in 2010 and the areas entered the Interim O&M Period, the SDT RCRA-Equivalent Cover was included with the other covers for ICS monitoring. That is, the term "ICS" generically refers to the combined SDT and ICS covers in O&M. The entire ICS is currently in the Interim O&M Period, as defined by Section 1.0 of the LTCP (TtEC 2011d). The Interim O&M Period is the period between completion of construction (i.e., after irrigation) and a determination that the cover is O&F. Monitoring and maintenance is conducted during the Interim O&M Period. However, performance standards were not enforceable until April 21, 2015, five years after construction was completed. Refer to Figure 6.3-81 (Sheets 1 and 2) for ICS details.

Though the ICS is still in the Interim O&M Period, enforcement of the performance standards began on April 21, 2015. According to Section 3.6 of the LTCP, the following conditions indicate that compliance standards are not being met, resulting in the cover being considered out of compliance and subject to enforcement by the regulatory agencies.

- **Percolation (RCRA-Equivalent covers only):** Greater than 1.3 mm/year of water measured in the lysimeters over a rolling 12-month evaluation.
- **Cover thickness (all covers):** Less than 42 inches of soil cover layer are present above the capillary barrier material for RCRA-equivalent covers, less than 36 inches of soil cover layer are present above subgrade for 3-ft covers, or less than 24 inches of soil cover layer are present above subgrade for 2-ft covers.
- **Vegetation (RCRA-Equivalent covers only):** The following vegetation standard is not met:
  - Total live vegetation not less than 25 percent in any single year, and
  - Two-year running average value for total ground cover not less than 50 percent, and
  - Three-year running average value for total ground cover not less than 67 percent.

An initial compliance determination was made in May 2016 based on cover performance data collected over the previous 12-month period. Data collected from monitoring activities will be used to support the O&F determination for the RCRA-Equivalent Covers.

Percolation Performance

The RCRA-equivalent covers have been designed and constructed with the objective of isolating wastes and reducing deep percolation of moisture to minimize the migration of contamination to groundwater. These covers use a network of lysimeters to monitor percolation. The ICS has 15 lysimeters located throughout the RCRA-equivalent covers; four located on Complex (Army) Disposal Trenches, four located on Basin A, three located on South Plants, one located on Lime Basins, and three located on SDT. The 2-ft and 3-ft covers do not have a percolation performance standard and deep percolation is not measured on these covers.

Percolation measurements for each lysimeter were recorded throughout this FYR period. Percolation measurements were compiled and reported in the quarterly Soil Cover Moisture Monitoring System Data Evaluation Summaries, quarterly percolation reporting tables, and the Annual Covers Reports for the Integrated Cover System.

Deep percolation measured by the ICS lysimeters remained below the performance standard of 1.3 mm/year for most cases between April 2015 and March 2020. However, there were some notable exceptions. The percolation standard exceedance events in Table 6.3-38 are listed in chronological order.

Table 6.3-38. Integrated Cover System (ICS) Percolation Exceedance Events

Lysimeter Number	Percolation Exceedance Period	Peak Percolation Quantity (mm)*	Presumed Causes of Excess Percolation
001	June 2014 to May 2017	49.17	Water used preferential pathways associated with the moisture sensor system to pass through the cover soil.
002	June 2014 to August 2017	48.77	Water used preferential pathways associated with the moisture sensor system to pass through the cover soil.
003	September 2013 to May 2017	37.23	Water used preferential pathways associated with the moisture sensor system to pass through the cover soil.
004	July 2016 to May 2017	1.70	Cause was not determined.
014	September 2018 to August 2019	1.96	Cause was not determined.

* The values shown are the highest rolling 12-month percolation quantities for the percolation event.

The percolation exceedances listed in Table 6.3-38 were subject to regulatory enforcement. Corrective measures were performed at Lysimeter 001, 002, and 003, in accordance with the *Integrated Cover System Corrective Measures Plan of Action For Shell Disposal Trenches RCRA-Equivalent Cover Percolation Exceedance* (Navarro 2019s) and the *Integrated Cover System Shell Disposal Trenches RCRA-Equivalent Cover Percolation Exceedance Corrective Measures Work Plan* (Navarro 2019m). Field investigations were completed, and the root cause of excess percolation was determined to be preferential flow associated with the moisture monitoring probes. Corrective measures included removing the probes and repairing the cover. Work was completed in April 2020. A Corrective Measures Completion Report was issued by the Army on December 9, 2020.

The percolation events at Lysimeters 004 and 014 were investigated, but root causes were not identified. Therefore, corrective measures were not performed. For the percolation events at Lysimeters 004 and 014, percolation assessment forms were used to document the assessments, conclusions, and recommended paths forward for each of the events in accordance with the LTCP. Percolation Assessment Form LYS004-2016 (Navarro 2019i) was approved by the regulatory agencies on January 9, 2020 and Percolation Assessment Form LYS014-2018 (Navarro 2019p) was approved by the regulatory agencies on October 23, 2019. The assessments did not find any evidence that the areas over the lysimeters require additional maintenance or further investigation, or that the cover in general is not performing as designed. These compliance issues have been closed.

Cover Thickness Performance

The ICS RCRA-equivalent and 3-ft covers include a network of 92 monuments used to quantitatively measure cover thickness, or the loss of soil cover due to wind and water erosion and/or settlement. These erosion/settlement monuments are buried in the cover soil on a 500-ft grid, except for the SDT RCRA-Equivalent Cover where six monuments were located by the regulatory agencies. The monuments are exposed at the cover surface and extend downward through the cover soil to a one-foot square plate at the bottom of the cover soil. The exposed length of each monument was measured semiannually and recorded during the performance of Type II cover inspections in accordance with LTCP SOP 001.

Minor areas of localized settlement were observed at several erosion/settlement monuments. This condition was routinely observed at erosion/settlement monuments on RMA caps and covers because the soil around each monument was placed by hand to prevent damage to the monument. As a result, the looser soil consolidated and created localized settlement. Maintenance personnel filled the localized depressions with cover soil from the Long-Term Cover Soils Stockpile to a level that matched surrounding grade.

All cover soil thickness loss measurements collected on the ICS between April 2015 and March 2020 were below the non-routine action trigger level of greater than 0.25 foot and the compliance standard of 0.5 foot.

Vegetation Performance

The LTCP SOP 002, Cover Vegetation Performance Assessment, provides the procedure to collect and document vegetation conditions for assessment and future management. This SOP includes a procedure for conducting the annual quantitative vegetation survey, which is performed near the end of the growing season each year. Data collected using LTCP SOP 002 were used to evaluate the vegetation against the vegetation performance standards.

Separate assessments were performed each year on the following areas:

- ICS RCRA-equivalent covers (30 transects sampled);

- ICS 2-ft and 3-ft soil covers (15 transects sampled).

In all years both assessment areas exceeded the minimum allowable values established in the compliance standard for allowable total absolute live vegetation cover, two-year running average for total absolute ground cover, and three-year running average for total absolute ground cover. Refer to Table 6.3-39 for the quantitative results of the RCRA-equivalent covers assessments, and Table 6.3-40 for the quantitative results of the ICS 2-ft and 3-ft soil covers assessments.

Table 6.3-39. ICS RCRA-Equivalent Covers Vegetation Performance (2015 – 2019)

Performance Standard	2015 (August 20 - 28)	2016 (August 9 - 17)	2017 (August 10 - 23)	2018 (September 17 - 21)	2019 (September 6 - 11)
Allowable Total Absolute Live Vegetation Cover (≥ 25%)	61.8%	63.4%	43.5%	55.8%	55.9%
Two Year Running Average for Total Absolute Ground Cover (≥ 50%)	96.0%	93.8%	92.0%	95.8%	92.5%
Three Year Running Average for Total Absolute Ground Cover (≥ 67%)	94.5%	93.7%	94.2%	93.5%	93.3%

Table 6.3-40. ICS 2-Foot and 3-Foot Cover Vegetation Performance (2015 – 2019)

Non-routine Action Trigger Level	2015 (August 14 - 20)	2016 (August 17 - 23)	2017 (August 23 -24)	2018 (September 5 - 6)	2019 (September 4 - 6)
Total live vegetation in a single year ≥ 25%	57.7%	66.1%	50.3%	57.1%	59.3%
Total Ground Cover (2-year average) ≥ 50%	97.2%	97.4%	97.1%	98.8%	95.6%
Total Ground Cover (3-year average) ≥ 67%	97.7%	96.6%	97.8%	97.7%	96.6%

Soil Cover Moisture Monitoring System

In addition to the measurement of percolation at each lysimeter, continuous soil moisture measurement was performed at each of the three SDT lysimeters from October 2007 through

October 2019 when the Soil Cover Moisture Monitoring System (SCMMS) was taken offline following the approval of OCN-LTCP-2019-003. Time-domain water content reflectometers (moisture probes) were used to monitor soil moisture throughout the soil cover profile including the area directly above the soil-capillary barrier material interface. Data collected by the SCMMS were used to determine whether a functional capillary barrier was present at the interface between the soil cover moisture storage layer and the underlying capillary barrier material, as designed. The soil moisture information was also useful in understanding moisture storage within the soil cover profile. Reporting the moisture probe data supported the objectives of the *Resolution Agreement: Use of Moisture Sensors on Full-Scale Resource Conservation Recovery Act (RCRA)-Equivalent Covers at the Rocky Mountain Arsenal, April 8, 2004* (RVO 2004) (Moisture Probe Resolution Agreement). In accordance with this agreement, data collected from moisture sensors (probes), in conjunction with other monitoring data, were used as follows:

- To demonstrate that a capillary break [barrier] develops at the interface between the moisture storage layer and the underlying material;
- To assist in selection of an appropriate corrective action in the event that percolation in excess of the 1.3 mm/year percolation compliance criterion is measured in a lysimeter and to assess the effectiveness of corrective actions performed; and
- To provide diagnostic information that may assist in selection and assessment of operation and maintenance activities.

Over the years the SCMMS clearly showed the development of an effective capillary barrier at the interface of the soil cover moisture storage layer and the underlying materials. Opportunities to use the data to support the other objectives of the moisture probe agreement have been rare. Data collected by the SCMMS were provided to the regulatory agencies, with accompanying percolation data, in quarterly reports.

Inspections and Maintenance

Inspections and assessments of the ICS were performed in accordance with the LTCP throughout the FYR period. These inspections included monthly lysimeter inspections, Type I inspections, Type II inspections, post-storm inspections, and annual vegetation assessments.

There were several inspection observations regarding the condition of the vegetation community. Weed control was a consistent area of emphasis with special attention given to species that are the most difficult to control such as bindweed, thistles, and cheat grass. The selected weed control methods were specific to the weedy species being addressed. Chemical control, either through spot-spraying or broadcast spraying, was routine. Herbicides were used to address specific species while minimizing the impact on the native perennial grasses. Ground clear herbicides were also applied to the perimeter road, access roads and around the Lime Basins Metering Building to prevent vegetative damage to the road surface and to provide a safe work area around the building that was free of habitat for potentially dangerous wildlife like rattlesnakes. Mowing was occasionally used to control weedy species such as kochia.

Areas that could benefit from overseeding were identified during formal inspections, performance of maintenance activities, and vegetation surveys throughout the growing seasons.

These areas were typically either weedy areas where the perennial grasses had not established themselves yet, or areas where soil repairs were made, leaving bare ground. Overseeding was performed by hand in small areas, but larger areas were overseeded with drill seeding techniques.

Prescribed burns were performed on the ICS in March 2016 and April 2019. The prescribed burns were intended to address excessive accumulation of vegetative litter that could be detrimental to the development of the perennial grass community. The burns were successful in removing excess litter and promoting the growth of the perennial grasses.

Another frequent inspection observation was differential settlement and areas that could pond or interrupt drainage. There were several observations of depressions in grassy drainages and around erosion/settlement monuments. Such depressions were filled to match surrounding grades with cover soil from the Long-Term Cover Soil Stockpile located in the southeast corner of Section 35.

Voids in the cover soil, commonly referred to as sinkholes, were also observed routinely throughout the FYR period. These voids first began to appear in the fall of 2013 following historic precipitation events and flooding throughout the Denver metro area. Most of the sinkholes were small (less than one cubic foot in volume), but they were widespread across the northeast portion of the ICS. Larger holes were filled using soil from the Long-Term Cover Soil Stockpile because they posed a safety concern for site personnel and wildlife. The smaller holes were monitored. In April of 2016 the Army and EPA cover inspectors noted that most of the holes had self-healed and were not relocatable. The Army selected 22 remaining holes in May of 2016 for further monitoring on a semiannual basis. In November of 2017, the Army and regulatory agencies agreed that the holes were all decreasing in size and increasing in vegetation, and thus the monitoring of the hole activity was discontinued.

Aside from the sinkholes exposed in 2013, several sinkholes have appeared around the perimeter of the ICS RCRA-equivalent covers; most notably southeast of the CAT cover and west of the Lime Basins and Basin A covers. These sinkholes were attributed to soil raveling into the underlying biota barrier material that extends 50 feet beyond the cover boundaries. These sinkholes were filled with soil from the Long-Term Cover Soil Stockpile as they were discovered.

In 2013, the USFWS initiated a prairie dog control program that significantly reduced the populations around the ICS and other sensitive areas of the RMANWR. While prairie dog invasion was an increasing issue prior to 2013, the USFWS control program was very successful and burrowing animals were not observed on the ICS again until late in 2016. Occasional prairie dog burrows were observed in 2017, 2018, and 2019. Lethal control of prairie dogs on the ICS was performed by the USFWS or pest-control contractors in coordination with the USFWS. Burrows were filled with soil from the Long-Term Cover Soil Stockpile. Cottontail rabbits were also observed on the ICS using sinkholes in the cover soil as burrows. Prairie dog and rabbit burrows were typically located in non-cover areas on the outskirts of the ICS.

Occasionally the engineering and access controls on the ICS have been found damaged. Wildlife, including bison, have damaged the ICS perimeter fence by trying to pass over it and under it.

The Army and USFWS have coordinated closely to routinely inspect the condition of the fence and make repairs when warranted.

Tumbleweeds and high winds in the winter have bent fence posts and pulled fence fabric off posts. Fence repairs were made in a timely manner to prevent unauthorized access to the site. A fence cleaner was used to remove tumbleweeds from the fence as they accumulated to prevent damage to the fence fabric and posts. Prescribed burns within the ICS Army maintained area occasionally burn the wood fenceposts despite efforts to mow around them in preparation for burns and spraying them with water as burns are performed. Fence posts that were heavily damaged were replaced.

The cover perimeter survey monuments were surveyed in the spring of 2020. All monuments were successfully recovered except for six that were not installed in the concrete-lined drainage channels and in fence post concrete.

Erosion monuments were inspected semiannually. In 2017, it was noted that the cap of erosion monument ER21 had become loose and needed to be repaired. The repair was performed in 2018. Localized depressions in the cover soil around the erosion monuments were common. Cover soil was used to fill the depressions to match surrounding grades.

The stormwater drainage structures of the ICS have occasionally required cleaning and repair. Caulk used in the expansion joints of the concrete channels separated from the substrate and was missing in some locations. The damaged caulk was removed and replaced. Drainage crossings in the ICS perimeter road also required occasional maintenance after they silted up following heavy rains. Gravel in the drainage crossing was replaced as needed.

Additional details regarding the inspections and maintenance performed on the ICS are available in the Annual Covers Reports for ICS, issued annually in November (Navarro 2015e, 2016b, 2017a, 2018d and 2019f).

6.3.6.4 Basin F RCRA-Equivalent Cover Monitoring

After construction of the Basin F Cover was completed in 2010, the Army maintained area entered the Interim O&M Period, as defined by Section 1.0 of the LTCP (TtEC 2011d). The Interim O&M Period was the period of time between completion of construction (i.e., after irrigation) and a determination that the cover is O&F. The EPA determined that the Basin F remedy project was O&F on September 18, 2019 and provided a letter to the Army documenting the determination (EPA 2019a). Therefore, the Basin F Cover is now in the O&M Period as defined in Section 1.0 of the LTCP. Monitoring and maintenance were conducted during the Interim O&M Period and have continued into the O&M Period.

In addition to the LTCP, the Basin F Cover is also subject to O&M requirements identified in the *Basin F Post-Closure Plan* (TtEC 2011c) because Basin F is an interim status unit under RCRA. While the O&M requirements are largely the same, some administrative requirements are different. Details regarding O&M of the Basin F Cover, such as inspection procedures, are contained within the Basin F Post-Closure Plan. Refer to Figure 6.3-82 (Sheets 1 and 2) for Basin F Cover details.

Enforcement of the performance standards on the Basin F Cover began on March 2, 2015. According to Section 3.6 of the LTCP and Section 3.6 of the *Basin F Post-Closure Plan*, the following conditions indicate that performance standards are not being met, resulting in the Basin F Cover being considered out of compliance and subject to enforcement by the Regulatory Agencies.

- **Percolation:** Greater than 1.3 mm/year of water measured in the lysimeters over a rolling 12-month evaluation.
- **Cover thickness:** Less than 42 inches of soil cover layer are present above the capillary barrier material for RCRA-equivalent covers.
- **Vegetation:** The following vegetation standard is not met:
    - Total live vegetation not less than 25 percent in any single year, and
    - Two-year running average value for total ground cover not less than 50 percent, and
    - Three-year running average value for total ground cover not less than 67 percent.

An initial compliance determination was made in April 2016 based on cover performance data collected over the previous 12-month period. Data collected from monitoring activities was used to support the O&F determination for the RCRA-equivalent cover (Navarro 2017e).

Percolation Performance

The Basin F cover was designed and constructed with the objective of isolating wastes and reducing deep percolation of moisture to minimize the migration of contamination to groundwater. The cover uses a network of five lysimeters to monitor percolation.

Percolation measurements for each lysimeter were recorded throughout this FYR period. Percolation measurements were compiled and reported in the quarterly Soil Cover Moisture Monitoring System Data Evaluation Summaries, quarterly percolation reporting tables, and the annual reports.

Deep percolation measured by the Basin F lysimeters remained below the performance standard of 1.3 mm/year for all five lysimeters in all cases between April 2015 and March 2020.

Cover Thickness Performance

The Basin F Cover includes a network of 18 monuments used to quantitatively measure cover thickness, or the loss of soil cover due to wind and water erosion and/or settlement. These erosion/settlement monuments are buried in the cover soil on a 500-ft grid. The monuments are exposed at the cover surface and extend downward through the cover soil to a one-ft square plate at the bottom of the cover soil. The exposed length of each monument was measured semiannually and recorded during the performance of Type II cover inspections in accordance with Basin F Post-Closure Plan SOP 001.

All cover soil thickness loss measurements collected on the Basin F Cover between April 2015 and March 2020 were below the non-routine action trigger level of 0.25 foot and the compliance standard of 0.5 foot.

Vegetation Performance

The *Basin F Post-Closure Plan SOP 002, Cover Vegetation Performance Assessment*, provides the procedure to collect and document vegetation conditions for assessment and future management. This SOP includes a procedure for conducting the annual quantitative vegetation survey, which is performed near the end of the growing season each year. Data collected using Basin F Post-Closure Plan SOP 002 were used to evaluate the vegetation against the vegetation performance standards.

Each year 15 transects were sampled on the Basin F Cover. The cover vegetation exceeded the minimum allowable values established in the compliance standard for allowable total absolute live vegetation cover, two-year running average for total absolute ground cover, and three-year running average for total absolute ground cover. Refer to Table 6.3-41 for the results of the annual vegetation performance assessments.

Table 6.3-41. Basin F Cover Vegetation Performance (2015 – 2019)

Performance Standard	2015 (August 11 & 12)	2016 (August 23 - 25)	2017 (August 8 & 9)	2018 (September 5)	2019 (September 3 & 4)
Allowable Total Absolute Live Vegetation Cover (≥ 25%)	71.0%	57.3%	49.8%	61.9%	57.7%
Two Year Running Average for Total Absolute Ground Cover (≥ 50%)	88.4%	90.1%	99.1%	98.8%	94.9%
Three Year Running Average for Total Absolute Ground Cover (≥ 67%)	88.9%	92.1%	92.9%	99.0%	96.2%

Inspections and Maintenance

Inspections and assessments of the Basin F Cover were performed in accordance with the LTCP (TtEC 2011d) and *Basin F Post-Closure Plan* (TtEC 2011c) throughout the FYR period. These inspections included monthly lysimeter inspections, Type I inspections, Type II inspections, post-storm inspections, and annual vegetation assessments.

Most of the inspection observations at Basin F regarded the condition of the vegetation community. Weed control was a consistent area of emphasis with special attention given to weedy species that are the most difficult to control such as bindweed, thistles, and cheat grass.

The selected weed control methods were specific to the weedy species being addressed. Chemical control, either through spot-spraying or broadcast spraying, was routine. Herbicides were used to address specific species while minimizing the impact on the native perennial grasses. Ground clear herbicides were also applied to the perimeter road and around monitoring wells to prevent vegetative damage to the road surface and to provide safe work areas around wells that were free of habitat for potentially dangerous wildlife like rattlesnakes. Mowing was occasionally used to control weedy species such as kochia.

Areas that could benefit from overseeding were identified during formal inspections, performance of maintenance activities, and vegetation surveys throughout the growing seasons. These areas were typically either weedy areas where the perennial grasses had not established themselves yet, or areas where soil repairs were made, leaving bare ground. Overseeding was performed by hand in small areas, but larger areas were overseeded with drill seeding techniques.

A prescribed burn was performed on the Basin F Cover in April 2019. The prescribed burn was intended to address excessive accumulation of vegetative litter that could be detrimental to the development of the perennial grass community. The burn was very successful in removing excess litter and promoting the growth of the perennial grasses.

In 2013, the USFWS initiated a prairie dog control program that significantly reduced the populations around the Basin F Cover and other sensitive areas of the RMANWR. While prairie dog invasion was an increasing issue prior to 2013, the USFWS control program was very successful and burrowing animals were not observed on Basin F again until 2018. Burrows identified in 2018 were primarily located around the perimeter of the cover in the northwest portion of the site. Prairie dog invasion was a more significant issue in 2019 when burrows were created on the south and east sides of the Army maintained area. Prairie dogs persistently moved into the Army maintained area from large colonies adjacent to the cover. The Army used a pest-control contractor to manage the burrowing animal population both within the Army maintained area and in the surrounding colonies and coordinated efforts with the USFWS to minimize impacts on other species like burrowing owls and black-footed ferrets. Maintenance personnel backfilled the burrows with soil from the Long-Term Cover Soil Stockpile after the prairie dogs were eliminated.

Occasionally the engineering and access controls on the Basin F Cover were damaged. Wildlife have damaged the Basin F perimeter fence by trying to pass over it and under it. The Army and USFWS have coordinated closely to routinely inspect the condition of the fence and make repairs when warranted.

Tumbleweeds and high winds in the winter have also bent fence posts. Fence repairs were made in a timely manner to prevent unauthorized access to the site. A fence cleaner was used to remove tumbleweeds from the fence as they accumulated to prevent damage to the fence fabric and posts.

The cover perimeter survey monuments were surveyed in the spring of 2020. All monuments were successfully recovered.

The stormwater drainage structures of the Basin F Cover have occasionally required cleaning and repair. Caulk used in the expansion joints of the concrete channels separated from the substrate and was missing in some locations. The damaged caulk was removed and replaced.

Additional details regarding the inspections and maintenance performed on the Basin F Cover are available in the Annual Covers Reports for Basin F and Basin F Cover and Groundwater Monitoring Reports, issued annually in November (Navarro 2015f, 2016c, 2017b, 2018c, 2019h).

6.3.7 Land Use Control Monitoring (#99)

Annual monitoring of land use controls is required to ensure they remain effective and are protective of human health and the environment. Annual reports documenting the results of the monitoring have been issued for each fiscal year in the FYR period (Navarro 2015a, 2016a, 2018l, 2018a, 2019a). These reports identify any issues with maintenance or implementation of LUCs, provide corrective actions for these issues, and track follow-up of previously identified issues.

As a result of monitoring activities during this FYR period, the following issues related to land use controls were identified. Corrective actions performed are noted as well.

- Continued follow-up regarding the public gardening use-by-right included in the Commerce City Prairie Gateway Planned Unit Development (PUD). This use appears inconsistent with the land use restrictions delineated in the Refuge Act, which prohibit non-remedy agricultural activities. This issue was first identified in 2009 and is being tracked by the Army pending revision of the PUD by Commerce City.
- Continued follow-up regarding uses identified in the Commerce City Prairie Gateway PUD that may be in conflict with the residential use restriction.
  - In December 2016, Congress passed the National Defense Authorization Act for Fiscal Year 2017, which modified the Refuge Act to include provisions for Commerce City to modify or remove the restriction that prohibits the use of the property for residential or industrial use, provided a determination is made that the property will be protective of human health and the environment for the proposed use with an adequate margin of safety following the modification or removal of the restriction. The determination can be made after completion of a risk assessment and any response actions necessary to protect human health and the environment to allow for the proposed use. This new requirement eliminates the need for further follow up with Commerce City for revision of the Prairie Gateway PUD.
- In 2007, the USFWS deeded approximately 28 acres of land in Section 33 and approximately 14 acres in Section 20 (Section 20 NE Parcel) to Commerce City and in exchange acquired approximately 148 acres of the Prairie Gateway for incorporation into the refuge. The issue of the exchange being inconsistent with the ROD or FFA was identified as an issue in the 2015 FYRR. Documentation associated with the transfer was

provided to the regulatory agencies and was determined to be sufficient, resolving the issue. Revision of the LUCP was considered and determined to not be necessary.

- Two groundwater monitoring wells along the Lake Ladora trail were damaged from prescribed burn activities. Repairs were completed November 14, 2017.
- The required notification language was not included on all well permits in the off-post area. Permits for use of existing wells or to replace an existing well were issued without the notification language. The Army and TCHD coordinated with the SEO to ensure the required RMA notification was present for all completed permits.
- Visual inspections should be performed for transferred property to monitor for activities that could conflict with the land use restrictions. The annual inspection form was revised to document these inspections.

There was one trespass incident reported during this FYR period involving remediation systems. In October 2017, there was a vandalism event at the NWBCS. The glass was broken on the emergency power shutdown switch and the switch was activated, resulting in power loss to the plant. In addition, several well caps were removed from the system extraction wells and the well hand/off/auto (HOA) switches were turned out of position. The incident was investigated by the Adam's County Sherriff's Department; however, no arrests were made. In response to the event and to improve security, the emergency power shutdown switch was moved inside the plant, spring-loaded HOA switches were installed on the wells, and security cameras were installed at each treatment plant. There were no trespass incidents that threatened the integrity or effectiveness of the remedy or created any potential for exposure.

During the FYR period, a public concern was identified with oil and gas wells near RMA potentially encountering RMA contamination. These concerns are related to two separate issues: past subsurface waste disposal at RMA associated with the former hazardous waste injection well, and contaminated alluvial groundwater. RMA's deep injection was isolated from drinking water aquifers and was used to inject waste over 12,000 feet below the ground surface. For that reason, it is not a source of groundwater contamination or other health or environmental concerns. The existence of alluvial groundwater contamination is not considered to be an impediment to oil and gas development. Oil and gas development companies typically take appropriate measures to prevent cross-contamination, as they drill through the alluvial aquifer to where oil and natural gas are located. Therefore, RMA contamination in the alluvial aquifer should not impact oil and gas drilling occurring north of RMA. Also, in May 2018, the USFWS received a request for permission to conduct seismic exploration along the northern tier of the Refuge including Sections 19, 20, 23 and 24 for potential development of oil and gas production. Mineral rights in this area are federally owned and the USFWS denied the request.

Inspection of sanitary sewer markers is included as part of the LUC monitoring (Figure 6.3-83). The markers are inspected once every five years to ensure that the location of the abandoned sanitary sewer is adequately marked and to ensure they remain intact and visible. The plugged manholes and markers along the abandoned sanitary sewers were located and inspected. Refer to Table 6.3-42 for inspection results. Several markers had been inadvertently buried by site activities or burrowing animals and were uncovered during the inspection to provide better visibility. Complete inspection results are included in the 2019 Land Use Control Monitoring Report (Navarro 2019a). Two manholes required more significant dirt removal and clearance of the manholes was completed in July 2020.

Table 6.3-42. 2020 Sanitary Sewer Manhole and Marker Inspection Results

Manhole ID	Section	Easting	Northing	Field Located	Notes
1	34	2173737.27	181785.43	Y	
2	34	2173889.00	181579.29	Y	
2A	34	2176734.86	182097.35	Y	
3	34	2174044.07	181388.26	Y	
4	34	2174171.91	181115.59	Y	
5A	34	2174174.97	180591.98	Y	
6	3	2174175.53	180486.53	Y	
7	3	2173899.56	180484.81	Y	
8	3	2173599.85	180483.02	Y	
9	3	2173356.31	180481.58	Y	
10	3	2173224.65	180204.70	Y	
11	3	2173074.99	179887.31	Y	
12	4	2172900.09	179886.81	Y	
13	4	2172901.20	179513.78	Y	
14	4	2172901.73	179163.90	Y	
15	4	2172902.54	178814.29	Y	
16	4	2172903.47	178464.49	Y	
17	4	2172904.39	178114.50	Y	
18	4	2172905.48	177763.55	Y	
19	4	2172905.48	177495.37	Y	
19A	3	2173159.28	177360.22	Y	
19B	3	2173413.19	177223.24	Y	
19C	3	2173632.22	177001.45	Y	
20	4	2172806.13	177494.48	Y	
21	4	2172806.27	177115.17	Y	
22	4	2172806.38	176764.42	Y	
23	4	2172806.36	176413.82	Y	
24	4	2172806.92	176034.28	Y	
24A	4	2172806.93	175945.95	Y	Obscured by vegetation
25	4	2172806.89	175752.39	Y	
26	4	2172651.84	175753.57	Y	
27	4	2173066.96	175944.37	Y	
27A	4	2172896.66	175944.82	Y	
28	4	2173067.04	175644.37	Y	
30	4	2173365.99	175393.97	Y	Obscured by vegetation
31	3	2173661.60	175393.95	Y	

Table 6.3-42. 2020 Sanitary Sewer Manhole and Marker Inspection Results

Manhole ID	Section	Easting	Northing	Field Located	Notes
32	3	2173762.48	175618.43	Y	
32A	3	2173737.52	176412.86	Y	Buried beneath approximately 1 foot of soil
33	3	2174070.38	175621.86	Y	
33A	3	2174032.8	175425.7	Y	
34	3	2174468.81	175624.80	Y	Partially buried, prairie dogs, uncovered
35	3	2174763.74	175626.89	Y	
36	3	2175119.39	175629.55	Y	
37	3	2175370.21	175631.65	Y	
38	3	2175639.00	175632.60	Y	Located approximately 60 feet east of perimeter fence
392-1	34	2176888.00	182053.20	Y	
392-2	34	2176944.21	182109.73	Y	
392-3	34	2177942.29	182171.73	Y	
392-4	35	2178940.37	182233.73	Y	
392-5	35	2179938.44	182295.74	Y	
393-1	34	2173792.00	181771.70	Y	
393-2	34	2174580.73	181883.51	Y	
393-3	34	2175376.46	181966.03	Y	
393-4	34	2176172.20	182048.56	Y	
SQI18	24	2184033.60	191307.80	Y	
SQI19	25	2183881.20	191116.20	Y	
SQI20	25	2183691.70	190877.30	Y	
SQI21	26	2183489.00	190620.70	Y	
SQI22	26	2183272.10	190455.30	Y	
SQI23	26	2183033.40	190273.50	Y	
SQI23A	26	2183182.90	190083.10	Y	
SQI23B	26	2183258.50	189994.10	Y	
SQI23C	26	2183259.50	189849.40	Y	Buried next to road, uncovered
SQI23D	26	2183219.90	189850.10	Y	
24	26	2182838.75	190125.31	Y	
25	26	2182621.75	189844.41	Y	
26	26	2182416.75	189578.61	Y	
27	26	2182110.50	189652.75	Y	
28	26	2181838.75	189718.86	Y	Marker covered with dirt, cleared
36	26	2182445.00	187745.20	Y	
37	26	2182414.50	187468.84	Y	

Table 6.3-42. 2020 Sanitary Sewer Manhole and Marker Inspection Results

Manhole ID	Section	Easting	Northing	Field Located	Notes
38	26	2182387.25	187219.97	Y	
39	26	2182346.00	186849.83	Y	
40	26	2182322.25	186635.16	Y	
41	26	2182486.00	186432.84	Y	
42	26	2182627.50	186258.81	Y	
43	26	2182709.25	186261.81	Y	
44	26	2182933.25	185998.03	Y	
45	35	2183140.50	185755.19	Y	
46	35	2183028.00	185444.31	Y	Buried approximately 2 inches in soil, uncovered
47	35	2182833.75	185306.33	Y	Minor scratches in plaque from plow/disc
48	35	2182773.25	185102.44	Y	
49	35	2182709.27	184886.82	Y	
50	35	2182537.25	184894.67	Y	Buried beneath approximately 6 inches of soil.
58	35	2181221.00	184081.14	Y	
59	35	2180941.25	184053.23	Y	
60	35	2180707.25	183827.22	Y	
67A	35	2181015.01	182096.49	Y	
67B	35	2181211.09	182131.95	Y	
67C	35	2181315.83	182302.73	Y	
67D	35	2181421.31	182473.36	Y	Buried, soil and vegetation, cleared and uncovered
73	35	2180180.42	181114.71	Y	
318A	35	2183631.30	181038.70	Y	
318B	35	2183631.30	180962.50	Y	
318C	35	2182806.40	181112.70	Y	
318D	35	2181745.70	181397.10	Y	
318E	35	2181197.30	181544.80	Y	
CERCLA-1	35	2183318.80	180975.90	Y	
CERCLA-2	35	2182294.00	181249.40	Y	

6.3.8 Chemical Agent in Soil Post Remedy Verification

During preparation of the 2015 Five-Year Review Report (Navarro 2016), the EPA raised a concern over changes in persistence and toxicity information related to Army chemical agents and a lack of post-remediation sampling. Specifically, the United States Army Public Health Command (USAPHC) issued revised Health-Based Environmental Screening Levels (HBESLs) in July 2011 using chronic toxicity criteria and risk assessment methodology to derive screening criteria for assessing potential long-term exposure to soil contaminated from contact with liquid chemical agents (USAPHC 2011). Although the Record of Decision (ROD) (Foster Wheeler 1996) included remediation for all RMA areas with chemical agent potential, the ROD did not specifically require post-remedy verification sampling for agent cleanup areas.

The sampling program was conducted per the *Chemical Agent in Soil Post-Remedy Verification Sampling and Analysis Plan* (Navarro 2019n). The Army conducted this sampling to collect post-remedy soil data in areas that are not under soil cover where chemical agents were stored or disposed to determine if concentrations of mustard or O-ethyl S-(2-diisopropylamoinoethyl) methylphosphonothiolate (VX) in soil exceed the Army industrial HBESLs. Soil samples were collected from locations depicted on Figure 6.3-83.

There were no detections of mustard or VX in any of the samples collected and reporting limits met the decision criteria developed in the data quality objectives. Results of the verification sampling are documented in the *Chemical Agent in Soil Post-Remedy Verification Data Summary Report* (Navarro 2020g). No further action is required.

6.4 SITE INSPECTIONS

Site inspections were conducted on June 23 through June 25, 2020, by representatives from the Army, EPA, CDPHE, and TCHD. The purpose of the inspections was to visually assess the protectiveness of selected features and components of the On-Post and Off-Post RMA remedy. Field inspections were focused on the operating groundwater remedy. The status of these remedy components is captured in the project discussions in Section 4.0, and inspection results are discussed in Appendix D.

The inspected components of the remedy included:

- Groundwater treatment systems and associated extraction, recharge, and monitoring wells
  - RYCS
  - BANS
  - NWBCS
  - NBCS
  - OGITS (including Northern Pathway Modifications)
- HWL/ELF Leachate Storage/Loadout Facility
- Confined Flow System Wells
  - Basin F
- Section 20 Transferred Parcel
- Groundwater well protection near new trails in the Refuge public use areas.

During the inspections, groundwater treatment systems were observed for general condition and operational status of groundwater extraction and treatment facilities and equipment. Wells were inspected for the condition of protective features, such as pads, surface casings, caps and locks, and identification markings.

Appendix D contains a compilation of the completed inspection checklists used to document observations made by the Army, EPA, CDPHE, and TCHD representatives conducting the inspections. Deficiencies were noted during the inspections, as shown in Table 6.4-1. The Army and Shell responses and actions taken are also included in Table 6.4-1.

No issues were identified during the field inspections that affect the overall protectiveness of the remedy.

Table 6.4-1. 2020 Five-Year Review Field Inspection Summary

Location/ Inspection Item	Observations	Response/Corrective Action
Section 7	Monitoring well 07001, located near new public access trail, requires a locking cap.	Lock was installed in September 2020.
Section 20 Northeast Parcel	A bridge, road and public trail have been constructed on the site. Public access is present along Second Creek.	None. No exposure potential.
Basin F Wells	The wells visited north of Basin F are not locked.	Not in public use area. Areas that require locks are addressed by the Land Use Control Plan (Navarro 2013).
	Wells in former Borrow Area 4 (Section 23) need maintenance to repair well pads that are undermined.	Noted.
	Army is tracking detection of dieldrin north of Basin F in CFS.	Identified as FYR issue, Table 8.0-1.
Basin A Neck Treatment Plant	O&M Manual is dated 2008, but 2020 revisions are present in redline-strikeout. Manual should be finalized.	The Army will review O&M Manual and revise as appropriate.
NBCS Treatment Plant	Spare quartz tubes for UV Oxidation system are no longer made and can no longer be purchased.	Supply adequate for near future. New treatment plant will use updated UV system.
	O&M Manual is dated 2012. It is unclear if it is up to date.	The Army will review O&M Manual and revise as appropriate.
	No secondary containment of wastewater and influent sumps.	None, not required.
NBCS Wells	Damaged well pad at well 23253.	Noted.
	Compression cap was not locked on well 24006.	Not in public use area. Areas that require locks are addressed by the Land Use Control Plan (Navarro 2013).
	Some wells have illegible labeling. Most wells were identified with painted well numbers. Numerous wells outside the fence line were missing ID tags. Permanent monitoring wells should be clearly labeled with locking protective cases.	The Army will review to ensure appropriate labelling and well security.

Table 6.4-1. 2020 Five-Year Review Field Inspection Summary

Location/ Inspection Item	Observations	Response/Corrective Action
	Due east of north entrance road an unmarked PVC well has no protective casing.	
NWBCS Treatment Plant	O&M Manual is dated 2012. It is unclear if it is up to date.	The Army will review O&M Manual and revise as appropriate.
	External electrical boxes are not tamper proof.	The Army will review for potential security.
	No secondary containment of wastewater and influent sumps.	None, not required.
	Vault covers are not locked and could endanger trespassers.	None. Not a public use area.
NWBCS Wells	Downgradient performance wells (37330, 37331, 37332, 37333, 37600) are not locked/secured. Flush mount not bolted and not locked. Permanent monitoring wells should be clearly labeled with locking caps or some other form of protection.	Flush mount covers were secured and well labels and locks were verified, August 2020.
OGITS Treatment Plant	One carbon adsorber showed signs of past leakage and staining on the outside of the adsorber tank.	On the date of the inspection, staff indicated that a leaking weld had caused the seepage and had since been repaired.
OGITS Wells	Some of the well heads are located in box vaults that have shifted over time.	Replacement is planned for FY20.
RYCS Wells	Given nearby public visitors center, wells should be locked.	Not in public use area. Areas that require locks are addressed by the Land Use Control Plan (Navarro 2013).

7.0 ASSESSMENT

The purpose of the FYR is to conduct a protectiveness level review to determine whether the remedies for RMA defined in the RODs and RAOs remain protective of human health and the environment, and are functioning as intended, and whether required O&M is being performed, considering the changes in ARARs and TBCs that occurred during the FYR period.

7.1 QUESTION A: IS THE REMEDY FUNCTIONING AS INTENDED BY THE DECISION DOCUMENTS?

Consistent with the EPA FYR guidance (EPA 2001) the following topics should be evaluated for projects under construction:

Is the remedy being constructed in accordance with the decision documents and design specifications?

Is the remedy expected to be protective when complete and will performance standards likely be met?

Are access controls and ICs in place to prevent exposure during construction?

For operating or completed projects, the following topics are considered during the assessment:

Remedial Action Performance

Does the Remedial Action continue to be operating and functioning as designed?

Is the Remedial Action performing as expected and are cleanup levels being achieved?

Is containment effective?

Systems Operations/O&M

Will operating procedures, as implemented, maintain the effectiveness of the response actions?

Do large variances in O&M costs indicate a potential remedy problem?

Is monitoring being performed and is it adequate to determine protectiveness and effectiveness of remedy?

Implementation of Institutional Controls and Other Measures

Are access controls in place and preventing exposure (e.g., fencing and warning signs)?

Are ICs in place and preventing exposure?

Are other actions (removals) to address immediate threats complete?

Opportunities for Optimization

Do opportunities exist to improve performance and/or costs of monitoring, sampling, and treatment systems?

Early Indicators of Potential Remedy Problems

Do frequent equipment breakdowns or changes indicate a potential risk?

Could other issues or problems place protectiveness at risk?

7.1.1 On-Post Soil Remedies Under Construction

As discussed in Section 4.0, soil cover projects that are in the Interim O&M period are evaluated as under construction. The on-post soil remedies in Interim O&M are assessed against the criteria described above in Section 7.1 using the results and information presented in Section 4.2.1 and Section 6.3.6.3.

7.1.1.1 Integrated Cover System Interim Operations and Maintenance: Basin A Consolidation and Remediation Area (#15), South Plants Balance of Areas and Central Processing Area (#34), Complex (Army) Disposal Trenches Remediation Cover (#38), Shell Disposal Trenches 2-foot Soil Covers (#39), and Section 36 Lime Basins Cover (#47)

The physical construction of the ICS covers is complete and documented in the Integrated Cover System Project (Basin A, Complex (Army) Disposal Trenches, Lime Basins, Shell Disposal Trenches, South Plants) Subgrade and Cover Construction, Construction Completion Report – Part 1 (TtEC 2010b). Construction was conducted in accordance with the decision documents and design specifications discussed in Section 4.2.1.1. Final inspections have been completed for each cover element and no further construction is required. Containment of contaminated soil and debris beneath the covers has achieved the remedial objectives to prevent exposure to the contaminated soil/debris, prevent migration of contaminants to groundwater, and prevent contact with physical or chemical agent hazards.

Routine percolation monitoring, vegetation assessments, and cover maintenance activities have been on-going since cover construction was completed and are required during the Interim O&M and O&M periods. Accordingly, the projects that comprise the ICS are expected to be protective and performance standards will likely be met. Because this project consists of monitoring activities on the completed cover surface, prevention of exposure to COCs is not a concern. The covers serve as containment facilities; therefore, they are subject to long-term O&M requirements as presented in the LTCP (TtEC 2011d). The ICs identified in the cover design (fences, signs, and obelisks) are in place and being maintained. Implementation of the LUCP (Navarro 2013) continues to satisfy the Refuge Act and On-Post ROD requirements.

The ICS has been in the Interim O&M Period, as described in Section 1.0 of the LTCP, since the Final Inspection held on April 21, 2010. The Interim O&M Period will continue until the EPA, in coordination with CDPHE, TCHD, and the Army, determine that the ICS is Operational and Functional (O&F). The O&F determination will be based on cover performance. During the quarterly caps and covers O&M status meeting held on January 22, 2020, the Army suggested that enough ICS performance data had been collected to begin preparing the CCR – Part 2. The regulatory agencies agreed that preparation of the ICS CCR – Part 2 was appropriate. The Army drafted the report and submitted it for agency review on July 29, 2020. The Army anticipates that the regulatory agencies will use the information in the CCR – Part 2 to support an O&F determination of the ICS project.

7.1.1.2 Shell Disposal Trenches RCRA-Equivalent Cover Interim Operations and Maintenance (#39)

The physical construction of the SDT RCRA-Equivalent Cover is complete and a CCR – Part 1 has been completed (TtEC 2008b). The project is in an interim O&M Period while cover performance data are being collected. Construction was conducted in accordance with the decision documents and design specifications discussed in Section 4.2.1.2. A final inspection was completed, and no further construction is required.

Routine percolation monitoring, vegetation assessments, and cover maintenance activities have been on-going since cover construction was completed and are required during the Interim O&M and O&M periods. Refer to Section 6.3.6.3 for additional information. Because monitoring activities are conducted on the completed cover surface, prevention of exposure to COCs was not a concern. The ICs identified in the cover design (fences, signs, and obelisks) are in place and being maintained. Implementation of the LUCP (Navarro 2013) continues to satisfy the Refuge Act and On-Post ROD requirements.

Containment of contaminated soil and debris beneath the covers has achieved the remedial objective to prevent exposure to the contaminated soil/debris. Percolation measurements at the three lysimeters within the SDT RCRA-Equivalent Cover have exceeded the percolation compliance standard on several occasions. In 2018, the Army determined that the root cause of the excessive percolation was preferential flow paths through the cover soil associated with installation of the Soil Cover Moisture Monitoring System (SCMMS) during cover construction. The result of the preferential flow paths around the SCMMS was that percolation data collected by the SDT lysimeters was not representative of the RCRA-equivalent cover's performance. Since the majority of the preferential flow paths were located over the lysimeter pans, and the percolation was captured by the pans rather than migrating to groundwater, it is likely that the RAO to prevent migration of contaminants to groundwater was met even when percolation rates were unacceptably high. Regardless, the Army has implemented corrective measures as described in Section 5.2.4 and will continue monitoring cover performance to ensure that the corrective measures are effective.

The SDT RCRA-Equivalent Cover has been in the Interim O&M Period, as described in Section 1.0 of the LTCP, since the Final Inspection held on April 21, 2010. The Interim O&M Period will continue until the EPA, in coordination with CDPHE, TCHD, and the Army, determine that the SDT RCRA-Equivalent Cover is Operational and Functional. The O&F determination will be based on cover performance. Once enough performance data are collected and the corrective measures performed on the cover are validated, the SDT RCRA-Equivalent Cover's performance will be summarized in the *Shell Disposal Trenches RCRA-Equivalent Cover CCR—Part 2*. The O&F determination for the SDT RCRA-Equivalent Cover will be made when performance data justify the determination.

7.1.2 Operating Groundwater Remedial Actions in the On-Post OU

The on-post groundwater remedies are assessed against the criteria described above using the results and information presented in Section 4.1.1 and Section 6.3.1. Optimization of the operation of the groundwater containment and mass removal systems is ongoing under the

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individual system operations programs. Detailed evaluations of the groundwater containment, mass removal, and treatment systems are presented in the FYSR (Navarro 2020b).

7.1.2.1 Shell Disposal Trenches Slurry Walls (Dewatering) (#17)

Based on criteria in the Design Document (RVO 1997), On-Post ROD, and 2010 LTMP, the SDT slurry wall and cover did not perform as described in the Decision Documents during most of the FYR period.

The performance requirement for Shell Trenches is to demonstrate that groundwater elevations are below the disposal trench-bottom elevations within the slurry-wall enclosure. Groundwater elevations were below the bottom of the trenches in all of the borehole locations except at Bore 3453. The groundwater elevation has been above the target elevation at this location since the second quarter of FY14. This was identified as an issue in the 2015 FYRR. Although a decreasing trend in water levels was evident during the FYR period, the groundwater elevation at Bore 3453 did not decrease sufficiently to meet the performance criterion. Refer to Section 6.3.2.2 for additional information.

An evaluation of dewatering options was completed for Shell Trenches in March 2019 (Navarro 2019x). The report concluded that active dewatering was not necessary as the slurry wall provided sufficient containment of disposal waste. In addition, the report concluded that Bore 3453 may not be an appropriate location to evaluate groundwater/disposal trench interaction as it is uncertain that disposal trenches extended to the area of Bore 3453. However, the report conclusions were disputed by CDPHE and additional discussion resulted in agreement to complete investigative borings in the southwestern portion of the Shell Trenches to confirm the presence and bottom elevation of a trench for potential revision of the LTMP performance goal.

An investigation plan was finalized in March 2020 to complete investigative borings within the suspected disposal trench area and the installation of a monitoring well in the western portion of the site. The trench investigation was completed in June 2020 and a trench-bottom elevation was successfully identified at Bore SDT-02. A new groundwater monitoring well was installed near the newly identified trench location to provide additional groundwater elevation data in the area. Monitoring data show the groundwater elevation is currently below the identified trench bottom. Based on the results of the investigation, the LTMP was revised to replace the performance goal at Bore 3453 with the new trench-bottom elevation at SDT-02. Operation and maintenance plans are in place and the monitoring being performed is adequate.

7.1.2.2 Complex (Army) Disposal Trenches Slurry Walls (Dewatering) (#17)

The Complex (Army) Disposal Trenches (CADT) slurry wall and dewatering system were installed in accordance with the On-Post ROD to lower groundwater levels below the disposal trenches. Based on criteria in the Design Document (RVO 1997), On-Post ROD, and 2010 LTMP, the Complex (Army) Disposal Trenches dewatering system is performing as expected in the Decision Documents.

The performance criteria for the CADT dewatering system are based on demonstrating hydraulic containment by achieving water elevation goals below the bottoms of the disposal trenches and water levels inside the slurry wall lower than the water levels outside the slurry wall (i.e., maintain an inward gradient). The inward hydraulic gradient has been maintained; however, the dewatering system has not attained the dewatering elevation goal in one of the two monitoring wells. Refer to Section 6.3.2.1 for additional information.

As a result, an evaluation was completed in 2019 to assess the current system conditions and evaluate whether additional active dewatering is necessary. Evaluation of groundwater elevations at the CADT indicated that the existing active dewatering system provides hydraulic control at both performance evaluation locations. Because the hydraulic gradient toward the extraction trench represents containment, the LTMP was revised (OCN-LTMP-2019-009) to incorporate demonstration of hydraulic control as an alternate performance goal. In FY19, the CADT system met the performance criteria and objectives established in the 2010 LTMP as revised by the OCN.

Operation and maintenance plans are in place and the monitoring being performed is adequate. Groundwater extracted from CADT is treated at BANS. Effluent concentrations were below CSRGs/PQLs in the BANS treatment plant effluent during the FYR period. As of the end of FY19, the dewatering system is functioning as intended in the ROD and design document. Early indicators of potential remedy problems were not identified.

7.1.2.3 Bedrock Ridge Extraction System (#28)

The BRES was installed in accordance with the On-Post ROD to prevent contaminant migration from the Basin A area toward First Creek. Extracted water is treated at BANS. The CCR for this project was finalized in September 2008 (Washington Group International 2008) and the system was accepted as O&F by the EPA.

Based on criteria in the BRES design document, On-Post ROD, and 2010 LTMP, the BRES is not functioning as intended in the decision documents. The BRES did not meet the plume capture performance criteria and objectives established in the 2010 LTMP. Although the plume appears captured at both edges of the system, bypass may be occurring within the west-central portion of the extraction system. Analytes 12DCLE and trichloroethylene in downgradient performance well 36566 show increasing concentration trends. Refer to Section 6.3.1.5 for additional information. Protectiveness is not affected due to downgradient containment at the NBCS. However, this is an early indicator of a potential remedy problem and is included as an Other Finding in Section 9.1.

Operation and maintenance plans are in place and are being implemented. Treatment of extracted groundwater occurs at the BANS and effluent concentrations were below CSRGs/PQLs in the BANS treatment plant. Two new monitoring wells were installed to provide additional data for system evaluation. Further monitoring and evaluation of the system will continue through 2021 to determine the need for additional extraction and system optimization to improve plume capture. Optimization opportunities include evaluation of extraction system configuration to improve plume capture.

7.1.2.4 North Plants Fuel Release (#40)

The LNAPL pilot removal system was implemented in 2008 to remove LNAPL due to a historical release of fuel oil in the North Plants and to gather operating data for the potential design of a full-scale LNAPL removal action. The monitoring wells installed as part of the pilot system have been monitored since inception of the program. During the previous FYR period, no LNAPL had accumulated in the recovery wells and the monitoring frequency was reduced to annual. Monitoring in this FYR period occurred as planned, and no measurable LNAPL within the former North Plants area was present in the wells. These data are consistent with data collected since FY13.

The monitoring data indicate that potentially mobile LNAPL no longer appears to be present. The thickness of LNAPL remaining in the formation (if any) is probably insufficient to overcome the capillary pressure of the wells. Typically, a falling water table causes the apparent thickness of LNAPL in the wells to increase if sufficient potentially mobile LNAPL is still present in the formation; however, that has not been observed during the past five years of decreasing water elevations. Due to the lack of observed LNAPL in North Plants wells, the Army/Shell recommends that the LNAPL monitoring program be discontinued.

7.1.2.5 Section 36 Lime Basins Slurry/Barrier Wall (Dewatering) (#47)

Lime Basins Slurry Wall Dewatering commenced during 2009. The dewatering goals are to lower the water levels inside the Lime Basins slurry wall to below the waste, and to maintain an inward hydraulic gradient from outside to inside the slurry wall.

Based on criteria in the Design Document (TtEC 2007c), ROD Amendment (TtEC 2005), and 2010 LTMP, the Lime Basins dewatering system is functioning as intended in the Decision Documents. Groundwater elevations have been below the bottom elevation of the waste since June 2016 and continue to decrease with operation of the dewatering system.

An inward hydraulic gradient has been established on the southern side while an outward gradient was still present for the well pairs on the northern side. However, groundwater elevations inside of the slurry wall have been steadily decreasing and the gradient decreased over the FYR period. Groundwater levels should continue to fall with continued operation of the dewatering system; however, due to declining water levels outside the slurry wall, the date for meeting the inward gradient performance goal cannot be reliably projected. However, a new goal of September 2024 was established to track progress toward meeting the goal. Monitoring and evaluation of progress toward meeting this goal will continue in the next FYR period. Treatment of extracted groundwater occurs at the BANS and concentrations were below CSRGs/PQLs in the BANS treatment plant effluent.

Operations and maintenance plans are in place and the monitoring being performed is adequate. As of the end of FY19, the dewatering system is performing as expected in the ROD and design document. Early indicators of potential remedy problems were not identified.

7.1.2.6 Section 36 Lime Basins DNAPL Remediation (O&M) (#47)

The monitoring wells for DNAPL long-term monitoring were constructed in accordance with the ROD, DNAPL FS, and approved design package drawings and specifications and are considered operational and functional. Water level monitoring, VOC sampling/analysis, and DNAPL monitoring are continuing as part of long-term O&M activities, and monitoring data have been collected as required by the selected remedy. DNAPL accumulating in the wells is recovered and transported off site for treatment and disposal. Based on criteria in the Design Document (TtEC and URS 2012), the Lime Basins DNAPL Remediation project is functioning as intended. Both the water quality and water level data indicate that the slurry wall has not been adversely impacted by DNAPL. Early indicators of potential remedy problems were not identified.

7.1.2.7 Railyard Containment System (#58)

The RYCS was 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 Irondale System to the new RYCS in July 2001. The Rail Yard System was evaluated based on the performance data presented in the ASRs and the FYSR (Navarro 2016f, 2017c, 2018e, 2019l and 2020b).

Based on criteria in the Railyard IRA Decision Document (MKE 1990), On-Post ROD, 2010 LTMP and Shut-Off Monitoring Plan, the RYCS is functioning as intended in the decision documents and is achieving the remedial objectives for the system. Operation of the extraction wells during the first portion of the FYR period (FY15-FY16) resulted in effective plume capture. Concentrations were below CSRGs in the RYCS treatment plant effluent and the contaminant concentrations were below the CSRG in the downgradient wells monitored during the FYR period.

The RYCS met shut-off criteria and was shut down on May 25, 2016. RYCS shut-off monitoring took place on a quarterly basis for a one-year period from the second quarter of FY17 through the first quarter of FY18, with detections at or below the CSRGs for DBCP and trichloroethylene. Annual monitoring is continuing in accordance with the LTMP. Refer to Section 6.3.3.10 for additional information.

Operation and maintenance plans were implemented until system shut off and maintained the effectiveness of the action. Both the operational monitoring (FY15-FY16) and shut-off monitoring (FY17-FY19) performed are adequate. An opportunity for optimization exists in the next FYR period as the post-shut-off monitoring network is developed. No indicators of potential issues have been identified.

7.1.2.8 Basin A Neck System (#59)

The BANS is a mass removal system that treats water migrating through the Basin A area as well as water extracted by the CADT dewatering system, the BRES, and the Lime Basins dewatering system. The performance of BANS during the FYR period is described and evaluated in the ASRs and in the FYSR (Navarro 2016f, 2017c, 2018e, 2019l and 2020b). Additional detail is provided in Sections 4.1.1.1 and 6.3.1.4.

The BANS met the treatment plant compliance requirements established in the 2010 LTMP. All extracted groundwater was effectively treated and contaminant levels in reinjected water were below the CSRGs. The concentrations were below CSRGs/PQLs in the BANS treatment plant effluent, and BANS mass removal improved the performance of the boundary systems by reducing contaminant loading. The BANS met the 75 percent mass removal criterion throughout the FYR period. The estimated BANS mass removal ranged from 76.2 to 99.7 percent and averaged approximately 89 percent during the FYR period. Concentrations of most analytes (except dieldrin and PPDDT, and single detections of 12DCLE and CPMSO2), are below CSRGs/PQLs in the downgradient performance wells. The trends indicate that concentrations of these analytes are not increasing.

For FY18 and FY19, the regulatory agencies approved use of the revised approach to calculate the mass removal percentage for comparison against the performance goal. The revised approach focuses on the extraction system performance by evaluating its effectiveness in capturing the approaching contaminant plume and accounts for contaminant mass not captured by the system. The revised approach will be evaluated further during the next FYR period to determine the appropriateness of the revised approach and whether the LTMP performance goal requires revision.

The BANS is functioning as intended based on criteria in the BANS IRA Decision Document (Army 1989), the On-Post ROD, and the 2010 LTMP (TtEC and URS 2010) and meets the protectiveness objectives for the system. Optimization opportunities include continued review of effluent monitoring requirements and monitoring network design. Operations and maintenance plans are in place and the operating procedures, as implemented, are maintaining the short-term and long-term effectiveness of the action. The monitoring being performed is adequate. No early indicators of potential remedy problems have been identified.

7.1.2.9 Northwest Boundary Containment System (#61)

The NWBCS is designed to prevent the off-post migration of contaminants and to treat groundwater contaminant plumes from the South Plants and the Basins A, C, and F areas to the RMA boundary. The performance of this system during the FYR period is described and evaluated in the ASRs and the FYSR (Navarro 2016f, 2017c, 2018e, 2019l and 2020b). Refer to Section 6.3.1.1 for additional information.

Based on criteria in the On-Post and Off-Post RODs, Off-Post Remediation Scope and Schedule, and 2010 LTMP, the NWBCS is functioning as intended in the Decision Documents. Effluent concentrations for all contaminants were below their respective CSRGs except for dieldrin in the first and third quarters of FY15, and NDMA in the second and third quarters of FY17. The effluent met the four-quarter moving averages throughout the five-year review period for all CSRG analytes. A reverse hydraulic gradient was maintained within the system and plume capture was evident within the original system as well as within the Northeast Extension and Southwest Extension.

Although dieldrin was detected above the PQL in Original System and Northeast Extension downgradient performance wells, the performance criterion was met because the long-term trend is not increasing in downgradient performance wells. Dieldrin above the PQL in the NWBCS downgradient performance wells may be due to a variety of factors including contamination due to mobilization of residual dieldrin or possible system bypass around the north end of the slurry wall. Although the trends are not increasing, the prolonged detection of dieldrin contamination in these wells has prompted additional evaluation to determine probable causes. Additional monitoring is being conducted and the potential for contaminated flow within the Northeast Extension will be further evaluated in 2020/2021.

Optimization opportunities include continued review of effluent monitoring requirements and monitoring network design. Potential future enhancements may include the addition of extraction or recharge wells in the Northeast Extension. Operations and maintenance plans are in place and the monitoring being performed is adequate. Although the system performance evaluation criteria were met, dieldrin concentrations above the PQL in downgradient performance wells is an early indicator of a potential remedy problem and has been identified as an issue in Section 8.0.

7.1.2.10 North Boundary Containment System (#62)

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 performance of the NBCS system during the FYR period is described and evaluated in the ASRs and the FYSR (Navarro 2016f, 2017c, 2018e, 2019l and 2020b).

Based on criteria in the On-Post and Off-Post RODs, Off-Post Remediation Scope and Schedule and 2010 LTMP, the NBCS is functioning as intended in the Decision Documents. Extracted groundwater was effectively treated to contaminant levels below the CSRGs before reinjection. The effluent met the four-quarter moving averages throughout the five-year review period for all organic CSRG analytes and arsenic, thereby meeting the effluent compliance requirements. According to the On-Post ROD, ARARs for chloride and sulfate at the NBCS will be achieved through attenuation as described in Development of Chloride and Sulfate Remediation Goals for the North Boundary Containment System at the Rocky Mountain Arsenal (MKE 1996). A reverse hydraulic gradient was maintained within the system throughout the year and plume capture was evident. The primary LTMP performance criteria were met throughout the FYR period.

Dieldrin concentrations are above the PQL in downgradient performance wells but show stable or decreasing trends in the majority of wells. There were also sporadic detections of NDMA and anions above their respective CSRGs. The downgradient detections are the result of residual contamination and are therefore not representative of system effectiveness. In particular for dieldrin, the concentrations present above the PQL in the downgradient wells are likely due to its lower solubility and more sorptive nature. Fluctuations in groundwater levels downgradient of the NBCS slurry wall caused by variations in the recharge trench flow rates and variable recharge from First Creek likely causes desorption of dieldrin from the aquifer sediments. As mentioned above, CSRGs for the anions will be achieved through attenuation. Refer to Section 6.3.1.2 for additional information.

As stipulated in the 2010 LTMP, when the primary performance criteria are met, the NBCS is functioning as intended. The mechanisms causing the downgradient concentrations of a few analytes to be above the CSRGs/PQLs appear to be unrelated to system performance. Therefore, when the primary criteria are met, the NBCS is functioning as intended.

Optimization opportunities include continued review of effluent monitoring requirements and monitoring network design. Potential future enhancement includes optimization of extraction well pump sizes relative to current flow rate requirements. Operations and maintenance plans are in place and the operating procedures, as implemented, are maintaining the short-term and long-term effectiveness of the action, and the monitoring being performed is adequate. No early indicators of potential issues have been identified.

7.1.3 Operating Groundwater Remedial Actions in the Off-Post OU

7.1.3.1 Off-Post Groundwater Intercept and Treatment System (#94)

The OGITS is a mass removal system designed to extract and treat contaminated alluvial groundwater from the First Creek and Northern Pathway alluvial channels, downgradient of the NBCS, and return treated water to the alluvial aquifer. Operation of the NPS includes the original system and the modified system installed in 2006. The performance of the OGITS during the FYR period is described and evaluated in the ASRs and the FYSR (Navarro 2016f, 2017c, 2018e, 2019l and 2020b). Additional detail is provided in Section 4.1.1.1 and 6.3.1.6.

Based on criteria in the Off-Post ROD, Off-Post Remediation Scope and Schedule and 2010 LTMP, the OGITS functioned as intended in the Decision Documents during of the FYR period. Extracted groundwater was effectively treated to contaminant levels below the CSRGs before reinjection. The effluent met the four-quarter moving averages throughout the five-year review period for all organic CSRG analytes and arsenic thereby meeting the effluent compliance requirements.

Chloride concentrations exceeded the four-quarter moving average in the OGITS effluent during four of the five years, FY15 – FY18, and sulfate exceeded in FY16. These analytes are not treated by OGITS and will meet CSRGs in the effluent by attenuation, consistent with the on-post remedy. Concentrations of both anions showed decreases over the FYR period. The moving average has been below the CSRG for chloride since the third quarter FY18. Sulfate concentration has been below the CSRG since the third quarter FY16.

The mass removal at the FCS and NPS met the performance goal of 75 percent removal throughout the FYR period. Under the current LTMP method, meeting the 75 percent mass removal goal will become more difficult as treatment plant mass removal percentages decrease since the differences in influent and effluent concentrations are small. As the overall system performance is comprehensively evaluated as a function of both extraction system performance and treatment system performance, the current methodology does not consider how effectively each system captures contaminated groundwater.

In FY18, a revised approach was developed to provide quantitative measures of extraction system performance to better quantify contaminated groundwater not captured as an indication of potential system bypass. This methodology focuses on measuring the effectiveness of mass removal at the point of capture (extraction) within each system with the understanding that once contaminated groundwater is extracted it undergoes treatment as influent within each respective plant to meet the requirements in the ROD. Quantitatively, the mass captured through system extraction is compared to the overall mass of the plume approaching the system, resulting in an overall percentage that is compared to the performance goal, currently 75 percent. For FY18 and FY19, the regulatory agencies approved use of the revised approach to calculate the mass removal percentage for comparison against the performance goal. Based on this revised approach, both the FCS and NPS demonstrated that greater than 75% of the mass within each contaminant plume was captured for treatment. The revised approach will be further evaluated during the next FYR period to determine the appropriateness of the revised approach and whether the LTMP performance goal requires revision.

At the FCS, all three downgradient performance wells had concentrations below the OGITS CSRGs/PQLs for the organic analytes, except for dieldrin in wells 37084 and 37343. Since FY16, the dieldrin concentration in both wells has continued to decrease (Figure 6.3-36). However, it is unlikely that the dieldrin detected downgradient is caused by bypass of the system because other FCS contaminants are not detected above the CSRGs in these wells. Therefore, the dieldrin detections above the PQL are not believed to be indicative of system bypass.

For the NPS, sporadic detections of arsenic, chloride, dieldrin, NDMA and NDPA occurred in downgradient performance wells at concentrations exceeding CSRGs/PQLs. During the FYR period, additional monitoring detected dieldrin above the PQL in the gap between modified system extraction wells 37817 and 37818. Additional monitoring confirmed the presence of dieldrin in the gap area between the two wells extending downgradient past the modified system. The plume is currently captured by original system extraction wells 37809 and 37810; however, these wells are located in the expiring lease area and will not be available long term. Due to the lease expiration, the Army has negotiated for an easement for the modified NPS. Although the combined NPS continues to meet the LTMP performance criteria, revision and completion of the system upgrade is required to address dieldrin bypass in the gap area and allow abandonment of the original system. The wellfield design includes components for extraction, recharge, and groundwater monitoring within the gap area (Navarro 2020n). Completion of the system upgrade to address the dieldrin plume is identified as an issue in Section 8.0.

Optimization opportunities include continued review of effluent monitoring requirements and monitoring network design. Potential future enhancements include improvements to the modified extraction system, elimination of the old system, and construction of new treatment facilities. Additional optimization opportunities include optimization of extraction well pump sizes relative to current flow rate requirements and review and refinement of the mass removal calculations and goals. Operations and maintenance plans are in place and the operating procedures, as implemented, are maintaining the short-term and long-term effectiveness of the action. The monitoring being performed is adequate to monitor system performance; however, the monitoring network will need to be reviewed and adjusted as necessary once development plans are completed.

7.1.3.2 Private Well Network (#96)

The Off-Post Private Well monitoring is conducted by TCHD for the Army. As described in Section 6.3.3.5, TCHD samples off-post private wells to determine the water quality of new off-post wells as required by the Off-Post ROD, to respond to citizen requests, and to determine whether CFS wells are acting as conduits for contaminant transport from the UFS to the CFS. Execution of the program depends on cooperation from the private well owners, and access to the wells is therefore not consistent. Thirty wells were sampled at least once during the review period including 15 alluvial wells and 15 Arapahoe aquifer wells.

All the private CFS well results were below the CSRG for DIMP, except for well 359A and replacement well 359D. The Army continues to provide bottled water to the residents at this location to minimize exposure to the contaminated water. Refer to Section 6.3.3.5 for additional information. Evaluation of the presence of DIMP in this location and options for alternate water supply are ongoing. This is identified as an issue in Section 8.0.

7.1.3.3 Off-Post Institutional Controls (#98)

TCHD continued to provide oversight of the SEO to ensure that requirements of the off-post well notification program were met. In 2011, the well notification program was modified to include both the potential CSRG exceedance area and the historical area of contamination (PMRMA 2011). The historical area of contamination is identified in the Off-Post ROD and was defined as the area of DIMP contamination based on the 0.392 parts per billion reporting limit. The two notification areas were incorporated into the final LUCP and the revised requirements were communicated to the SEO.

There were 15 permits issued for new wells during this FYR period, one permit for a replacement well, and two permits issued to use an existing well. All permits for new wells carried the required notification language. However, on one permit issued in 2018, the SEO inadvertently included the wrong notification language on the permit. TCHD discussed this error with the SEO and a corrected permit was issued.

Notification language was not included on the permit for the replacement well or the permits for use of existing wells. The SEO indicated that they believed the notification was not required since it was not for a completely new well. The Army communicated to the SEO that all permits issued for the drilling of any new well, replacement well, or use of an existing well within the notification areas should include the required RMA notification.

The well notification program continues to function as intended and monitoring of the program is adequate. No early indicators of potential remedy problems have been identified.

7.1.4 Operating On-Post Soil Remedies

The on-post soil remedies are assessed against the criteria described above in Section 7.2 using the results and information presented in Section 4.2.2 and Section 6.3.6.

7.1.4.1 Hazardous Waste Landfill Operations and Maintenance (#8)

The HWL is a closed landfill facility containing remediation waste from various areas at RMA. Approximately 1.8 million cubic yards of material were placed into the HWL. The HWL liner system consists of two composite liners, each made of high-density polyethylene geomembrane and a compacted clay layer. A granular leachate collection layer overlies the primary liner. A geocomposite leak detection layer has been placed between the primary and secondary liners. The greatest thickness of the waste is approximately 65 ft.

The HWL cap was designed to provide long-term minimization of the migration of liquid into the closed landfill and to function with minimum maintenance. The cap has slopes between 5:1 Horizontal to Vertical Ratio (H:V) and 20:1 H:V with a minimum three percent at the crown. The gravel erosion layer also functions as a gas vent layer for the cap. Gas vents located at the perimeter of the cap collect gas from this layer and vent it to the biota barrier layer, through the overlying soil layers or to the edge of the biota barrier material, and ultimately to the atmosphere.

Surface water controls on the cap include a series of terrace channels to direct water off the cap. Terrace channels direct stormwater to downchute structures that terminate in energy dissipaters. The stormwater flows to perimeter channels, away from the HWL and to the surface water detention area located outside of and north of the HWL fence line in Section 24. Where required, channels are lined with articulated concrete block.

To detect the potential migration of contaminants to the groundwater beneath the HWL, a network of wells is used to monitor groundwater elevation and quality both upgradient and downgradient of the HWL during the post-closure period.

Wastewater from the HWL LDS sumps was sampled quarterly until May of 2019 when the sampling frequency was changed to an as-needed basis. Samples collected from the LDS were analyzed to monitor for potential leaks in the landfill liner systems and to provide data necessary for interpreting whether contamination in downgradient monitoring wells can be tied to leakage from the HWL. The LDS samples have not indicated that the HWL LCS liner systems are leaking. As described in Section 6.3.6.1 the HWL LDS wastewater frequently has a variety of contaminants. When elevated concentrations were reported in LDS sample results the Regulatory Agencies were notified and the Army evaluated potential sources including LCS leachate, borrow soil used to construct the liner, and laboratory contaminants. The contaminant source was typically attributed to the on-site borrow source of clay for the liner. Therefore, a variety of information was reviewed to evaluate the effectiveness of the HWL to contain waste, including the evaluation of leachate analytical results, LDS volumes, and groundwater data. None of these evaluations have indicated potential leaks in the landfill liner systems.

Leachate and other wastewater collected in the sumps of the HWL is transferred to the nearby LS/LF as sump levels approach the maximum allowable levels. HWL wastewater is transported off site for incineration. Treatment of HWL wastewater is not performed on site.

Operating procedures detailed in the HWL Post-Closure Plan (Navarro 2019d), as well as other work plans and SOPs implemented by the Army’s O&M contractor, were implemented throughout the FYR period and adequately maintained the facility, and thereby ensured the effectiveness of the response action. Sections 6.3.3.6 and 6.3.6.1 describe the LCS/LDS and groundwater monitoring, and operations and maintenances activities performed on each of the HWL systems.

Institutional controls implemented for the HWL include land use restrictions, access control, and visitor policies, and are detailed in the LUCP (Navarro 2013). The HWL was designed with specific engineering controls to delineate the boundary of the waste containment area maintained during the post-closure period. Engineering controls include erosion/settlement monuments built into the HWL cap soil to measure the loss of soil cover thickness, a perimeter chain-link fence enclosing the HWL and ELF, warning signs posted on the fence at 100-ft centers and on access gates, and survey plats of the limits of the HWL recorded with Adams County, Colorado. Implementation of these controls, in addition to the site-wide controls described in the LUCP, prevent exposure to the remediation waste.

Based on the routine surface inspections, groundwater monitoring results, and average daily flowrate calculations of the HWL LDS sumps performed during this FYR period, the HWL is operating and functioning as intended, is meeting its RAOs, and the containment of the waste stored within the facility is effective. There were no early indicators of potential remedy problems.

7.1.4.2 Enhanced Hazardous Waste Landfill Operations and Maintenance (#13)

The ELF is a closed landfill facility containing remediation waste from various areas at RMA. Approximately 1.1 million cubic yards of material were placed into the ELF. The ELF liner system consists of three composite liners, each made of high-density polyethylene geomembrane and a compacted clay layer. Each compacted clay layer is overlaid by an LCS or LDS. Waste containment liquids are removed through the LCS or LDS that is installed above each geomembrane. The greatest thickness of the waste is approximately 70 feet.

The ELF cap was designed to provide long-term minimization of the migration of liquid into the closed landfill and to function with minimum maintenance. The cap has slopes between 6:1 H:V and 20:1 H:V with a minimum three percent at the crown. A layer of geocomposite functions as a gas vent layer for the cap. Four gas vents located at the perimeter of the cap collect gas from material below the cap geomembrane and vent it to the biota barrier material layer, through the overlying soil layers or to the edge of the biota barrier, and ultimately to the atmosphere through the Gravel Drainage Layer.

Surface water controls on the ELF cap include a series of terrace channels to direct water off the cap. Terrace channels direct stormwater to downchute structures that terminate in energy dissipaters. The stormwater flows to perimeter channels, away from the ELF and to the surface water detention area located outside of and north of the HWL fence line in Section 24. Where required, channels are lined with articulated concrete block.

To detect the potential migration of contaminants to the groundwater beneath the ELF, a network of wells is used to monitor groundwater elevations and quality both upgradient and downgradient of the ELF during the post-closure period.

Wastewater from the ELF LDS sumps was sampled quarterly until May of 2019 when the sampling frequency was changed to an as-needed basis. Samples collected from the LDS sumps were analyzed to monitor for potential leaks in the landfill liner systems and to provide data necessary for interpreting whether contamination in downgradient monitoring wells can be tied to leakage from the ELF. The LDS samples have not indicated that the ELF LCS liner systems are leaking. As described in Section 6.3.6.2 the ELF LDS wastewater frequently has a variety of contaminants. When elevated concentrations were reported in LDS sample results the Regulatory Agencies were notified and the Army evaluated potential sources including LCS leachate, borrow soil used to construct the liner, and laboratory contaminants. The contaminant source was typically attributed to the on-site borrow source of clay for the liner. Therefore, a variety of information was reviewed to evaluate the effectiveness of the ELF to contain waste, including the evaluation of leachate analytical results, LDS volumes, and groundwater data. None of these evaluations have indicated potential leaks in the landfill liner systems.

Leachate and other wastewater collected in the sumps of the ELF is transferred to the nearby LS/LF as sump levels approach the maximum allowable levels. ELF wastewater is transported off-site for incineration. Treatment of ELF wastewater is not performed on site.

Operating procedures detailed in the ELF Post-Closure Plan (Navarro 2020f), as well as other work plans and SOPs implemented by the Army's O&M contractor, were implemented throughout the FYR period and adequately maintained the facility, and thereby ensured the effectiveness of the response action. Sections 6.3.3.7 and 6.3.6.2 describe the LCS/LDS and groundwater monitoring, and operations and maintenances activities performed on each of the ELF systems.

Institutional controls implemented for the ELF include land use restrictions, access control, and visitor policies, and are detailed in the LUCP (Navarro 2013). The ELF was designed with specific engineering controls to delineate the boundary of the waste containment area maintained during the post-closure period. Engineering controls include erosion/settlement monuments built into the ELF cap soil to measure the loss of soil cover thickness, a perimeter chain-link fence enclosing the ELF and HWL, warning signs posted on the fence at 100-ft centers and on access gates, and survey plats of the limits of the ELF recorded with Adams County, Colorado. Implementation of these controls, in addition to the site-wide controls described in the LUCP, prevent exposure to the remediation waste.

Based on the routine surface inspections, groundwater monitoring results, and average daily flowrates calculations of the ELF LDS sumps performed during this FYR period, the ELF is operating and functioning as intended, is meeting its RAOs, and the containment of the waste stored within the facility is effective. There were no early indicators of potential remedy problems.

7.1.4.3 Basin F/Basin F Exterior RCRA-Equivalent Cover Operations and Maintenance (#46)

The physical construction of the Basin F Cover is complete and documented in the *Basin F/ Basin F Exterior Remediation Project Part 2 (Basin F Cover Project) Construction Completion Report – Part 1* (TtEC 2010c).

The Basin F Cover was in the Interim O&M Period, as described in Section 1.0 of the LTCP, following the Final Inspection on March 2, 2010 until the EPA determined that the cover was O&F on September 18, 2019 (EPA 2019a). The Army prepared the *Basin F/Basin F Exterior*

Remediation Project Part 2 CCR – Part 2 (Navarro 2017e) to summarize the cover's performance during the Interim O&M Period. The CCR – Part 2 was approved by the EPA on September 19, 2017 (EPA 2017). Information contained within the CCR – Part 2 was used by the EPA, in coordination with the CDPHE, TCHD, and the Army, to make the O&F determination based on performance data that showed conformance with the cover performance standards. The O&F determination was documented in a letter from the EPA to the Army dated September 18, 2019 (EPA 2019a).

Routine percolation monitoring, vegetation assessments, and cover maintenance activities have been on-going since cover construction was completed. Refer to Section 6.3.6.4 for additional information. No early indicators of potential remedy failure have been identified through these activities. Because the RCRA-equivalent cover consists of monitoring activities on the completed cover surface, prevention of exposure to COCs was not a concern. The cover serves as a containment facility; therefore, the project is subject to long-term O&M requirements as presented in the LTCP (TtEC 2011d). Long-term groundwater monitoring is being performed in accordance with the Basin F PCGMP (TtEC 2011c). Groundwater monitoring results during Basin F post-closure have been reported through 2019 and identify no early indicators of potential remedy failure (Navarro 2015f, 2016c, 2017b, 2018c and 2019h). The ICs identified in the cover design (fences, signs, and obelisks) are in place and being maintained. Implementation of the LUCP (Navarro 2013) continues to satisfy the Refuge Act and On-Post ROD requirements.

Based on the routine surface inspections, percolation monitoring, vegetation assessments, and groundwater monitoring results, the Basin F Cover is operating and functioning as intended, is meeting its RAOs, and the containment of the contaminated soil and debris beneath the cover is effective. There were no early indicators of potential remedy problems.

7.1.5 Other Operating Projects

7.1.5.1 Site-Wide Biota Monitoring (#48)

Site-Wide Biota Monitoring was implemented in accordance with the Long-Term Contaminant Biomonitoring Program for Terrestrial Ecological Receptors at Rocky Mountain Arsenal (BAS 2006) to help evaluate the effectiveness of the remedy in accordance with the requirements of Section 9.7 of the ROD. Phase 1 of the BMP included collection of starling brain and kestrel egg samples between 2007 and 2013. Although the starling evaluation was completed as planned, the kestrel portion of the BMP could not be completed as outlined in the BMP due to difficulties in obtaining sufficient kestrel samples.

The Army conducted a series of meetings with the regulatory agencies to determine requirements for completion of the program. It was agreed that instead of kestrel sampling, requirements for program completion were revised to focus on soil sampling. Additional detail is provided in Section 6.3.5.

Soil sampling was conducted in November 2017 throughout the area where limited kestrel results indicated potential exposure. All soil results were below the selected screening criteria of 110 µg/g for dieldrin indicating that the remedy effectively eliminated significant exposure pathways in the area sampled (Navarro 2018i).

The Army completed the Data Summary Report for soil sampling in June 2018 (Navarro 2018i) and prepared a draft MCR in December 2018 to document completion of the ROD-required biomonitoring program. The MCR is awaiting final EPA review. Completion of the BMP documentation is included under Other Findings in Section 9.1.

7.1.5.2 Site-Wide Surface Water Monitoring

On-Post Surface Water Quality Monitoring (#50a)

The on-post surface water monitoring program was implemented as required by the ROD and the Short-Term Surface Water Sampling and Analysis Plan. The surface water sampling locations are shown on Figure 6.3-77. Sample concentrations from Lake Ladora and Borrow Area 5 were below the aquatic life standards and below the CBSGs/PQLs, indicating that runoff from exposed surface soil from the South Plants cover and landfill caps did not adversely impact biota at those locations, respectively. The lake sample concentrations were below the aquatic life standards and below the CBSGs/PQLs. Thus, these data indicate that runoff from exposed surface soil from the South Plants cover does not have the potential to impact surface water above acute or chronic aquatic life standards, and that South Plants groundwater plumes are not migrating into the lakes above CBSGs.

Location SW25101, a localized point of surface water accumulation during high precipitation events within the former North Plants area, exceeded the calculated aquatic life standards. Based on local topography, contaminants at this location do not have the potential to migrate to downstream receptors or have the potential to migrate off-post and exceed the remediation goals in off-post surface water.

Surface water at SW26002, within the former Basin E area, contained dissolved metals concentrations exceeding the calculated aquatic life standards in multiple samples collected. This was identified as an issue in the 2015 FYRR and follow-up sampling confirmed the detections. A soil sampling program was completed and determined the presence of trace metals in the surface soil are naturally occurring and there was no anthropogenic source of metals. Based on these results, the weight of evidence indicates that the remedy has had no adverse impacts on water quality related to aquatic life. Conclusion of the former Basin E investigation completed the requirements of the short-term surface water monitoring program (Navarro 2020d).

There were no indicators of potential remedy problems and no further on-post surface water monitoring is required.

Off-Post Surface Water Monitoring (#50c)

Surface water locations SW08003, SW24004, and SW37001 were sampled annually FY15–FY19 and are shown on Figure 6.3-77. During the five-year reporting period, only arsenic was detected at concentrations above the off-post CSRG in samples collected in First Creek near 96th Avenue (SW24004) in FY19 and Highway 2 (SW37001), downgradient of RMA, in FY15, FY16, FY18, and FY19 (Table 6.3-32). The concentration of arsenic remains higher in First Creek at off-post location SW37001 than at boundary location SW24004—consistent with the historical trend in arsenic detected within First Creek. Therefore, it is likely that the presence of arsenic in surface water at SW37001 is naturally occurring and not attributable to RMA activities.

Over the past several years the flow in First Creek has increased and ponding of surface water has occurred across the First Creek System area where data indicate surface water is in contact with contaminated groundwater based on the similarity in water quality and presence of organic contaminants. With the continuing removal of organic contaminants from the groundwater in the area, concentrations of the target suite of organic constituents in surface water at off-post station SW37001 are expected to continue to decrease. Treatment of groundwater contaminants at the NBCS and the OGITS appear to be having a positive effect on First Creek water quality. Accordingly, the remedy is performing in accordance with the Off-Post ROD.

7.1.5.3 Site-Wide Groundwater Monitoring (#50)

Discussion of the results for the Site-Wide Groundwater Monitoring Program are provided in Section 6.3.3. Overall, the monitoring program is being implemented as expected based on the requirements of the LTMP. Monitoring results are adequate to evaluate water levels and water quality for both the On-post and Off-post OUs. Identified inconsistencies between the RMA groundwater program and the monitoring program established by the 2010 LTMP are described in Section 6.3.3. The deviations were typically associated with inability to sample damaged wells or the addition of wells based on monitoring results.

On-Post Monitoring

A year-to-year comparison of water levels indicates that there were higher groundwater elevations in 2015 and with a gradual decrease through the reporting period in areas of the UFS where saturated alluvium is present across the site. Overall, based on the comparison for 2015 through 2019, groundwater flow directions and associated migration of contaminant plumes have not changed significantly.

During the five-year reporting period, migration flow paths have not been affected. While the concentrations of most analytes demonstrate stable or decreasing trends, the concentrations of some analytes have demonstrated increasing statistical trends during the five-year reporting period.

Statistical increasing trends in UFS groundwater were demonstrated for chloroform and dieldrin downgradient of former Basin F and Sand Creek Lateral and upgradient of the NWBCS; fluoride and chloride downgradient of former Basin F and upgradient of the NBCS; and arsenic and trichloroethylene downgradient of the former Basin A and upgradient of BANS. However, concentration trends in these source areas do not represent a change in site conditions that affect remedy performance, and the contaminant plumes are captured by the existing treatment systems. Continued monitoring of the current water quality tracking network is recommended to evaluate long-term trends for these contaminants. The next water quality tracking monitoring will be conducted in 2022. There were no early indicators of potential remedy problems for the on-post water level or water quality tracking programs.

Off-Post Exceedance Monitoring

The off-post exceedance monitoring was conducted as required by the ROD and LTMP. Monitoring well locations are shown on Figure 6.3-56. Deviations from the planned sampling of the wells in the 2010 LTMP exceedance well network are described in Section 6.3.3.

Overall, development pressure in the off-post area is resulting in damage to some monitoring wells or unsafe conditions due to significant increases in local traffic. A review of the off-post monitoring network is underway by the Army to identify monitoring locations that need to be retained and appropriate safe locations for replacement wells. Loss of monitoring wells from the off-post network is an early indicator of a potential remedy problem and this is identified as an issue in Section 8.0.

Confined Flow System Monitoring

CFS monitoring is required by the On-Post ROD to identify vertical or lateral migration of contaminants to or within the CFS in the Basin A, Basin F, and South Plants areas. The CFS well network is specified in the 2010 LTMP (TtEC and URS 2010) and the well locations are shown on Figure 6.3-55. Generally, the CFS monitoring was implemented as required under the ROD and LTMP with minor deviations from the planned sampling described in Section 6.3.3. The following observations summarize the findings form the CFS monitoring during the FYR period:

- During the five-year reporting period, the vertical hydraulic gradients were downward in most UFS/CFS well pairs, with an upward gradient in one well pair in South Plants. The head differentials in the South Plants well pairs have decreased in response to soil cover completion.
- Chloride and organic analytes chlorobenzene and dieldrin were detected in CFS wells within the monitoring network. Chloride results demonstrated stable or decreasing trends for the areas monitored with the exception of well 35067, downgradient of former Basin A, where the trend in the CFS is comparable to the UFS. The downward gradient indicates the aquifer may be semi-confined in this area.
- Chlorobenzene was detected in Basin A well 02057; however, concentrations in FY17 and FY19 demonstrate a decreasing trend over the past five years.
- Dieldrin was detected in FY19 in three CFS wells, all downgradient of former Basin F, for the first time and in well 26153 for the first time in more than 25 years. Based on the first-time presence of dieldrin in groundwater CFS wells since remedy was completed, CFS wells 23187, 23193, 26147, and 26153 should be evaluated to determine the source of CFS contamination.

Chloride in well 35067, downgradient of former Basin A, and dieldrin concentrations above the CSRGs in CFS wells downgradient of Basin F, are identified as Other Findings in Section 9.1.

7.1.5.4 Land Use Controls (#99)

Land use restrictions and on-post ICs continue to be implemented successfully in accordance with the LUCP as described in Section 4.3.1.2. The LUCP includes primary land use restrictions identified in the FFA and ROD as well as access control requirements to limit access to certain on-post areas depending on the remedy activities being performed. In addition, the LUCP incorporates controls for other specific areas, including additional LUCs for the buried lake sediments (SSA-3b), access restrictions for the covers, and protection of groundwater remedy structures.

Access restrictions and ICs have been implemented and revised as necessary. They have effectively prevented individuals from exposure to unacceptable levels of risk. There were no trespass incidents that threatened the integrity or effectiveness of the remedy or created any potential for exposure. There was one trespass incident reported during this FYR period involving remediation systems. In October 2017, there was a vandalism event at the NWBCS. The glass was broken on the emergency power shutdown switch and the switch was activated, resulting in power loss to the plant. In addition, several switches were turned out of position. In response to the event and to improve security, the emergency power shutdown switch was moved inside the plant, spring-loaded switches were installed on the wells, and security cameras were installed at each treatment plant. Overall, project-specific access controls continue to provide adequate control to limit access to remediation areas to required or authorized personnel only.

Annual monitoring of land use controls is required to ensure they remain effective and are protective of human health and the environment. Results of the monitoring are provided in annual monitoring reports and are summarized in Section 6.3.7. Generally, issues identified during annual monitoring have been addressed as part of site O&M. As a result, these early indicators of potential remedy failure have been addressed, and the remedial action continues to function as designed. The Army continues to coordinate with the USFWS to ensure compliance with the existing restrictions on the Refuge. Adherence to the existing controls demonstrates that the LUCs are being effectively implemented.

In 2013, the USFWS finalized a Habitat Management Plan for the RMANWR (USFWS 2013) that included specific goals for management of the bison population to ensure long-term sustainability of restored prairie and shrubland. To meet these goals and effectively manage the bison herd at or below carrying capacity, it is necessary to periodically remove animals from the Refuge. However, when animals leave the Refuge, it becomes possible that they could be consumed by the public at some point in the future. Because consumption of game is currently prohibited by the ROD, the USFWS initiated a process of tissue sampling and risk evaluation to determine if RMANWR bison are safe for human consumption. Tissue sampling was completed over three sampling events in June 2019, October 2019, and October 2020. The tissue sampling program is designed to determine if contaminant concentrations in bison tissue are below levels that would pose an unacceptable risk to humans who ingest those tissues. Final data reports were issued in May 2021 documenting that all samples were non-detect for organochlorine pesticides and that the calculated risk from consumption did not present an unacceptable risk. The USFWS will coordinate with the Army and the regulatory agencies if a change to the ROD restriction is needed. However, there is no impact on protectiveness of the remedy because the existing LUC on game consumption continues to be implemented.

Two issues identified during annual monitoring were also included as issues in the 2015 FYRR. Review of the Commerce City Prairie Gateway PUD revealed a use-by-right for public gardening that appears inconsistent with the land use restrictions delineated in the Refuge Act, which prohibit non-remedy agricultural activities. In addition, the PUD includes some land uses (e.g., bed and breakfasts, group homes) that may be in conflict with the residential use restriction. The Army continues to meet regularly with the Commerce City Planning Department to maintain open communications regarding land use control issues, and potential changes to the PUD are discussed at these meetings. Planning Department personnel have consistently confirmed their awareness of the residential and agricultural use exclusions for the Prairie Gateway and have confirmed that these uses would not be approved while the restrictions were in force.

Land transfers were identified as an issue in the 2015 FYRR. Both the ROD and FFA include statements that the U.S. Government shall retain ownership of RMA. However, some land, including the Section 20 Northeast Parcel, was transferred outside federal control, and there was a concern that the CERCLA 120(h) process had not been followed. Although there were multiple discussions with the regulatory agencies regarding potential changes to the LUCP to clarify this issue, CERCLA 120(h) requirements are independently applicable, and it was agreed that no change to the LUCP was needed.

Overall, the LUCs are being effectively implemented and there are no issues that currently prevent the response action from being protective. However, changes to the Prairie Gateway PUD are still needed to ensure consistency with the existing land use restrictions. This is included as an issue in Section 8.0.

7.1.6 Completed Projects

Each of the following projects have been completed in accordance with the On- or Off-Post ROD requirements and other change documentation and have been documented in a project-specific CCR. Evidence of compliance with the appropriate ROD is indicated in acceptance letters received from the EPA that state the following:

- Remedial action activities have completed all construction items identified in the Scopes of Work and the Final Design Packages, as modified, for these projects.
- The State of Colorado has concurred with the CCRs.
- The EPA has approved the CCR and accepted the projects as complete.

These completed projects were reviewed in more detail than were projects under construction. This reflects the added emphasis placed on completed ROD projects as stated in the EPA guidance on FYRs.

7.1.6.1 Sanitary Sewer Manhole Plugging Phase II (#35)

The Sanitary Sewer Manhole Plugging Project Phase II was completed during the 2010 FYR period and documented as complete in the 2010 FYRR. However, as noted in Section 4.2.3.1, additional work was identified for this project after the 2010 FYR and the 2015 FYR.

The Sanitary Sewer Manhole Plugging Project Phase II Addendum 1, Addendum 2 and Addendum 3 have been completed. As documented in the CCRs (TtEC 2013, Navarro 2017j, Navarro 2020h), remedial actions under this project are expected to be protective of human health and the environment. The remedial action continues to function as designed. Because this project consisted of plugging manholes, containment and O&M are not relevant to this project.

Land use controls in the form of aboveground markers to indicate the abandoned sewer location are included in the remedy. Beginning in 2009, inspections have been conducted as part of the LUC monitoring effort to confirm the presence of aboveground markers along the abandoned sanitary sewer line. These inspections include segments of sewer addressed during Phase I (discussed in the 2000 FYRR) and Phase II (discussed in the 2010 FYRR) of the project. Implementation of the RMA LUCs (Navarro 2013) continues to satisfy the Refuge Act and On-Post ROD requirements. With completion of the LUCP in 2013, the inspection frequency was changed to once every five years. Results of the sewer marker inspections are discussed in Section 6.3.7.

Because this project has been completed, optimization is not relevant. No indicators of potential remedy problems were identified.

7.1.6.2 Secondary Basins Soil Remediation Part 2, Basin C Supplemental Soil Excavation Project (#37)

As noted in Section 4.2.3.2, the Basin C Supplemental Soil Excavation Project has been completed (Navarro 2019k). Section 4.2.3.2 provides a description of the project investigation and remedy implementation. The remedial action continues to function as designed and cleanup levels have been achieved. Because this was an excavation project, containment and O&M are not relevant to this project. RMA site access restrictions and project-specific health and safety measures ensured the safety of workers and visitors. Implementation of the RMA LUCs (Navarro 2013) continues to satisfy the Refuge Act and ROD requirements. As a completed excavation project, optimization is not relevant. No indicators of potential remedy problems were identified.

7.1.6.3 On-Post Surface Water Quality Monitoring (#50a)

As described in Section 4.1.2.1, the On-Post Surface Water Quality Project has been completed. As documented in the *Surface Water Remediation Project Monitoring Completion Report* (Navarro 2020d), remedial actions under this project have achieved the intent of the ROD to be protective of human health and the environment. RMA site access restrictions and project-specific health and safety measures ensured the safety of workers and visitors. Based on monitoring results, the remedial action continues to function as designed. Refer to Section 6.3.4.1 for additional information. Implementation of the RMA LUCs (Navarro 2013) continues to satisfy the Refuge Act and ROD requirements. As a completed monitoring project, optimization is not relevant. Early indicators of potential remedy problems were not identified.

7.1.6.4 Groundwater Mass Removal Project Post-Shut Off Monitoring (#60a)

As described in Section 4.1.2.2, the GWMR Mass Removal Project Post-Shut-Off Monitoring has been completed as documented in the *Groundwater Mass Removal Project Post-Shut-Off Monitoring Completion Report* (Navarro 2018j). The project area is located within the ICS cover and is subject to the O&M requirements specified in the LTCP (TtEC 2011d). RMA site access restrictions and project-specific health and safety measures ensured the safety of workers and visitors. Based on post-shut-off monitoring results, the STF benzene plume continues to be stable or receding and is not migrating toward the lakes. As a completed monitoring project, optimization is not relevant. Early indicators of potential remedy problems were not identified.

7.1.7 Cost

The original estimate for the remediation of RMA was $2.2 billion stated in FY95 dollars. This total included approximately $750 million of cost that was incurred prior to the signing of the ROD in 1996, $1.359 billion for baseline Remedial Actions, and an estimated $91 million in post-remedy long-term monitoring/maintenance costs. The remaining $1.359 billion represents the baseline construction estimate in FY95 dollars. The escalated estimate for the Remedial Action scope of activity, as shown in the RMA 1997 Report to the U.S. Senate Appropriations Committee, was $1.512 billion dollars (listed there as Remediation). As of March 31, 2020, RMA has recorded an actual cost-to-date of $1.371 billion dollars for the Remedial Action Construction. The Remedial Action Construction phase is 100% complete and no further costs are expected to be recorded under this category.

RMA began recording post-remedy long-term operations and monitoring and maintenance (LTM) costs in 2011. At the time of the original estimate, the $91 million in estimated post-remedy long term operations and LTM included cost through 2025, or 30 years from the date of the original estimate (1995). The current estimate includes costs through 2050 and totals $410 million. Of this total, $135 million has been incurred to date. Some post-remedy long-term operations and LTM activities are expected to continue indefinitely. Therefore, each year the estimate will be expanded by another year maintaining a 30-year projection until closure can be predicted to be within the 30-year estimate limit, or a definitive end date beyond the 30-year window can be identified.

7.2 QUESTION B: ARE THE EXPOSURE ASSUMPTIONS, TOXICITY DATA, CLEANUP LEVELS, AND REMEDIAL ACTION OBJECTIVES USED AT THE TIME OF THE REMEDY SELECTION STILL VALID?

This section includes a discussion of all ARARs and TBCs identified in the RODs, and exposure and toxicity assessment variables and risk assessment methods used to develop soil cleanup criteria (Ebasco 1994). ARARs are standards-based criteria, such as federal and state standards for soil or groundwater. ARARs can be chemical-specific, action-specific, or location-specific. TBCs are risk-based criteria established through risk assessments conducted for the relevant media and exposure pathways. The primary routes for potential exposure are ingestion, dermal contact, and inhalation.

For organizational purposes, the ARARs and TBCs are separated into four categories: water treatment system ARARs and TBCs, air ARARs and TBCs, soil ARARs and TBCs, and other media ARARs and TBCs.

7.2.1 Water Treatment System ARARs, TBCs, and PQL/MRLs

This section addresses ARARs, TBCs, and associated PQLs relevant to the water treatment systems that have changed during this FYR period. Potential changes in ARARs and TBCs for the different treatment systems are addressed in the following subsections. The ARAR, TBC, and PQL/MRL changes addressed here will not be used to assess past system performance, but they will be considered for future application.

7.2.1.1 Changes to Water Standards

Water treatment ARARs were identified for the NWBCS, NBCS, RYCS, OGITS, and BANS. The ARARs are based on state and federal standards as well as risk-based values. Potential modified standards were evaluated for all contaminants identified with a CSRG in the RODs. Potential new standards were evaluated for all contaminants that were included as target analytes in the water RI and for emerging contaminants. Table 7.4-1 lists existing standards and potential revision to those standards for the water treatment systems.

There are no ARAR changes since the last FYR that are relevant to the water treatment systems. However, existing CBSGs for two chemicals, 1,4-dioxane and N-nitrosodi-n-propylamine, were adopted as CSRGs following evaluations that confirmed the presence of the contaminants at RMA and the applicability of the standards (Army 2020).

The 2010 LTMP was revised to include 1,4-dioxane and NDPA on the appropriate CSRG tables and require monitoring for treatment plant influent, effluent, and water quality performance wells. In addition, 1,4-dioxane and NDPA were added to select water quality tracking wells and off-post CSRG exceedance network wells (OCN-LTMP-2020-002, OCN-LTMP-2019-001).

There were no changes to federal MCLs identified during this FYR period.

Table 7.2-1. Potential New or Revised Standards for Water Treatment Systems

Chemical	Existing CSRG (µg/L)	New or Revised Standard (CBSG) (µg/L)	2020 CSRG (µg/L)
Arsenic[1,2]	2.35/50	10 (2010)	2.35/50
Mercury	2		2
Chloride	250,000		250,000
Fluoride	2,000		2,000
Sulfate	540,000		540,000
Atrazine	3		3.0
Benzene[3]	3		3
Carbon tetrachloride[3]	0.3		0.3
Chlorobenzene	100		100
Chloroform[1]	6	3.5 (2010)	6
DDT	0.1		0.1
1,2-Dichlorobenzene	600		600
1,3-Dichlorobenzene	94		94
1,4-Dichlorobenzene	75		75
1,1-Dichloroethylene	7		7
1,2-Dichloroethane[1]	0.4	0.38 (2015)	0.4
1,2-Dichloroethylene[1]	70	14 to 70 (2015)	70
1,4-Dioxane[4]	NA	0.35	0.35
Dibromochloropropane	0.2		0.2
Dieldrin	0.002		0.002
DIMP	8		8
Endrin	2		2

Table 7.2-1. Potential New or Revised Standards for Water Treatment Systems

Chemical	Existing CSRG (µg/L)	New or Revised Standard (CBSG) (µg/L)	2020 CSRG (µg/L)
Hexachlorocyclopentadiene[1]	50	42 to 50 (2005)	50
Isodrin	0.06		0.06
Malathion[1]	100		100
Methylene chloride	5		5
NDMA[5]	0.00069		0.00069
NDPA[4]	NA	0.005	0.005
1,1,2,2-Tetrachloroethane	0.18		0.18
Tetrachloroethylene	5		5
Toluene	1,000		1,000
1,1,1-Trichloroethane	200		200
Trichloroethylene[3]	3		3
Xylenes[3]	1,000		1,000

Notes:

[1] Where the current CBSG differs from existing CSRG and evaluation was provided in a previous FYR, the year of the review is provided in parentheses.

[2] For arsenic, the health-based level of 2.35 µg/L applies to the NBCS, NWBCS and OGITS; the 1996 CBSG of 50 µg/L applies to BANS.

[3] The CSRG is a health-based value from the Off-post ROD and is more stringent than the existing CBSG.

[4] Colorado promulgated this standard subsequent to the ROD.

[5] The CSRG of 0.00069 µg/L for NDMA, which is the current CBSG, represents a change from the risk-based level of 0.007 µg/L identified in the ROD.

7.2.1.2 Groundwater TBCs

There were no reported changes to groundwater TBCs.

7.2.1.3 PQLs, Certified Reporting Limits, and MRLs

The On-Post ROD identifies the site-specific PQLs as "(c)urrent certified reporting limit or practical quantitation limit readily available from a commercial laboratory." The ongoing changes to the RMA analytical programs and advancements in analytical technology require periodic review of analytical methods to re-evaluate the PQLs. The most recent formal review was completed in 2012 and resulted in revision to the PQLs for aldrin, dieldrin and NDMA (TtEC 2012). Reporting limits for all other analytes with PQLs identified in the ROD are sufficient to meet the CSRGs and use of PQLs is no longer necessary.

Agreement was reached for the PQL values for aldrin and dieldrin and these were adopted with approval from CDPHE on April 12, 2012. For NDMA, there were concerns regarding the calculated value based on the limited data used to develop the new PQL. Therefore, agreement was reached to use an interim PQL for NDMA set at twice the calculated PQL value (RVO 2011). Evaluation of NDMA results during the 2015 FYRR confirmed the ability to determine concentrations at the PQL of 0.009 µg/L identified in the 2012 PQL Study Report. Therefore, the interim PQL for NDMA was replaced with the PQL established in the study of 0.009 µg/L following issuance of the 2015 FYRR in September 2016. The NDMA PQL is applicable for the NBCS, NWBCS and OGITS.

Review of analytical data for aldrin, dieldrin and NDMA indicate that the method reporting limits have not changed significantly during this review period. Therefore, additional PQL studies are not warranted.

7.2.2 Air ARARs and TBCs

During active remediation, the TBCs for the RMA site-wide air criteria were updated annually and documented in the Interactive Comprehensive Air Pathway Analysis, and air monitoring was conducted in accordance with the Site-Wide Air Quality Monitoring Program (SWAQMP). Routine ambient air monitoring performed under the SWAQMP was completed at the end of 2008, and results were presented and evaluated in the Air MCR (TtEC 2009a).

No air ARAR changes were identified over the FYR period that affected the protectiveness of the RMA remedy. For the chronic criteria, inhalation unit risks and inhalation reference doses published in Integrated Risk Information System were unchanged. No TBC changes were identified for the acute air criteria. The estimated risks presented in the Air MCR remain valid.

Overall, monitoring from this FYR period indicates that no adverse changes in exposure concentrations were discovered. In most cases concentrations have generally decreased, resulting in less risk over time. All ARARs established in the On-Post ROD relative to air and odor quality were met, and no federal or state ambient air quality standard was exceeded because of RMA remediation activity.

7.2.3 Soil ARARs and TBCs

No changes to chemical-specific ARARs for soils were identified. Similarly, no changes to risk-based chemical specific TBCs for RMA soil COCs were identified.

7.2.4 Other Media ARARs and TBCs

No other ARAR changes were identified that could potentially affect the protectiveness of the remedy.

7.2.5 Changes in Exposure Assessment Variables

The exposure scenarios considered in the On-Post OU have not changed significantly since the signing of the ROD. The physical characteristics of the site (climate, vegetation, hydrology, and surface water) have remained relatively unchanged. The soil and structure remedies are complete, and the groundwater remedy is ongoing, so known potential exposure pathways have been addressed.

The demographics considered in the Off-Post OU have changed since the signing of the ROD. The population north of RMA continues to increase as more of the area is being converted from agricultural use to residential use. However, because residential uses were included as part of the risk assessment, the associated exposure scenarios are unchanged. The current CSRG for fluoride of 2 mg/L is based on the agricultural CBSG rather than the human health standard of 4 mg/L. With the continued shift from agricultural use to residential, revision of the CSRG should be considered. This recommendation was included in the 2010 LTMP; however, the evaluation was never completed.

Exposure pathways were evaluated for contaminants in both OUs. The mechanisms of release in the On-Post OU and the Off-Post OU have not changed. Monitoring data described in this report indicate that exposure concentrations have generally decreased, resulting in less risk over time. In the On-Post OU the overall decrease in exposure concentrations can be primarily attributed to the removal or containment of source areas, while in the Off-Post OU the decrease can be attributed to effective groundwater intercept and treatment systems, as well as natural attenuation.

Vapor Intrusion

During the 2005 FYR period, an assessment of vapor intrusion from contaminated groundwater in the Off-Post OU was conducted. The assessment used site-specific information about off-post groundwater concentrations and subsurface conditions to estimate potential indoor air concentrations and associated human health risks. The assessment was conducted consistent with EPA's 2002 draft vapor intrusion guidance using the residential scenario. The evaluation indicated that site-specific risks were below the screening levels and that no further evaluation was necessary (EPA 2004). Emerging contaminants were reviewed to determine if contaminant properties or groundwater concentrations were sufficient to warrant re-evaluation of the previous assessment. NDMA was not evaluated in the 2004 assessment and was also reviewed. Concentrations of 1,4-dioxane and NDMA in off-post wells are significantly below EPA screening levels, and NDPA is not considered volatile. As a result, no re-evaluation is necessary.

In 2015, EPA finalized the vapor intrusion guidance (EPA 2015). However, the methodology used in the 2004 vapor intrusion assessment remains consistent with the final guidance. Updates during this five-year period consisted of revisions to toxicity values and physiochemical parameters. To evaluate the potential changes in risk due to vapor intrusion, the risks associated with RMA contaminants were reevaluated using EPA’s vapor intrusion assessment screening tool. Risks were calculated using the default screening parameters (except groundwater temperature which was adjusted for Adams County), current toxicity factors, and most recent groundwater concentrations. The results are presented on Table 7.2-2.

All cancer risk estimates are below 10^{-6} except for chloroform, which is slightly above at 1.3×10^{-6}. The CERCLA acceptance range for cancer risk is 10^{-4} to 10^{-6}. All results for carcinogenic risks are also below the 10^{-5} cancer risk screening level established in the 2004 assessment, and all results are below the non-carcinogenic screening level HQ = 1. Maximum calculated risks are also lower than the calculated risks in 2004. The risks estimated are considered conservative because the vapor intrusion screening tool uses conservative default parameters in its calculations. In addition, the calculated risk values assume a constant groundwater contaminant concentration over 30 years; however, concentrations are expected to continue to decrease due to the ongoing groundwater treatment and continued attenuation. The results of the evaluation indicate that risks remain below the screening levels and no further evaluation is necessary.

Table 7.2-2. Off-Post Vapor Intrusion Risk Screening Evaluation

Chemical	Groundwater Concentration[1] (µg/L)	Calculated Indoor Air Concentration (µg/m³)	Carcinogenic Risk	Hazard Quotient
Carbon Tetrachloride	0.13*	0.15	2.0×10^{-7}	8.9×10^{-4}
Chloroform	1.58	0.237	1.3×10^{-6}	1.5×10^{-3}
1,2-Dichloroethane	0.81	0.039	2.2×10^{-7}	3.3×10^{-3}
Methylene chloride	1.98*	0.26	1.7×10^{-9}	2.8×10^{-4}
Tetrachloroethylene	3.31	2.40	1.3×10^{-7}	3.3×10^{-2}
Trichloroethylene	0.22	0.089	1.1×10^{-7}	2.6×10^{-2}

Notes:

[1]Groundwater monitoring data used for the estimates are from 2015 – 2019 from the same set of monitoring wells used in the 2004 assessment, based on the plume extent shown on 2002 off-post CSRG exceedance map.

*All groundwater monitoring data are nondetect; ½ the reporting limit is used to calculate the indoor air concentration and risks.

Emerging Contaminants

The identification of the emerging contaminants 1,4-dioxane, NDPA and PFOA/PFOS at RMA results in additional potential exposures not identified in the RODs.

1,4-Dioxane

For 1,4-dioxane, two separate risk evaluations were performed during the five-year period to address this contaminant. For potential on-post exposures, exposure was evaluated for inhalation due to volatilization from water used for irrigation or from the surface of Lake Ladora. Ingestion was not evaluated due to the restriction on consumption of groundwater or surface water on RMA. Although on-post groundwater is no longer being used to supply Lake Ladora, the evaluation conservatively included the maximum 1,4-dioxane concentration from the water supply wells in Section 4. The resulting evaluation estimated cancer risk at 1.1×10^{-7} and noncancer hazard at 7.2×10^{-4} (Navarro 2018m).

As part of the Feasibility Study completed for 1,4-dioxane, a risk assessment for potential off-post exposure scenarios was performed. This evaluation included all potential exposure pathways and used the methodology developed in the Off-post Operable Unit Endangerment Assessment/ Feasibility Study (HLA 1992). Risks were estimated in various off-post zones depending on the current and expected land uses and the groundwater concentrations in each zone. Estimated cancer risks are less than 10^{-6} for all receptors with the exception of residential receptors in Zone 2, which is located between the NBCS and the NPS, where estimated cancer risk is 1.2×10^{-6}. Noncancer hazards are well below a hazard index of 1.0 for all off-post receptors and zones (Navarro 2019e). Since the cumulative risks are below the acceptable risk ranges specified by EPA, remedial action for 1,4-dioxane in the off-post OU is not warranted. However, to meet the On-Post ROD RAOs, which require treatment of groundwater flowing off RMA to meet CBSGs identified as ARARs, the 1,4-dioxane CBSG was adopted as a CSRG for the NBCS and NWBCS. Additional discussion is provided in Section 6.3.3.9.

NDPA

n-Nitosodi-n-propylamine was initially identified as an emerging contaminant exceeding the CBSG in the 2015 FYRR. The CBSG for NDPA was promulgated after the On-Post and Off-Post RODs were completed and no CSRG for NDPA was identified in the RODs. During the FYR period, characterization sampling confirmed concentrations exceeding the CBSG of 0.005 µg/L in groundwater in both the on-post and off-post OUs and RMA was identified as a source of contamination (Navarro 2018aa). Additional discussion is provided in Section 6.3.3.9.

Review of treatment plant data shows that NDPA is present above the CBSG in all plant influent samples at concentrations above the CBSG. Effluent concentrations at all plants are below the CBSG, indicating effective treatment from the existing systems. To meet the On-Post ROD RAOs, which require treatment of groundwater flowing off RMA to meet CBSGs identified as ARARs, the NDPA CBSG was adopted as a CSRG for the NBCS and NWBCS. Because concentrations exceed the CBSG upgradient of both the FCS and NPS, the NDPA CBSG was also adopted as a CSRG for the OGITS (Navarro 2020e).

PFOA/PFOS

During the FYR period, PFOA/PFOS were identified as emerging contaminants. Consistent with Army and EPA guidance (Army 2016a, 2018; EPA 2019b), groundwater and treatment plant sampling were conducted to determine whether PFOA/PFOS were present in RMA groundwater above the EPA health advisory level of 0.07 µg/L. Although PFOA/PFOS were detected in 19 of the 25 wells sampled, there were only five wells that exceeded the health advisory level. These wells are located near the South Plants area where foam was used for vapor suppression on an acetone spill. Results of the sampling performed indicate that RMA does not appear to be a significant source of PFOA/PFOS contamination in groundwater (Navarro 2017h, Navarro 2020i). Additional discussion is provided in Section 6.3.3.9.

No risk assessment was performed for potential exposure to on-post groundwater since the existing land use controls prohibit potable use of groundwater. All monitoring results for off-post groundwater were below the EPA health advisory level. However, long-term monitoring was incorporated into the LTMP to provide continued monitoring of groundwater and treatment plant effluent for comparison to the EPA health advisory level (OCN-LTMP-2020-004).

7.2.6 Changes in Toxicity Assessment Variables

There were no changes in toxicity criteria identified since the previous FYR.

7.2.7 Changes in Risk Assessment Methods

There were no changes in risk assessment methodology identified that would require revision of the original risk assessment work.

7.3 QUESTION C: HAS ANY OTHER NEW INFORMATION COME TO LIGHT THAT COULD CALL INTO QUESTION THE PROTECTIVENESS OF THE REMEDY?

There was no other information obtained that would call into question the effectiveness of the remedy.

7.4 TECHNICAL ASSESSMENT SUMMARY

According to the data reviewed, the documents reviewed, and the site inspections, the remedy is generally functioning as intended by the ROD and as modified by the ROD amendments, ESDs, and other administrative changes documented in Fact Sheets. There are several groundwater-related remedy components that are not functioning as intended and these issues are identified in Section 8.0. In addition, other findings that do not affect protectiveness but warrant investigation are included in Section 9.1. There have been no changes in the physical conditions of the site that would affect current or future protectiveness of the remedy. Risk-based site evaluation criteria for soil presented in the ROD are being met. There were no changes in the toxicity factors for the COCs that were used in the baseline risk assessment. There have been no changes to the exposure assessment variables or standardized risk assessment methodology that affect the protectiveness of the remedy. Emerging contaminants have been assessed and remediation goals and monitoring requirements have been incorporated where appropriate.

8.0 ISSUES

As stated in Section 5.2, the EPA FYR guidance identifies FYR issues as "all issues that currently prevent the response action from being protective or may do so in the future" and "early indicators of potential remedy problems." This section identifies issues that meet these criteria in that they had not been addressed at the end of the FYR period (Table 8.0-1). Events or potential issues that occurred, but were addressed during the FYR period, are discussed as appropriate in Sections 6.0 and 7.0 of this report.

Table 8.0-1. Issues Identified and Effect on Current or Future Protectiveness

Remedy Component	Issue	Affects Protectiveness (Y/N)	
		Current	Future
On Post Operable Unit (OU-3)			
Northwest Boundary Containment System, Northeast Extension System Performance	Dieldrin is present above the PQL in the NWBCS Northeast Extension downgradient performance wells. System bypass could be a contributing factor for these exceedances.	No	Yes
Land Use Controls	Uses identified in the Prairie Gateway PUD are inconsistent with the land use restrictions.	No	Yes
Off Post Operable Unit (OU-4)			
Dieldrin Downgradient from the Northwest Boundary Containment System	Dieldrin is present above the PQL in the off-post area downgradient of the NWBCS. A permanent monitoring network has not been identified.	No	Yes
Private Well 359D	DIMP concentrations exceed the CBSG in private drinking water well 359D.	No	Yes
Northern Pathway System	Dieldrin was identified above the PQL in the gap between modified NPS system extraction wells 37817 and 37818. The lease is expiring for the area where original system wells capture this portion of the plume.	No	Yes
Off-Post Monitoring Network	Off-post monitoring wells have been damaged or are unsafe to sample due to road construction or increased traffic.	No	Yes

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9.0 RECOMMENDATIONS AND FOLLOW-UP ACTIONS

This section presents recommendation on how the issues identified in Section 8.0 will be addressed. The recommendations and associated milestones are summarized in Table 9.0-1

9.1 OTHER FINDINGS

In addition, the following are recommendations that were identified during the FYR and may improve remedy operations, management of O&M or completeness of the site file, but do not affect current and/or future protectiveness.

Biomonitoring Program Documentation

The Army completed the Data Summary Report for tissue sampling in November 2016 and conducted a soil sampling in November 2017. All soil results were below the selected screening criteria (Navarro 2018i) indicating that the remedy effectively eliminated significant exposure pathways in the area sampled. A soil Data Summary Report in June 2018 (Navarro 2018i) and prepared a draft MCR in December 2018 to document completion of the biomonitoring program. The report is awaiting EPA review. Although all field work and data review have been completed, the MCR must be finalized and approved.

Bedrock Ridge Extraction Systems

At the BRES, increasing concentrations of three contaminants (1,2-dichloroethane, tetrachloroethylene and trichloroethylene) have been observed in one downgradient performance monitoring well at the west end of the system. This was identified as an issue in the 2015 FYRR with a recommendation for additional monitoring. Two new monitoring wells were installed to provide additional data for system evaluation. Further monitoring and evaluation of the system is ongoing to determine the need for additional extraction and system optimization to improve plume capture. Protectiveness is not affected due to downgradient containment at the NBCS. Recommended actions include completion of the planned monitoring for the new and existing wells to provide adequate data for system evaluation and evaluation of the monitoring data and system performance to determine if remedy adjustments are warranted.

Basin F Groundwater Impacts

Groundwater along the Basin F principal threat flow path appears to have been impacted, with observed increases of select ICs in downgradient wells. During post-closure monitoring, chloroform, DIMP, sulfate, and tetrachloroethylene appear to be increasing upgradient of Basin F compared to baseline data for the Basin F PT wells, and several ICs appear to be increasing in more than one downgradient well. Recommended action includes additional evaluation of Basin F groundwater data, the monitoring network, and statistical data evaluation process.

Lime Basins Dewatering

Groundwater levels within the slurry wall continue to decrease as dewatering continues. However, an outward gradient remains along the northern slurry wall. Groundwater levels should continue to fall with continued operation of the dewatering system; however, due to declining water levels outside the slurry wall, the date for meeting the inward gradient performance goal cannot be reliably projected. A new goal of September 2024 was established to track progress toward meeting the goal. Monitoring and evaluation of progress toward meeting this goal will continue in the next FYR period. Protectiveness is not affected due to downgradient capture at the BANS and the NWBCS. Recommendation includes continued water level monitoring and evaluation of progress toward meeting the goal in the Five-Year Summary Reports.

Confined Flow System Network

The 2015 FYRR identified a concern with the adequacy of the CFS monitoring network due to damaged or unsuitable wells. During the FYR period, alternate wells were identified and sampled, and one well had an obstruction cleared to allow continued sampling. However, the overall concern for the site-wide CFS program has not been resolved. The Army will continue to coordinate with the regulatory agencies to discuss potential modifications to the program.

Dieldrin in CFS Wells Downgradient of Basin F

Dieldrin was detected in four CFS wells downgradient of Basin F and concentrations in two of the wells increased during the FYR period. There are downward vertical gradients in the area, but the paired UFS wells have not been sampled in recent years, making correlation with UFS data difficult. It is possible the wells have lost some integrity due to leaking well seals. Recommended actions include downhole camera inspection of the CFS wells to evaluate for potential damage that might allow migration from the UFS to the CFS, water quality sampling for paired UFS wells, increased monitoring frequency, and evaluation of existing well network to determine if additional monitoring points are necessary.

Chloride Concentrations in Well 35083

Chloride concentrations in CFS well 35083 have shown a general increasing trend, although the concentration was stable during the FYR period. There is a downward vertical gradient in the area. The concentrations in well 35083 are higher than in nearby UFS wells by one to two orders of magnitude. Further evaluation of chloride in the vicinity of the well related to lateral flow from the southeast and east, as well as vertical flow from the UFS immediately adjacent to well 35083 is recommended to determine the source of elevated chloride in the CFS. Investigation of this issue was initiated in this FYR period and is ongoing.

Well Security and Labeling

Several monitoring wells were identified as unsecured during the site inspections or had illegible/missing identification. Off-post downgradient performance wells for NWBCS were checked and secured in August 2020. Several wells noted as unsecured are located in areas not accessible to the public. The wells will be evaluated to determine if additional security is warranted. One well in Section 7 was identified as located along a newly constructed public trail. The recommendation is to lock the well consistent with the LUCP. Wells with missing or unreadable labels will be relabeled.

Treatment Plant O&M Manuals

The O&M Manuals located at the treatment plants have redline/strikeout changes, but the cover pages do not reflect the dates of revision. It is unclear whether all manuals are up to date. Recommendation is to review all manuals and update as necessary.

Bison Consumption

The USFWS is pursuing a change to the restriction on game consumption taken at RMA and is implementing a bison tissue sampling program to support the change. The tissue sampling program is designed to determine if contaminant concentrations in bison tissue are below levels that would pose an unacceptable risk to humans who ingest those tissues. The USFWS is in the process of collecting bison tissue over several sampling events. Tissue analysis and data evaluation are ongoing. Reporting requirements and risk evaluation needs are still being determined in consultation with the regulatory agencies. Although this concern is not yet resolved, it is not a FYR issue because the existing restriction has not been violated, and current bison management does not prevent the remedy from being protective.

In 2013, the USFWS initiated a process to remove or modify the game consumption restriction as it relates to bison to allow the Refuge to manage its bison herd similar to other bison herds across the country. Any change requested by the USFWS to the LUCs currently required by the ROD relating to bison will be coordinated with the regulatory agencies and will follow the required CERCLA process including ROD modification.

Community Involvement Plan

Based on the results of interviews conducted during the FYR period, those interviewed expressed a high level of confidence in the remedy and its management and satisfaction with the opportunities they had to ask questions or receive information about upcoming projects. They indicated, however, that new residents, members of the Spanish-speaking community and newly elected officials would benefit from additional information about the site's history as a former manufacturing and environmental clean-up site. Community members living north, and northwest of the site also indicated they would like to better understand the groundwater remediation program and the progress being made toward achieving groundwater remediation goals. Recommendation is to review the site's current Community Involvement Plan to identify opportunities to update, improve and tailor communications to community audiences.

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Table 9.0-1. Recommendations and Follow-Up Actions

Issue	Recommendations/Follow-Up Actions	Party Responsible	Oversight Agencies	Milestone Date
On Post Operable Unit (OU-3)				
Dieldrin is present above the PQL in the NWBCS Northeast Extension downgradient performance wells. System bypass could be a contributing factor for these exceedances.	Additional evaluation of system performance and potential flow north of the slurry wall to identify potential system modifications necessary to maintain plume capture.	Army	USEPA CDPHE TCHD	June 30, 2023
Uses identified in the Prairie Gateway PUD are inconsistent with the land use restrictions.	Continue coordination with Commerce City to ensure appropriate changes are made to the Prairie Gateway PUD to resolve apparent conflicts with the LUCs.	Army	USEPA CDPHE TCHD	September 30, 2024
Off Post Operable Unit (OU-4)				
Dieldrin is present above the PQL in the off-post area downgradient of the NWBCS. A permanent monitoring network has not been identified.	Review the off-post monitoring network to determine locations suitable for long-term monitoring of the dieldrin plume downgradient of the NWBCS.	Army	USEPA CDPHE TCHD	March 31, 2022
DIMP concentrations exceed the CBSG in private drinking water well 359D.	Additional evaluation of well 359D and other private wells in the area to determine the most appropriate action for providing an alternate water source.	Army	USEPA CDPHE TCHD	December 31, 2021
Dieldrin was identified above the PQL in the gap between modified NPS system extraction wells 37817 and 37818. The lease is expiring for the area where original system wells capture this portion of the plume.	Construct system upgrades for extraction and recharge to address dieldrin plume in the gap area. Finalize lease for modified NPS location.	Army	USEPA CDPHE TCHD	June 1, 2022
Off-post monitoring wells have been damaged or are unsafe to sample due to road construction or increased traffic.	Review off-post monitoring network to ensure adequate coverage for monitoring off-post contaminant plumes and identify appropriate safe locations for replacement wells.	Army	USEPA CDPHE TCHD	December 31, 2021

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10.0 PROTECTIVENESS STATEMENTS

The protection of human health and the environment by the remedial actions in both the On-Post and Off-Post OUs is discussed below. All controls are in place to adequately minimize risks.

10.1 ON-POST OPERABLE UNIT (OU-3)

The remedy for the On-Post OU currently protects human health and the environment because remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks. Placement of contaminated soils and debris in the HWL, ELF, and Basin A has been completed with engineered cap/cover systems in place. These sites have specific groundwater monitoring and ongoing cover O&M programs that monitor remedy effectiveness. Fences and signs are maintained around these areas and institutional controls prohibiting intrusive activities are in place to prevent exposure. Groundwater contamination is being treated to remediation goals at the RMA boundary (NWBCS and NBCS) as well as on post at the RYCS (through FY16) and at the BANS, and operation and maintenance plans are in place to ensure long-term protection. The long-term and operational groundwater and surface water monitoring programs effectively monitor contaminant migration pathways on post and ensure effective operation of the treatment systems as well as track off-post contamination trends. Monitoring programs were completed for emerging contaminants. Treatment system CSRGs and long-term monitoring requirements were revised for 1,4-dioxane and NDPA to maintain protectiveness. Monitoring for PFOA/PFOS indicates that RMA is not a significant source and no drinking water sources are impacted. The long-term biomonitoring program was completed during the FYR period and review of the tissue and soil sample results demonstrate the remedy is protective of wildlife. Completion of the Monitoring Completion Report is pending. Risks to human health and the environment are also minimized through implementation of LUCs restricting land and groundwater use to prevent exposures. The LUCP requirements were effectively implemented and monitoring of LUCs to ensure protectiveness continued during this FYR period. To be protective in the long-term, further evaluation of potential bypass at the NWBCS Northeast Extension needs to be completed and system adjustments made as necessary, and the Prairie Gateway PUD needs to be revised to resolve conflicts with the existing land use restrictions.

10.2 OFF-POST OPERABLE UNIT (OU-4)

The remedy for the Off-Post OU currently protects human health and the environment because remedial activities completed to date have adequately addressed all exposure pathways that could result in unacceptable risks in these areas. Groundwater contamination is being treated to Off-Post ROD remediation goals at the RMA boundary as well as at the OGITS. Chloride and sulfate concentrations are attenuating toward their CSRGs. Groundwater monitoring plans and system operation and maintenance plans are in place to ensure long-term protection. The required institutional control, notifying well permit owners of potential groundwater contamination, remains effective in its implementation. To be protective in the long-term, monitoring adjustments are needed for the off-post monitoring network, particularly downgradient of the NWBCS, to maintain adequate coverage for monitoring contaminant plumes. The NPS needs to be upgraded to address the existing dieldrin plume and revised easement. Contamination present in private well 359D needs to be further evaluated.

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11.0 NEXT FIVE-YEAR REVIEW

The next FYR for RMA is required by September 22, 2026, five years from the completion date of this FYR review.

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