LMS/SHP/S35978

Annual Performance Report April 2020 Through March 2021 for the Shiprock, New Mexico, Disposal Site

April 2022

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

CFR	*Code of Federal Regulations*
COC	contaminant of concern
DOE	U.S. Department of Energy
ft	feet
GCAP	Groundwater Compliance Action Plan
gpm	gallons per minute
LM	Office of Legacy Management
MCL	maximum concentration limit
mg/L	milligrams per liter
N	nitrogen
SOWP	Site Observational Work Plan
UMTRCA	Uranium Mill Tailings Radiation Control Act

Executive Summary

This annual report evaluates the performance of the groundwater remediation system at the Shiprock, New Mexico, Disposal Site (Shiprock site) for April 2020 through March 2021. The Shiprock site, a former uranium-ore processing facility remediated under the Uranium Mill Tailings Radiation Control Act, is managed by the U.S. Department of Energy (DOE) Office of Legacy Management (LM). Site annual reports such as this typically include an analysis of water quality and groundwater-level data obtained during semiannual sampling events. Due to the coronavirus pandemic and pursuant to public health directives issued by the Navajo Nation, LM did not conduct any environmental monitoring during the entire reporting period. Therefore, the scope of this 2020–2021 annual performance report is limited primarily to an analysis of groundwater flow rates associated with the extraction wells, drains, and seeps and a summary of evaporation pond conditions.

Background

The Shiprock mill operated from 1954 to 1968 on property leased from the Navajo Nation. Remediation of surface contamination, including stabilization of mill tailings in an engineered disposal cell, was completed in 1986. During mill operation, nitrate, sulfate, uranium, and other milling-related constituents leached into underlying sediments and contaminated groundwater in the area of the mill site. In March 2003, DOE initiated active remediation of groundwater at the site using extraction wells and interceptor drains. At that time, DOE developed a Baseline Performance Report that established specific performance standards for the Shiprock site groundwater remediation system.

The Shiprock site is divided into two distinct areas: the floodplain and the terrace. The floodplain remediation system consists of two groundwater extraction wells, a seep collection drain, and two collection trenches installed in 2006 (Trench 1 and Trench 2). The terrace remediation system currently consists of nine groundwater extraction wells, a collection drain (Bob Lee Wash), and a terrace drainage channel diversion structure. All extracted groundwater is pumped into a lined evaporation pond on the terrace.

Current Site Status

LM cancelled the semiannual sampling events previously scheduled for September 2020 and March 2021 because of the coronavirus pandemic. Pursuant to general directives in Navajo Nation Public Health Emergency Order No. 2020-007, most site maintenance activities were delayed until late 2020. LM deferred sampling of the approximate 130 site monitoring wells, the adjacent San Juan River, and remaining surface locations until September 2021. Active remediation continued, albeit at reduced rates relative to the historical record.

About 4 to 5 years ago, LM observed that the evaporation pond liner was aging to a point warranting assessment of the need to either replace the liner or decommission the pond entirely. On April 21, 2017, LM suspended pumping of groundwater from most Shiprock site treatment system locations when water filled the evaporation pond to its maximum capacity. Since then, LM's approach has been to maintain a balance of pumping enough water to ensure that the evaporation pond sediments remain covered while remediating as much as possible in accordance with the site compliance strategy. The pumping suspension continued into this reporting period for most treatment system locations.

The floodplain trenches and extraction well 1089 were pumped primarily to maintain sufficient water levels in the pond and prevent further deterioration of the pond liner. Terrace extraction well 0818 was pumped intermittently but the volume of groundwater extracted was small relative to the floodplain trenches. Pumping of interceptor drain 1087 in Bob Lee Wash continued because pumping this location eliminates a potential point of exposure. However, corresponding flows and groundwater extraction volumes are uncertain for this reporting period because of flow meter malfunctions. Also, a leak in the water line observed in December 2020 was LM's first opportunity to perform site maintenance activities following the onset of the global pandemic.

Compliance Strategy and Remediation Goals

As documented in the Groundwater Compliance Action Plan (GCAP), the U.S. Nuclear Regulatory Commission-approved compliance strategy for the floodplain is natural flushing supplemented by active remediation. The contaminants of concern at the site are ammonia (total as nitrogen), manganese, nitrate (nitrate + nitrite as nitrogen), selenium, strontium, sulfate, and uranium. The compliance standards for nitrate, selenium, and uranium are listed in Title 40 *Code of Federal Regulations* Section 192. Regulatory standards are not available for ammonia, manganese, and sulfate; remediation goals for these constituents are either risk-based alternate cleanup standards or background levels based approximately on limited background data available at the time the GCAP was developed. These standards and background levels apply only to the compliance strategy for the floodplain. The compliance strategy for the terrace is to eliminate exposure pathways at Bob Lee Wash and at seeps and to reduce groundwater elevations. LM is reevaluating the site compliance strategy, the approach for which is outlined in the recently issued *Revised Groundwater Compliance Action Plan (GCAP) Work Plan, Shiprock, New Mexico, Disposal Site*.

Summary of Remediation Performance and Site Evaluation Progress

From April 2020 through March 2021, about 11.7 million gallons of extracted groundwater were pumped to the evaporation pond; this was about 15% greater than the volume extracted during the previous reporting period (10.2 million gallons in 2019–2020). The bulk of this total volume (10.3 million gallons, or 88%) was from the floodplain trenches and extraction well 1089. Since DOE began active remediation in March 2003, about 55.1 million gallons have been extracted from the terrace and 176.6 million gallons have been extracted from the floodplain, yielding a total cumulative volume of about 231.7 million gallons of water pumped to the evaporation pond from all sources. The estimated masses of nitrate, sulfate, and uranium removed from the floodplain and terrace well fields during this performance period were (rounded) 11,600; 556,000; and 29.7 pounds, respectively. These masses were estimated using results from the September 2019 sampling event or, for wells that were dry or not operational at that time, the March 2019 event.

Conclusions

Because sampling was deferred until September 2021, it was not possible to evaluate contaminant concentrations on the floodplain nor water table conditions on the terrace throughout this reporting period. Site conditions discussed in the preceding (2019–2020) annual performance report are assumed to have been sustained. LM will resume comprehensive analysis of site conditions in the next (2021–2022) annual report to ensure that the Shiprock site continues to pose no adverse risk to human health or the environment.

1.0 Introduction

This report evaluates the performance of the groundwater remediation system at the Shiprock, New Mexico, Disposal Site for the period April 2020 through March 2021. The Shiprock site, a former uranium-ore processing facility remediated under the Uranium Mill Tailings Radiation Control Act (UMTRCA), is managed by the U.S. Department of Energy (DOE) Office of Legacy Management (LM).

The Shiprock mill operated from 1954 to 1968; mill tailings were stabilized in an engineered disposal cell in 1986. As a result of milling operations, groundwater in the mill site area was contaminated with uranium, nitrate, sulfate, and associated constituents. In March 2003, DOE initiated active remediation of the groundwater using extraction wells and interceptor drains. At that time, DOE developed a Baseline Performance Report (DOE 2003) that established specific performance standards for the Shiprock groundwater remediation system.

The Shiprock site is divided into two distinct areas: the floodplain and the terrace. An escarpment forms the boundary between these two areas. The floodplain remediation system consists of two groundwater extraction wells, a seep collection drain, and two collection trenches (Trench 1 and Trench 2). The terrace remediation system currently consists of nine groundwater extraction wells, a collection drain (Bob Lee Wash), and a terrace drainage channel diversion structure. All extracted groundwater is pumped into a lined evaporation pond on the terrace. Figure 1 shows the site layout and the major components of the floodplain and terrace groundwater remediation systems.

The Groundwater Compliance Action Plan (DOE 2002) (GCAP) documents the site compliance strategy, the basis for the remediation approach, and performance standards addressed in this report. The U.S. Nuclear Regulatory Commission-approved compliance strategy for the floodplain is natural flushing supplemented by active remediation. The compliance strategy for the terrace is to eliminate exposure pathways at Bob Lee Wash and at seeps and to reduce groundwater elevations.

1.1 Current Site Status and Scope of this Report

Due to the coronavirus pandemic and pursuant to public health directives issued by the Navajo Nation, LM cancelled both (September 2020 and March 2021) semiannual sampling events scheduled for this reporting period. LM deferred sampling of the approximate 130 site monitoring wells, the adjacent San Juan River, and remaining surface locations shown in Figure 2 until September 2021. Active remediation continued, albeit at reduced rates relative to the historical record. Therefore, the scope of this 2020–2021 annual performance report is limited primarily to an analysis of groundwater flow rates associated with the extraction wells, drains, and seeps, and a summary of evaporation pond conditions.

About 4 to 5 years ago, LM observed that the evaporation pond liner was aging to a point warranting assessment of the need to either replace the liner or decommission the pond entirely. On April 21, 2017, LM suspended pumping of groundwater from most of the Shiprock site treatment system locations when water filled the evaporation pond to its maximum capacity. Since then, LM's approach has been to maintain a balance of pumping enough water to ensure that the evaporation pond sediments remain covered while remediating as much as possible in

accordance with the site compliance strategy. The pumping suspension continued into this reporting period for most treatment system locations. The floodplain trenches and extraction well 1089 were pumped primarily in support of ongoing evaluations regarding the pond liner and to prevent desiccation of pond sediments. Terrace extraction well 0818 was pumped intermittently but the volume of groundwater extracted was small relative to the floodplain trenches. Pumping of interceptor drain 1087 in Bob Lee Wash continued because pumping this location eliminates a potential point of exposure. However, corresponding flows and groundwater extraction volumes are uncertain for this reporting period because of flowmeter malfunctions. A leak in the water line near the collection drain was observed in December 2020, LM's first opportunity to perform site maintenance activities following the onset of the global pandemic.

1.2 Remediation System Performance Standards

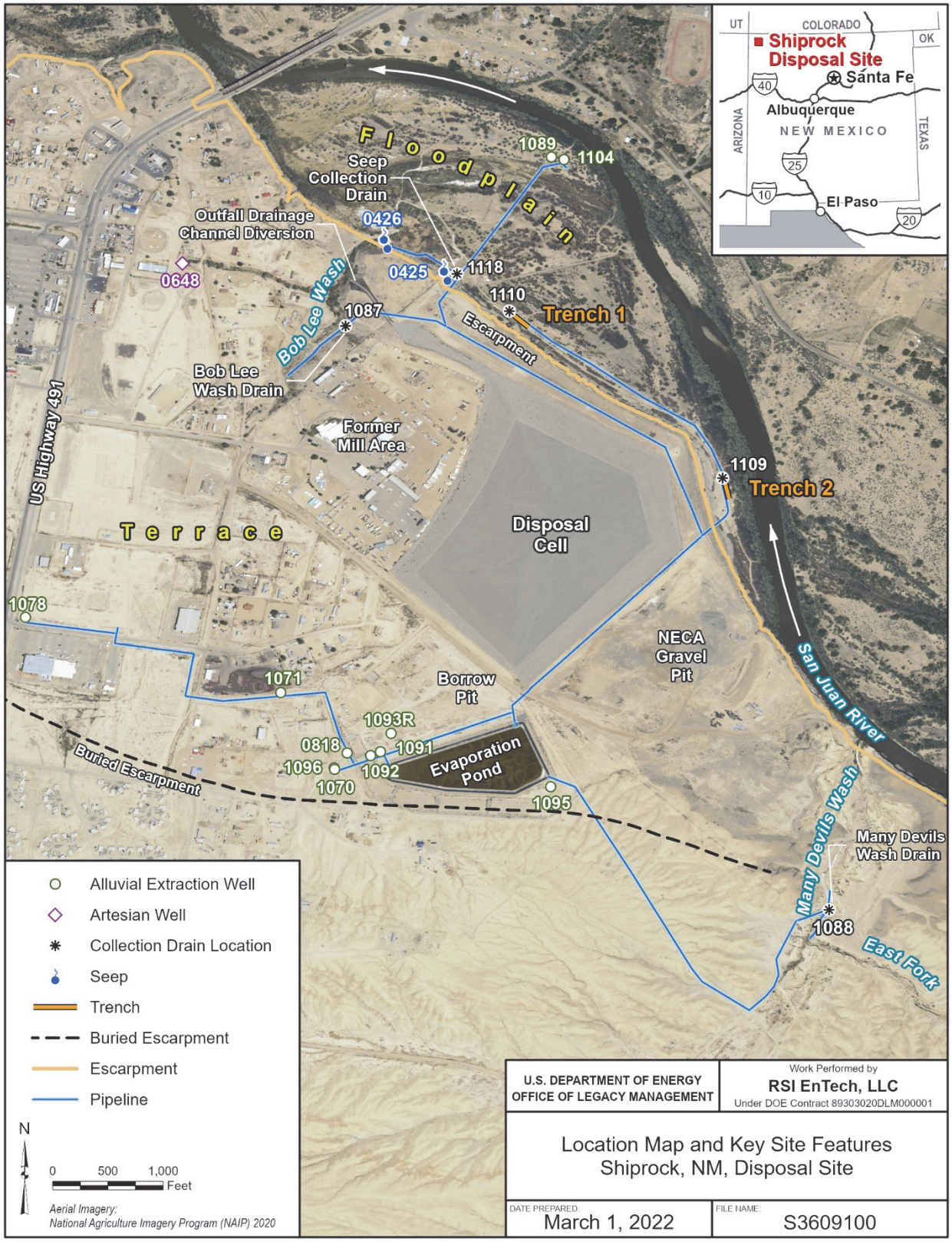
This performance assessment is based on an analysis of groundwater quality and water-level data obtained from site monitoring wells and groundwater flow rates measured at the extraction wells, drains, and seeps. The following specific performance standards or metrics were established for the Shiprock floodplain groundwater remediation system in the Baseline Performance Report (DOE 2003):

- Groundwater flow directions in the vicinity of the extraction wells should be toward the extraction wells to maximize the zones of capture.
- Groundwater contaminant concentrations should be monitored and compared to the baseline concentrations to indicate whether the floodplain extraction system is effective and contaminant levels are decreasing.

The following specific performance standards were established for the terrace groundwater remediation system in the Baseline Performance Report (DOE 2003):

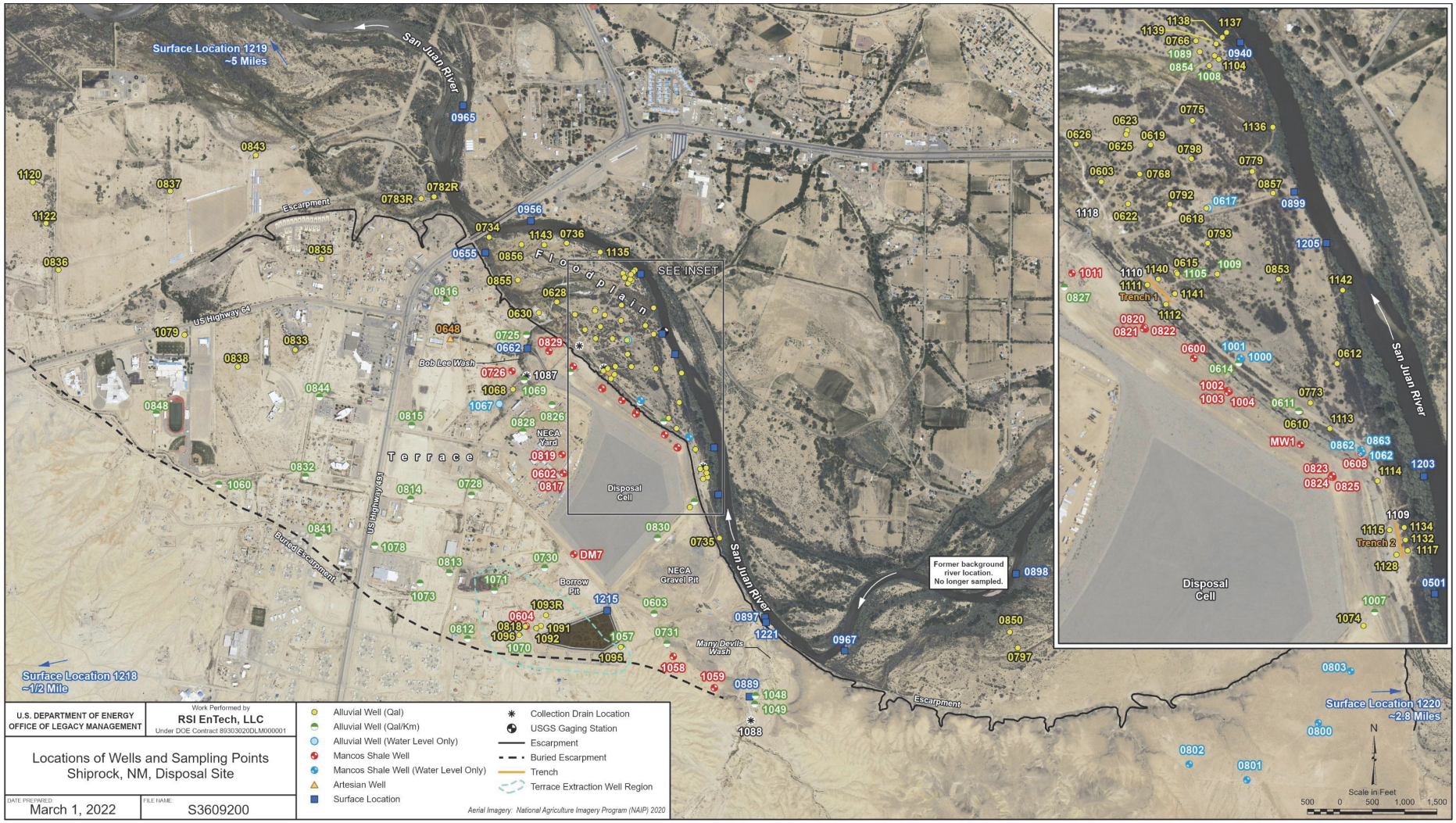
- Terrace groundwater elevations should decrease as water is removed from the terrace system.
- The volume of water discharging to the interceptor drains in Bob Lee Wash and Many Devils Wash should decrease over time as groundwater levels on the terrace decline.
- The flow rates of seeps at the base of the escarpment face (locations 0425 and 0426, represented by measurements from seep collection drain 1118) should decrease over time as groundwater levels on the terrace decline.

The performance standards summarized above are based on the active remediation aspects of the compliance strategies described in the GCAP (DOE 2002). The site conceptual model on which the GCAP was based is documented in the Site Observational Work Plan (DOE 2000) (SOWP). Based on subsequent evaluations and investigations (e.g., DOE 2005; DOE 2009; and DOE 2011b), LM has recently initiated an update of the site conceptual model and a revision of the GCAP. Initial supporting evaluations indicate that some of the performance metrics listed above may no longer be appropriate (DOE 2020).



Note: The Many Devils Wash collection drain (1088) has not been pumped since 2014 because of the need for repairs and the demonstrated lack of mill-related contamination. Decommissioning construction activities are tentatively scheduled to begin in late summer 2022.

Figure 1. Location Map and Groundwater Remediation System



U.S. DEPARTMENT OF ENERGY OFFICE OF LEGACY MANAGEMENT	Work Performed by RSI EnTech, LLC Under DOE Contract 89303020DLM000001
Locations of Wells and Sampling Points Shiprock, NM, Disposal Site	
DATE PREPARED: March 1, 2022	FILE NAME: S3609200

Note: This figure shows the groundwater and surface water sample locations that are typically monitored semiannually. Samples were not collected during this reporting period because of the coronavirus pandemic.
Abbreviations: NAIP = National Agriculture Imagery Program; NECA = Navajo Engineering and Construction Authority; USGS = U.S. Geological Survey

Figure 2. Locations of Wells and Sampling Points at the Shiprock Site

LM terminated remediation efforts in Many Devils Wash (Figure 1) because the groundwater discharging to the wash was found to be naturally contaminated, contradicting the original assumption of a mill site origin. The contamination in the wash was determined to be the result of the natural interaction of water with the Mancos Shale and is not related to the mill site (DOE 2011a; Morrison et al. 2012; Robertson et al. 2016). Pumping of the 1088 groundwater collection drain was terminated in March 2014, and associated infrastructure is slated for decommissioning in 2022–2023.

1.3 Contaminants of Concern and Remediation Goals

The contaminants of concern (COCs) for both the floodplain and the terrace, defined in the GCAP, are ammonia (total as nitrogen [N]), manganese, nitrate (nitrate + nitrite as N), selenium, strontium, sulfate, and uranium. These constituents are listed in Table 1 along with corresponding floodplain background data and maximum concentration limits (MCLs) established in Title 40 *Code of Federal Regulations* Section 192 (40 CFR 192), which apply to UMTRCA sites.

The remediation goals listed in Table 1 apply to the floodplain only because the compliance strategy for the terrace is to decrease groundwater elevations and flow rates at seeps. As listed in this table, the 40 CFR 192 compliance standards for nitrate, uranium, and selenium are 10, 0.044, and 0.01 milligrams per liter (mg/L), respectively. If the relatively high selenium concentrations in floodplain groundwater originate on the terrace (with naturally occurring elevated selenium concentrations), it may be unlikely that the 40 CFR 192 standard of 0.01 mg/L for this constituent can be met. Therefore, an alternate concentration limit for selenium of 0.05 mg/L was proposed for the floodplain in the GCAP (DOE 2002). This benchmark is the maximum contaminant level for drinking water established under the U.S. Environmental Protection Agency Safe Drinking Water Act, which is consistent with the State of New Mexico Environment Department groundwater standard.

Unlike for uranium and nitrate, regulatory standards have not been developed for sulfate, the other primary COC monitored at the Shiprock site. Historically, sulfate concentrations have been elevated in groundwater entering the floodplain from flowing artesian well 0648, where levels have ranged from 1810 to 2340 mg/L. Because of these elevated levels from a natural source, the GCAP proposed a cleanup goal of 2000 mg/L for sulfate in floodplain wells.

In addition to sulfate (a primary COC), regulatory standards have also not been established for ammonia, manganese, and strontium (Table 1). Along with selenium, these COCs have received less focus in LM's annual reporting. While levels of these constituents in site wells have at times exceeded background, this occurs to a more limited degree relative to the magnitude and extent of the primary COCs (uranium, nitrate, and sulfate). Two constituents, manganese and strontium, have never been definitively associated with former processing activities and as such have not been useful indicators of mill-related impacts. LM recently reassessed whether ammonia, manganese, selenium, and strontium still warrant designation as COCs (DOE forthcoming). Results of that evaluation are preliminary, but the process used to identify application areas based on flow regimes and to identify background well candidates will form the basis for LM's future reevaluation of background conditions for the terrace and floodplain.

Table 1. Groundwater COCs for the Shiprock Site and Floodplain Remediation Goals

Contaminant	40 CFR 192 MCL (mg/L)	Floodplain Remediation Goal[a] (mg/L)	Historical Range in Floodplain Background Wells[b] (mg/L)	Comments
Ammonia as N	–	–	<0.074–0.20	Most ammonia results for floodplain background wells have been nondetects (<0.1 mg/L).
Manganese	–	2.74	<0.001–7.2	The 2.74 mg/L cleanup goal is the maximum background concentration measured in floodplain background well 0850 at the time the GCAP was developed.
Nitrate as N	10	–	0.004–5.7	As demonstrated later in this report, the nitrate contaminant plume on the floodplain has reduced markedly relative to baseline (2000–2003) conditions.
Selenium	0.01	0.05	0.0001–0.02	The 0.05 mg/L floodplain cleanup goal is based on the EPA Safe Drinking Water Act maximum contaminant level (DOE 2002). This goal is the same as the State of New Mexico Environment Department groundwater standard.[c]
Strontium	–	–	0.18–10	EPA's Regional Screening Level for tap water is 12 mg/L, assuming a target hazard quotient of 1.0.[d]
Sulfate	–	2000	210–5200	Because of elevated sulfate levels in terrace artesian well 0648 (1810–2340 mg/L), the GCAP proposed a cleanup goal of 2000 mg/L (DOE 2002). Water sourced from well 0648 enters the northern portion of the floodplain in the region of the Bob Lee Wash outlet.
Uranium	0.044	–	0.004–0.12	Uranium levels measured in background well 0850 have varied widely and have exceeded the MCL in half of the 28 samples collected since 2006.

Notes:

[a] From Table 3-2 of the GCAP (DOE 2002). Remediation goals were established only for the floodplain and only for those constituents retained as COCs based on human health risk endpoints.

[b] Data are from floodplain background wells 0797 and 0850 (locations shown in Figure 2). LM is currently reevaluating the representativeness of these wells as background locations for floodplain alluvial groundwater (DOE forthcoming).

[c] https://www.env.nm.gov/gwqb/gw-regulations/.

[d] https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables/.

Abbreviations:

– = not applicable (contaminant does not have an MCL in 40 CFR 192, or the alternate cleanup goal is not relevant)
EPA = U.S. Environmental Protection Agency
mg/L = milligrams per liter

1.4 Hydrogeological Setting

This section presents a brief summary of the floodplain and terrace groundwater systems. More detailed descriptions are provided in the SOWP (DOE 2000), the refinement of the site conceptual model (DOE 2005), and the Trench 1 and Trench 2 floodplain remediation system evaluations (DOE 2011b; DOE 2009).

1.4.1 Floodplain Alluvial Aquifer

The thick Mancos Shale of Cretaceous age forms the bedrock underlying the entire site. A floodplain alluvial aquifer occurs in unconsolidated medium- to coarse-grained sand, gravel, and cobbles that were deposited in former channels of the San Juan River above the Mancos Shale. The floodplain aquifer is hydraulically connected to the San Juan River; the river is a source of groundwater recharge to the floodplain aquifer in some areas, and it receives groundwater discharge in other areas. In addition, the floodplain aquifer receives some inflow from groundwater in the terrace area. The floodplain alluvium is up to 20 feet (ft) thick and overlies Mancos Shale, which is typically soft and weathered for the first several feet below the alluvium.

Most groundwater contamination in the floodplain lies close to the escarpment east and north of the disposal cell. Contaminant distributions in the alluvial aquifer are best characterized by elevated concentrations of sulfate and uranium. In the northwest portion of the floodplain, lower levels of contamination occur along the escarpment base in part, because relatively uncontaminated surface water from Bob Lee Wash recharges the floodplain alluvial aquifer in this area. Surface water in Bob Lee Wash originates primarily as deep groundwater from the Morrison Formation that flows to the land surface via artesian well 0648. Well 0648 flows at approximately 65 gallons per minute (gpm) and drains eastward into lower Bob Lee Wash (DOE 2000).

Historically, background groundwater quality in the floodplain aquifer has been defined by the water chemistry observed at monitoring wells 0797 and 0850, which are installed in the floodplain approximately 1 mile upriver from the site (Figure 2). LM is reevaluating background conditions for the floodplain (DOE forthcoming). Preliminary findings of this analysis suggest that wells 0782R and 0783R may be more representative background locations for floodplain wells geochemically influenced by the San Juan River. This analysis also concluded that most of the recharge onto the northern portion of the floodplain is sourced from terrace artesian well 0648 at the head of Bob Lee Wash (DOE forthcoming).

1.4.2 Terrace Groundwater System

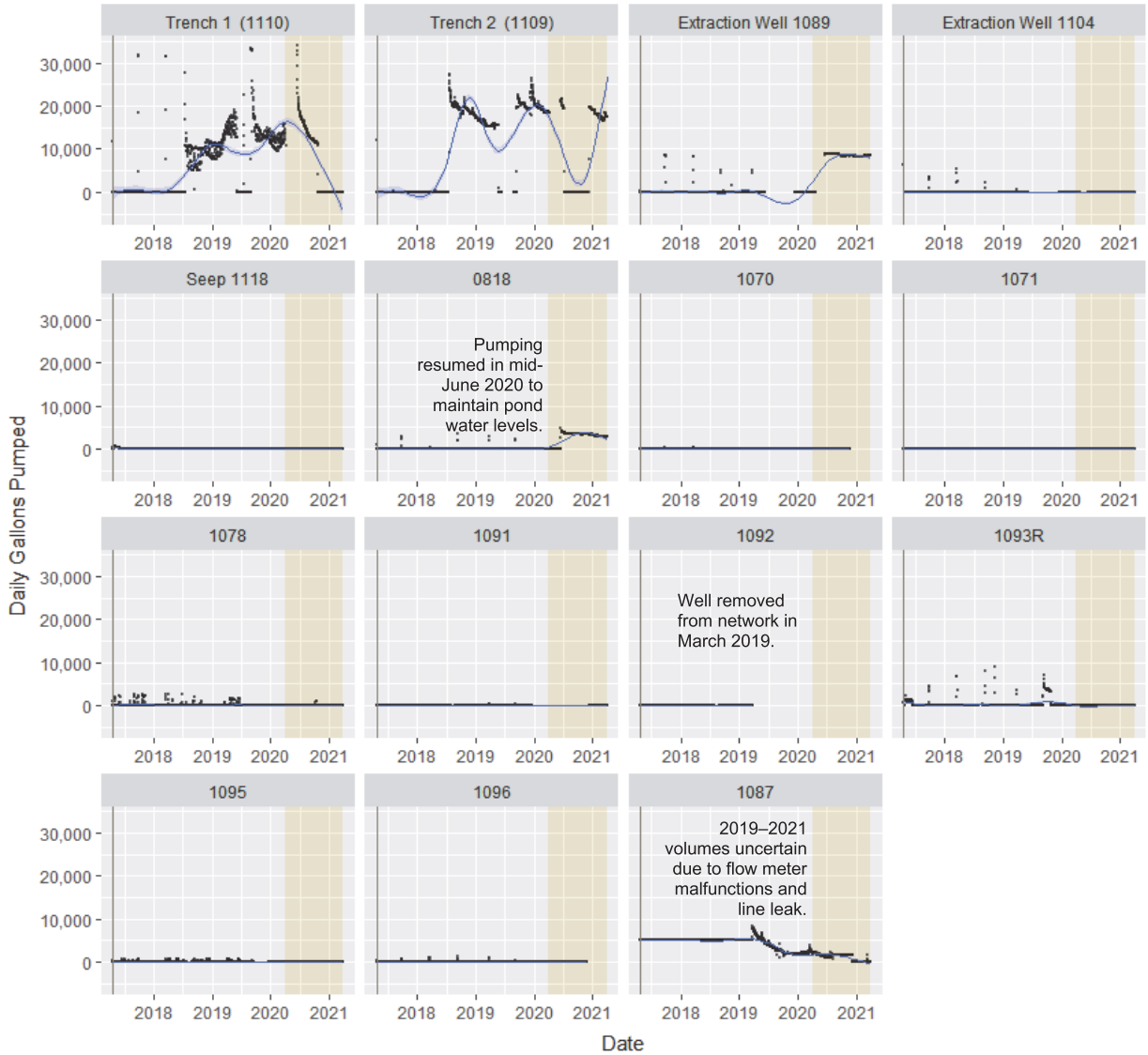
The terrace groundwater system occurs partly in unconsolidated alluvium in the form of medium- to coarse-grained sand, gravel, and cobbles deposited in the floodplain of the ancestral San Juan River. Terrace alluvial material is Quaternary in age; it varies from 0 to 20 ft in thickness and caps the Mancos Shale. Terrace groundwater also occurs in weathered Mancos Shale underlying the alluvium. The Mancos Shale is exposed in the escarpment adjacent to the San Juan River floodplain.

The terrace groundwater system is bounded on its south side by an east-west-trending buried bedrock (Mancos Shale) escarpment, about 1500 ft south of the southernmost tip of the disposal cell (Figure 1). The terrace system extends more than a mile west and northwestward, to more than 4000 ft west of U.S. Highway 491. Terrace alluvial material is exposed at ground surface near the terrace-floodplain escarpment; south and southwest of the former mill, the terrace alluvium is covered by eolian silt (deposited by wind), or loess, which increases in thickness with proximity to the buried bedrock escarpment. Up to 40 ft of loess overlies the alluvium along the base of the buried escarpment. Terrace alluvium consists of coarse-grained ancestral San Juan River deposits, primarily in the form of coarse sands and gravels.

Mancos Shale underlying the alluvium in the terrace area is soft and weathered. The weathered Mancos Shale is typically 2–10 ft thick, but some characteristics of weathering below the shale-alluvium contact occur as deep as 30 ft in places (DOE 2000). Groundwater in the Mancos Shale occurs in discrete discontinuous zones of limited lateral and vertical extent.

2.0 Remediation System Performance

This section describes the key components of the floodplain and terrace groundwater remediation systems and summarizes their performance for the 2020–2021 reporting period. Since the April 2017 pumping suspension, LM's approach has been to maintain a balance of pumping enough water to maintain sufficient water in the evaporation pond while extracting as much groundwater as possible. For example, LM resumed pumping of the floodplain trenches in July 2018 to prevent desiccation of pond sediments. As an introductory overview, Figure 3 illustrates the impacts of the revised pumping strategy for all site remediation system locations.



• Daily gallons pumped
LOESS locally weighted regression line and corresponding 95% pointwise confidence interval
Shading denotes current (2020–2021) reporting period
| Initial vertical line denotes April 21, 2017, cessation of pumping (see Notes)

Note: Shown first are the floodplain trenches, extraction wells, and seep 1118. Terrace extraction wells follow (wells 0818 to 1096); the last plot shows data for Bob Lee Wash sump location 1087.

Figure 3. Daily Groundwater Extraction Volumes Since April 2017 Pumping Suspension Overview Showing Floodplain and Terrace Remediation System Locations

2.1 Floodplain Remediation System

The floodplain remediation system consists of three major components shown in Figure 1: two extraction wells (wells 1089 and 1104); two drainage trenches (horizontal wells), Trench 1 and Trench 2; and a sump (collection drain location 1118) used to collect discharges from seeps 0425 and 0426 on the escarpment. The main objective of the floodplain groundwater extraction system is to supplement the natural flushing process by reducing the contaminant mass and volume within the floodplain alluvial aquifer. All groundwater collected from the floodplain extraction wells and trenches is piped south to the terrace and discharged into the evaporation pond.

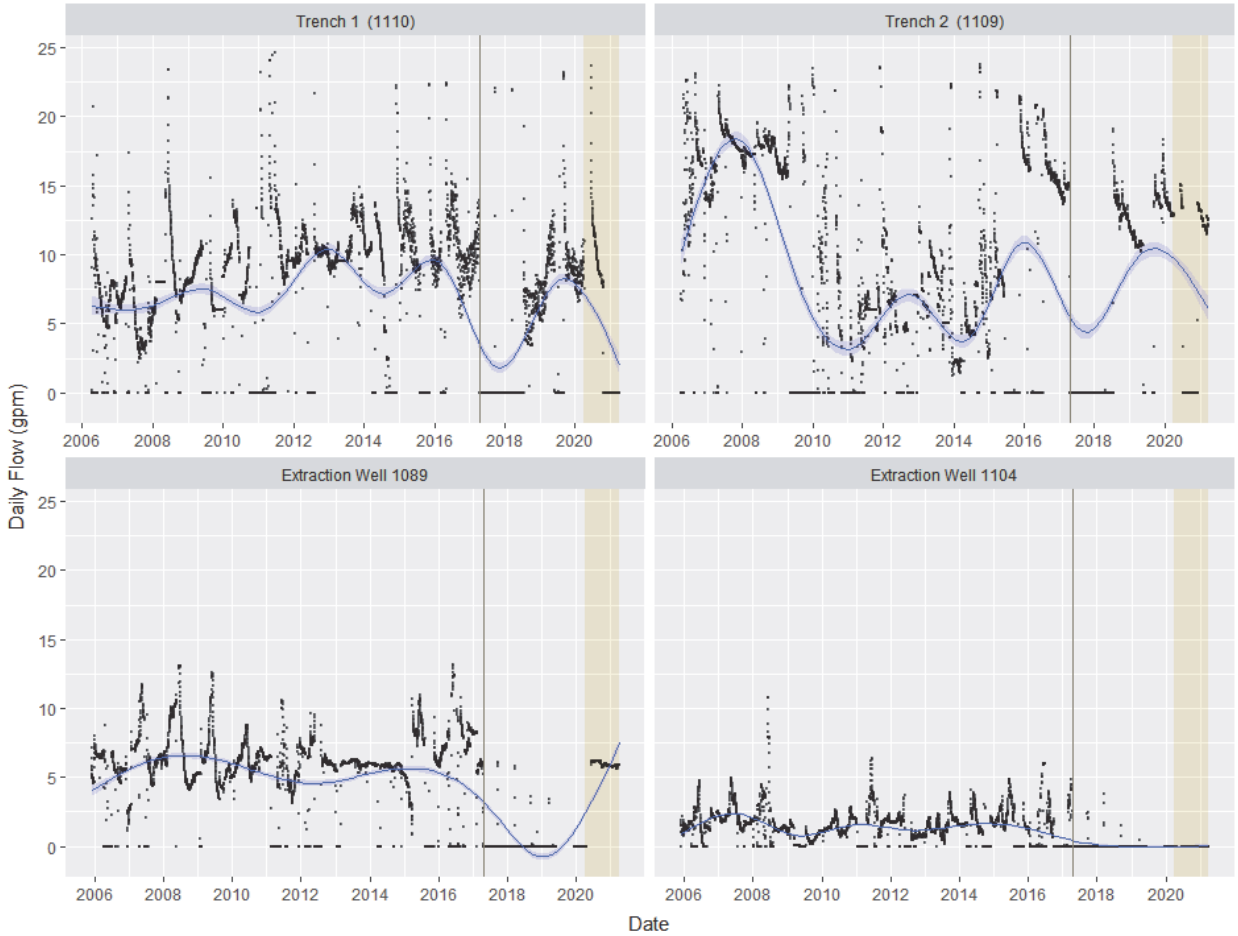
Average pumping rates and cumulative volumes of groundwater extracted from floodplain remediation system locations are summarized in Table 2 for the current and previous reporting periods. To maintain low but sufficient water levels in the evaporation pond while still extracting as much groundwater as possible, LM continued pumping from both trenches and extraction well 1089 (Figure 3). For extraction well 1104 and seep 1118, the pumping suspension initiated in April 2017 continued through this (2020–2021) reporting period.

Table 2. Floodplain Remediation System Groundwater Extraction Rates and Volumes Current and Previous Reporting Periods

Floodplain Location	Previous Period (April 1, 2019, Through March 31, 2020)		Current Period (April 1, 2020, Through March 31, 2021)	
	Average Annual Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Annual Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
1089	0.0001	44.7	5.1	2,685,255
1104	0	0	0	0
Trench 1 (1110)	7.6	4,017,639	6.9	3,652,062
Trench 2 (1109)	9.1	4,783,420	7.6	3,981,176
Seep (1118)	<0.0001	2.0	0	0
Total	**16.7**	**8,801,106**	**19.6**	**10,318,494**

2.1.1 Extraction Well Performance

The floodplain extraction well system consists of wells 1089 and 1104 (Figure 1), which were installed in late June 2003 using slotted culverts placed in trenches excavated to bedrock. From April 2020 through March 2021, 2.7 million gallons of water were removed from extraction well 1089, corresponding to an average pumping rate of 5.1 gpm. As indicated above and in Table 2, there is no recent performance to report for extraction well 1104 because the pumping suspension that began in April 2017 continued through the current (2020–2021) period. Since the start of operations in 2003 through the end of March 2021, totals of approximately 42.3 million and 8.6 million gallons of water have been removed from wells 1089 and 1104, respectively. Figure 4 plots historical daily flows (pumping rates) for extraction wells 1089 and 1104 and the two trenches.



Average daily flow rate (gpm)
LOESS locally weighted regression line and corresponding 95% pointwise confidence interval
Shading denotes current (2020–2021) reporting period
Denotes April 21, 2017, cessation of pumping (see Notes)

Notes: Data plotted are since the inception of the System Operation and Analysis at Remote Sites (SOARS) system in late 2005.
For the trenches, the nonpumping period extended from April 21, 2017, until July 19, 2018, after which pumping resumed to maintain a minimum water level in the evaporation pond. Except for brief intermittent periods, pumping was not resumed at extraction well 1104.

Figure 4. Historical Pumping Rates in Floodplain Trenches and Extraction Wells: 2005–2021

2.1.2 Floodplain Drain System Performance

In spring 2006, two drainage trenches—Trench 1 (1110) and Trench 2 (1109)—were installed in the floodplain just below the escarpment to enhance the extraction of groundwater from the alluvial system. Pumping began in April 2006. From April 2020 through March 2021, 3.7 million and 4.0 million gallons of water were removed from Trench 1 and Trench 2, respectively (Table 2); average pumping rates were 7–8 gpm. Since installation in 2006, totals of approximately 54.8 million and 67.2 million gallons of water have been removed from Trench 1 and Trench 2, respectively (totaling 121.9 million gallons).

2.1.3 Floodplain Seep Sump Performance

Seeps 0425 and 0426 were incorporated into the remediation system in August 2006. Groundwater discharge from these two seeps is piped into a collection sump (location 1118) and then pumped to the evaporation pond. The pumping suspension initiated in April 2017 continued through this (2020–2021) reporting period. No water has been pumped from the collection sump for the last 3 years (Figure 3). Consistent with LM's previous annual report (DOE 2021), about 3 million gallons of water have been removed from the 1118 collection sump since the seeps were incorporated into the remediation system in 2006.

2.2 Terrace Remediation System

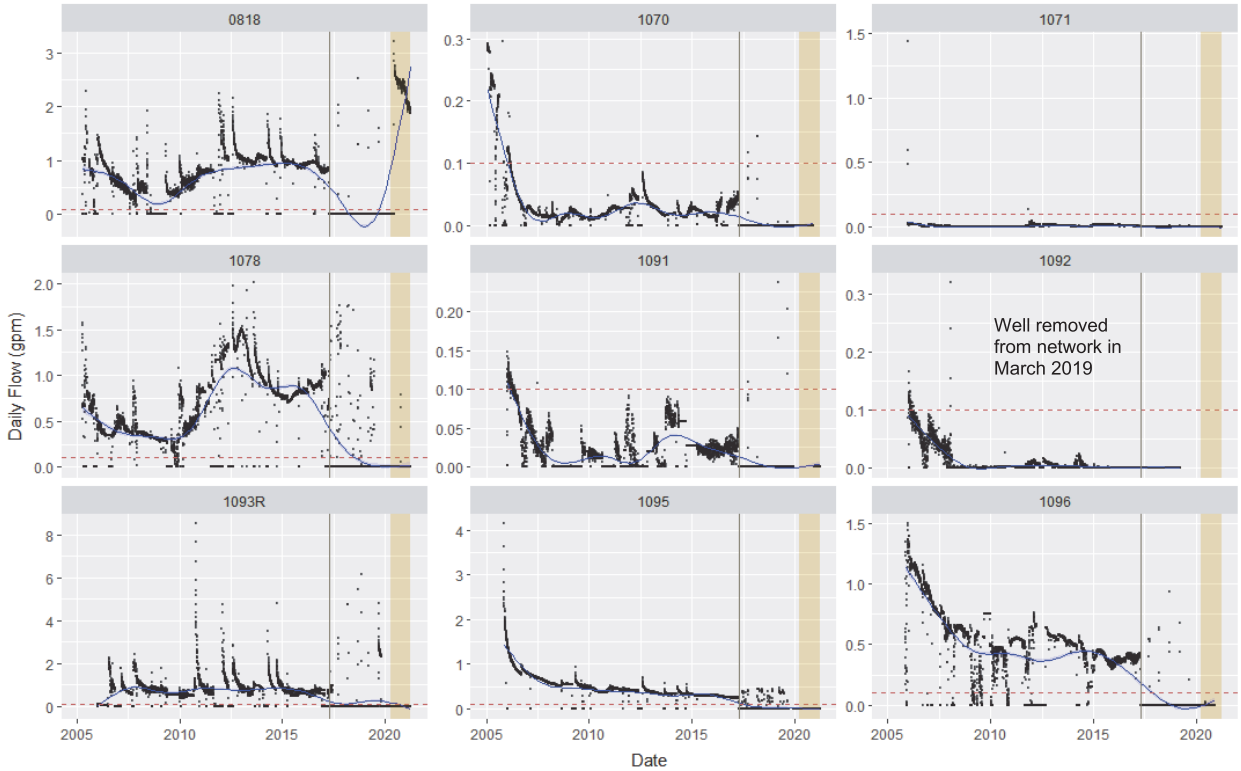
The objective of the terrace remediation system is to remove groundwater from the southern portion of the terrace area so potential exposure pathways at seeps and at Bob Lee Wash are eventually eliminated and the flow of groundwater from the terrace to the floodplain is reduced. The terrace remediation system consists of four major components shown in Figure 1: the extraction wells, the evaporation pond, the terrace drain at Bob Lee Wash, and the terrace outfall drainage channel diversion.

One of the initial objectives for the terrace remediation system was the attainment of a cumulative 8 gpm extraction rate, a goal based on groundwater modeling conducted for the SOWP (DOE 2000). To meet this objective, two wells (1095 and 1096) were installed near the evaporation pond in March 2005. In September 2007, DOE installed a new large-diameter well (1093R) to increase groundwater extraction yields. Despite these enhancements, even when the terrace pumping system was fully operational (between approximately 2008 and 2017), the 8 gpm objective was not achieved. Instead, the combined pumping rate from terrace extraction wells typically ranged from about 2 to 4 gpm. At that time, average pumping rates from about half of the wells were often less than 0.1 gpm, the minimum (150 gallons per day) yield required to be considered an aquifer under 40 CFR 192.

2.2.1 Extraction Well Performance

The terrace remediation well field consists of eight wells: 0818, 1070, 1071, 1078, 1091, 1093R, 1095, and 1096 (Figure 1). Well 1092 was removed from the network in late March 2019. To minimize inputs to the evaporation pond in support of LM's ongoing evaluation of the pond liner, the pumping suspension initiated in April 2017 continued into this (2020–2021) reporting period at most terrace extraction well locations. Pumping resumed at well 0818 in June 2020 to maintain the required water level in the pond. Wells 1078 and 1096 were also pumped intermittently, but volumes were negligible relative to those extracted from well 0818.

Figure 5 plots historical daily flows (pumping rates) for all terrace extraction wells, including former well 1092. Table 3 compares the average pumping rate and total groundwater volume removed from each terrace extraction well and drain location for the current (2020–2021) and previous (2019–2020) reporting periods. Because of the continued pumping suspension, average pumping rates at all terrace extraction wells were again low, ranging from 0–1.8 gpm (maximum from well 0818). The total volume removed from pumping the terrace extraction wells in 2020–2021 was approximately 966,500 gallons.



- Average daily flow rate (gpm)

LOESS locally weighted regression line and corresponding 95% pointwise confidence interval

0.1 gpm (150 gallons per day) low-yield definition for limited-use aquifer (40 CFR 192.11[e]). Only applies to period preceding pumping suspension.

Shading denotes current (2020–2021) reporting period

| April 21, 2017, pumping suspension

Notes: Data plotted are since the inception of the System Operation and Analysis at Remote Sites (SOARS) system in 2005–2006. *y*-axis scales are unique for each well to allow better resolution of the recent low values. As such, the plots are not directly comparable.

Figure 5. Historical Pumping Rates in Terrace Extraction Wells: 2005–2021

Table 3. Terrace Remediation System Groundwater Extraction Rates and Volumes Current and Previous Reporting Periods

Terrace Well or Drain[a]	Previous Period (April 1, 2019, Through March 31, 2020)		Current Period (April 1, 2020, Through March 31, 2021)	
	Average Annual Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Annual Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
0818	0.008	4,269	1.8	963,635
1070	<0.001	8.5	–	–
1071	<0.001	25.5	–	–
1078	0.07	36,802	0.005	2778
1091	0.001	756	–	–
1093R	0.33	175,468	–	–
1095	0.037	19,381	–	–
1096	0.001	301	<0.001	106
Extraction Well Subtotal[b]	**0.45**	**237,011**	**1.8**	**966,519**
Bob Lee Wash (1087)[c]	2.2	1,172,593	0.8	425,332[c]
Many Devils Wash (1088)[d]	0	0	0	0
Total[b]	**2.7**	**1,409,604**	**2.6**	**1,391,851**

Notes:

[a] Well 1092 is not listed in this table because it was removed from the terrace extraction well network in March 2019. Between 2008 and 2014, average pumping rates were <0.005 gpm; no groundwater has been pumped from this well since April 2014.

[b] Minor discrepancies in subtotal and total values versus manual addition of location-specific entries are due to rounding. Subtotals for average annual pumping rates are cumulative averages.

[c] The flow meter installed at Bob Lee Wash 1087 malfunctioned throughout the bulk of this reporting period. The site was inaccessible until December 10, 2020, at which time an underground water line leak and associated flooding near the collection drain was observed. The pump was offline through approximately March 2021. When the pump was operational but the flow meter was malfunctioning (April 1, 2020–December 10, 2020), extraction volumes were estimated using a surrogate value of 1.25 gpm, corresponding to the approximate average flow rate preceding the flow meter failure (Figure 6). Based on volumes reported for previous years, the approximate 425,000 gallons reported for 2020–2021 is likely underestimated.

[d] Many Devils Wash has not been pumped since 2014 because of the demonstrated presence of naturally occurring contamination (Robertson et al. 2016), contradicting the original assumption of a mill site origin. Decommissioning of associated infrastructure is anticipated to begin in late summer 2022.

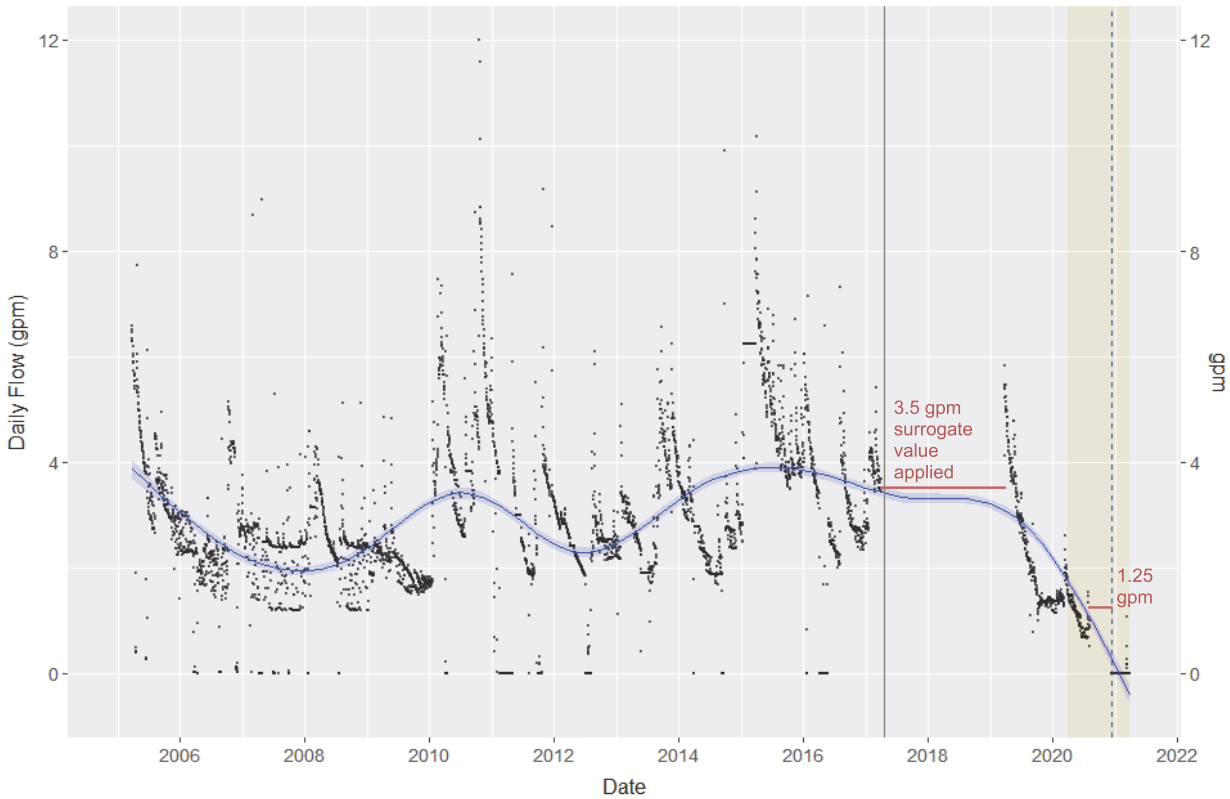
Abbreviation:

– = Not applicable (no data)

2.2.2 Bob Lee Wash Drain Performance

The terrace extraction system collects seepage from Bob Lee Wash using a subsurface interceptor drain. The drain, consisting of perforated pipe surrounded by drain rock and lined with geotextile filter fabric, is offset from the centerline of the wash to minimize the infiltration of surface water. All water collected by the Bob Lee Wash drain is pumped through a pipeline to the evaporation pond. Pumping continued at Bob Lee Wash location 1087 throughout most of this (2020–2021) reporting period because the wash is considered a potential point of exposure.

However, because the flow meter malfunctioned throughout the bulk of this reporting period, corresponding extraction volumes are uncertain. Due to the coronavirus pandemic and corresponding public health restrictions, it was not possible to access the site until early December 2020. At that time, technical staff noticed an underground water line leak and associated flooding near the sump. The pump was offline through approximately March 2021. As shown in Figure 6, during the approximate 4-month period when the pump was operating but the flow meter malfunctioned (between August 8, 2020, and December 10, 2020), extraction volumes were estimated using a surrogate value of 1.25 gpm. Based on flow rates measured in previous years (2–4 gpm average, as shown in Figure 6), the approximate 425,000 gallons assumed for this reporting period is likely underestimated; the average pumping rate was only 0.8 gpm (Table 3). The estimated cumulative volume extracted from the Bob Lee Wash sump since pumping began in 2003 is 28.3 million gallons. Again, this estimate is uncertain because of the periodic flow meter malfunctions documented since 2017.



- Average daily flow rate in gpm
- Surrogate average daily flow rate applied due to flow meter malfunctions
- LOESS locally weighted regression line and corresponding 95% pointwise confidence interval
- Shading denotes current (2020–2021) reporting period
- Denotes April 21, 2017, cessation of pumping at most Shiprock site treatment locations
- Dashed vertical line denotes the first time LM was able to access the site in 2020

Notes:
Data plotted are since the inception of the System Operation and Analysis at Remote Sites (SOARS) system in 2005. A surrogate value of 3.5 gpm was applied between April 2017 and early 2019. A surrogate value of 1.25 gpm was applied to the period between August 8, 2020, and December 10, 2020, when an underground water line leak and associated flooding near the collection drain was observed. The pump was offline through approximately March 2021.

Figure 6. Historical Flow Rates in Bob Lee Wash (1087): 2005–2021

2.2.3 Evaporation Pond

The current method for handling groundwater from the interceptor drains and extraction wells is solar evaporation. Contaminated groundwater is pumped to an 11-acre lined evaporation pond in the south part of the radon-cover borrow pit area (Figure 1). Figure 7 plots daily average pond water levels measured since September 2006. As discussed in the previous sections, LM suspended pumping of groundwater from most treatment system locations in April 2017. Since then, LM's approach has been to maintain a balance of pumping enough water to ensure that the evaporation pond sediments remain covered while remediating as much as possible in accordance with the site compliance strategy. Figure 8 is a photograph taken of the pond when water levels were low: approximately 0.8 ft on June 5, 2020. At the close of this reporting period (March 31, 2021), the water level in the evaporation pond was 1.6 ft, measured as the distance above transducers. The average water level during the reporting period was 1.0 ft.

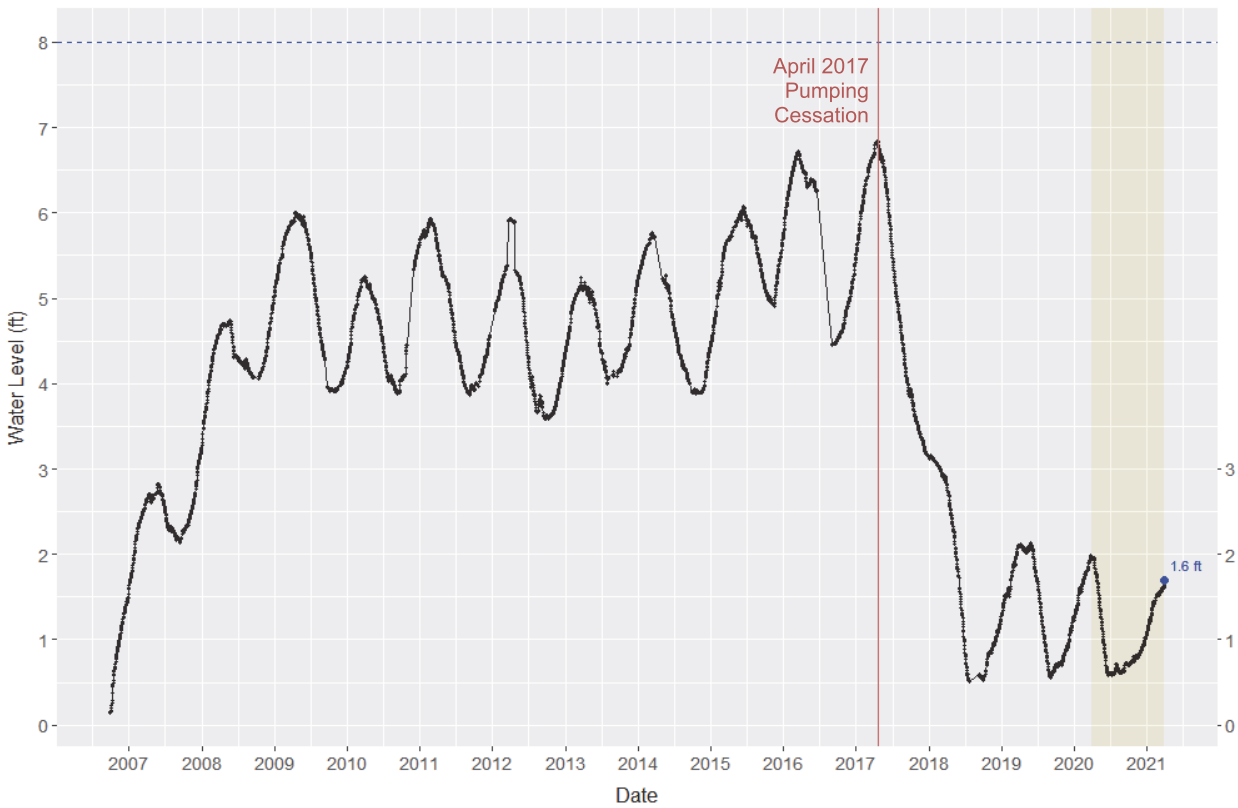
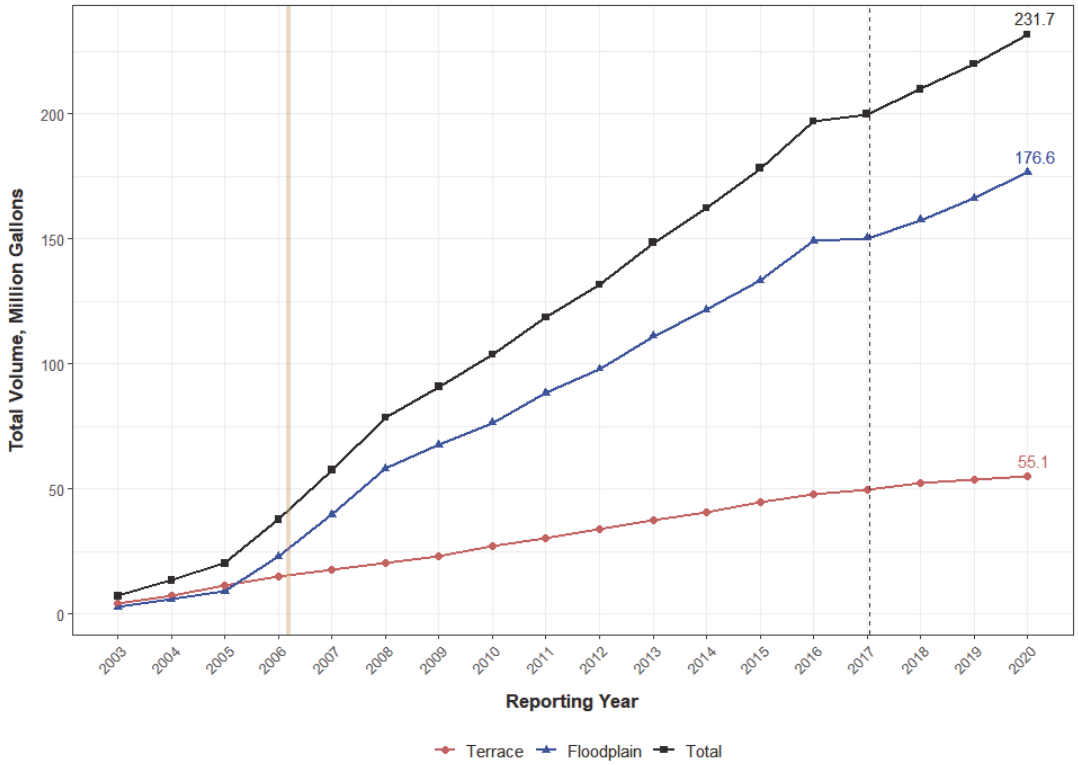


Figure 7. Water Levels in Evaporation Pond, 2006 Through March 2021

Figure 8. Shiprock Site Evaporation Pond, June 5, 2020
Pond Level at 0.8 ft (Distance Above Transducer); View to West-Southwest

From April 2020 through March 2021, an estimated 11.7 million gallons of extracted groundwater was pumped to the evaporation pond, about 15% greater than the volume extracted in 2019–2020 (10.2 million gallons). The bulk of this total volume (10.3 million gallons, or 88%) was from the floodplain trenches and extraction well 1089. At the end of the 2020–2021 reporting period, about 55.1 million gallons have been extracted from the terrace and 176.6 million gallons have been extracted from the floodplain since DOE began active remediation in March 2003 (Figure 9). This yields a total cumulative extracted volume of about 231.7 million gallons of water pumped to the evaporation pond from all sources. Total cumulative contributions continue to be about 24% from the terrace and 76% from the floodplain.

The estimated masses of nitrate, sulfate, and uranium pumped to the evaporation pond from the floodplain extraction wells and trenches and terrace groundwater extraction system during the 2020–2021 performance period were approximately 11,575 pounds nitrate (as N); 555,620 pounds sulfate; and 29.7 pounds uranium (Table 4). Because no sampling took place during this reporting period, these masses were estimated using results from the September 2019 or March 2019 sampling events (details provided in Table 4). In terms of mass, sulfate is the dominant COC that enters the evaporation pond because of its high concentrations in both the floodplain and terrace groundwater systems.



Installation of floodplain trenches, spring 2006
April 2017 pumping suspension, sustained for most terrace extraction wells

Note:
Years listed on *x*-axis correspond to the beginning of the reporting year. For example, total volumes shown for 2017 correspond to the amount of groundwater extracted between April 1, 2017, and March 31, 2018.

Figure 9. Total Groundwater Volume Pumped to the Evaporation Pond, 2003–2021

Table 4. Annual and Total Groundwater Volumes and Contaminant Masses Pumped from the Shiprock Site Terrace and Floodplain (Estimated for the Period April 1, 2020, Through March 30, 2021)

Location	2020–2021 Cumulative Volume (gallons)[a]	Total Cumulative Volume (gallons)[a]	Percent of Annual Total Volume Pumped (%)	Estimated Nitrate as N Average Concentration (mg/L)[b]	Estimated Nitrate Mass Removed (lb)[b,c]	Cumulative Mass of Nitrate Removed (lb)[a]	Estimated Sulfate Average Concentration (mg/L)[b]	Estimated Sulfate Mass Removed (lb)[b,c]	Cumulative Mass of Sulfate Removed (lb)[a]	Estimated Uranium Average Concentration (mg/L)[b]	Estimated Uranium Mass Removed (lb)[b,c]	Cumulative Mass of Uranium Removed (lb)[a]
Terrace												
0818	963,635	6,733,298	8.2	640	5,147	61,321	17,000	136,712	756,255	0.11	0.88	6.9
1070	0	545,106	–	550	–	4,232	16,000	–	81,779	0.11	–	0.6
1071	0	121,737	–	560	–	1,866	15,000	–	7,568	0.12	–	0.16
1078	2,778	4,797,240	0.02	330	7.7	23,411	13,000	301	553,063	0.11	0.003	5.3
1091	0	263,024	–	620	–	3,082	16,000	–	27,575	0.096	–	0.25
1093/1093R[d]	0	4,684,688	–	920	–	80,612	12,000	–	233,884	0.14	–	4.3
1095	0	2,850,773	–	1,700	–	38,512	4,200	–	134,696	0.04	–	1.3
1096	106	3,121,544	<0.01	500	0.4	15,256	17,000	15	365,472	0.10	0.0001	2.5
1087 (BLW)	425,332	28,340,614	3.6	200	710	69,033	6,100	21,652	1,664,490	0.36	1.3	126
1088 (MDW)	–	3,406,532	–	–	–	18,761	–	–	538,436	–	–	5.0
Floodplain												
1089	2,685,255	42,314,279	22.9	14.0	313.7	5,929	5,100	114,288	2,476,051	0.12	2.7	227
1104	0	8,565,939	–	15.0	–	2,935	5,500	–	612,076	0.14	–	68.8
Trench 1 (1110)	3,652,062	54,790,923	31.2	140	4,267	46,938	8,500	259,062	3,279,429	0.71	21.6	353
Trench 2 (1109)	3,981,176	67,186,019	34.0	34.0	1,130	38,825	710	23,589	791,404	0.096	3.2	112
Seep sump (1118)	0	3,013,885	–	36.0	–	1,259	6,500	–	150,641	0.42	–	11.9
Totals												
Total terrace	1,391,851	54,864,556	11.9	–	5,865	316,086	–	158,681	4,363,217	–	2.2	152
Total floodplain	10,318,494	175,806,714	88.1	–	5,710	95,885	–	396,939	7,309,601	–	27.5	772
Prior removals[e]		1,052,960	–	–	–	4,604	–	–	141,436	–		17.0
Total to pond[d]	11,710,345	231,724,230	–	–	11,575	416,576	–	555,620	11,814,254	–	29.7	941

Notes:

[a] Annual volumes reported as <1 gpm in the System Operation and Analysis at Remote Sites (SOARS) system are listed as zero. Cumulative volumes and masses are since 2003, when site remediation began.

[b] No sampling was conducted during this reporting period due to the coronavirus pandemic. Contaminant masses removed were estimated using September 2019 sampling results or, for Trench 2 location 1109 (not sampled in September 2019), March 2019 analytical results.

[c] Mass in pounds (lb) removed = annual volume (gallons) × average concentration (mg/L) × (3.7854 liters per gallon) × (1 lb per 453,592.37 milligrams).

[d] Cumulative volumes and masses listed for well 1093R combine data from former smaller-diameter well 1093 (2003–2007) with data from larger-diameter well 1093R (2008–present).

[e] Total cumulative volumes and masses listed in this row ("Prior removals") are from extraction wells that are no longer operating: terrace well 1092 (224,883 gallons, 2003–2015); terrace well 1094 (15,628 gallons, 2003–2004); and former floodplain pumping well 1077 (812,449 gallons in 2003–2005).

Abbreviations: – = Not applicable or no longer operational; BLW = Bob Lee Wash; lb = pounds; MDW = Many Devils Wash (the MDW interceptor drain has not operated since 2014)

3.0 Performance Summary

This section summarizes the findings of the most recent (April 2020 through March 2021) assessment of the floodplain and terrace groundwater remediation systems at the Shiprock site, marking the end of the 18th year of active groundwater remediation. This period is unusual in that no sampling or water level measurements were conducted. LM cancelled the semiannual sampling events previously scheduled for September 2020 and March 2021 because of the coronavirus pandemic. Pursuant to general directives in Navajo Nation Public Health Emergency Order No. 2020-007, most site maintenance activities were delayed until late 2020. LM deferred sampling of the approximate 130 site monitoring wells, the adjacent San Juan River, and remaining surface locations until September 2021. Active remediation continued, albeit at reduced rates relative to the historical record.

Because of the deteriorating evaporation pond liner, LM on April 21, 2017, suspended pumping at all Shiprock site treatment system locations except Bob Lee Wash. The (now 4-year) partial suspension continued into this reporting period for all treatment system locations except the floodplain trenches and extraction well 1089, terrace well 0818, and Bob Lee Wash. A few additional terrace wells were pumped intermittently, with only relatively small volumes extracted.

From April 2020 through March 2021, about 11.7 million gallons of extracted groundwater was pumped to the evaporation pond, about 15% greater than the volume extracted during the previous reporting period (10.2 million gallons in 2019–2020). The bulk of this total volume (10.3 million gallons, or 88%) was from the floodplain trenches and extraction well 1089.

Since DOE began active remediation in March 2003, about 55.1 million gallons has been extracted from the terrace and 176.6 million gallons has been extracted from the floodplain, yielding a total cumulative volume of about 231.7 million gallons of water pumped to the evaporation pond from all sources. The estimated masses of nitrate, sulfate, and uranium removed from the floodplain and terrace well fields during this performance period were (rounded) 11,600; 556,000; and 29.7 pounds, respectively. These masses were estimated using results from the September 2019 sampling event or, for wells that were dry or not operational at that time, the March 2019 event.

Because sampling was deferred until September 2021, it was not possible to evaluate contaminant concentrations on the floodplain or water table conditions on the terrace throughout this reporting period. Site conditions discussed in the preceding (2019–2020) annual performance report are assumed to have been sustained. LM will resume comprehensive analysis of site conditions in the next (2021–2022) annual report to ensure that the Shiprock site continues to pose no adverse risk to human health or the environment.

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Additional site-related documents can be found at:
https://lmpublicsearch.lm.doe.gov/SitePages/default.aspx?sitename=Shiprock