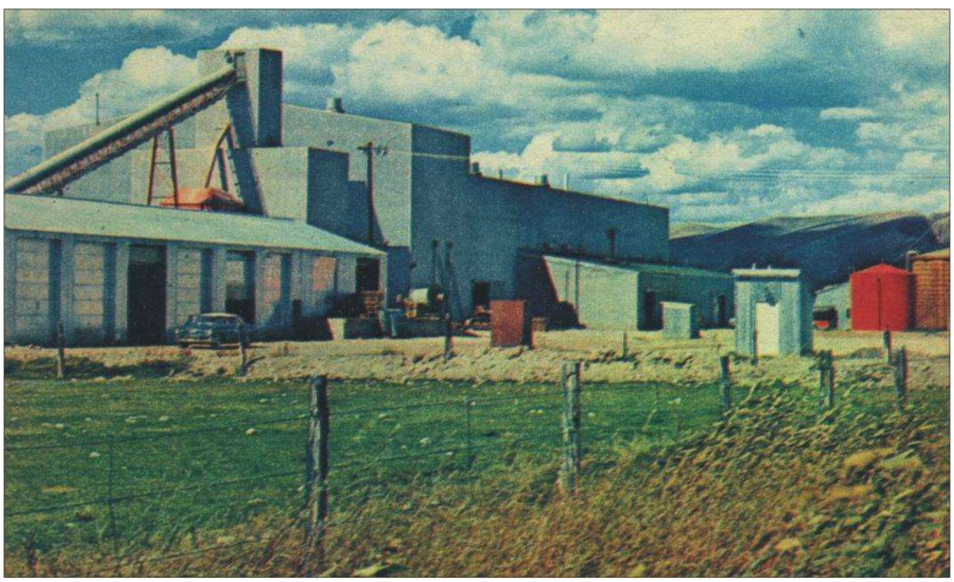
LMS/GUP/48214

2024 Verification Monitoring Report for the Gunnison, Colorado, Processing Site

May 2025



U.S. DEPARTMENT OF ENERGY | Legacy Management

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Cover photo: Gunnison, Colorado, Processing Site Circa 1957

Abbreviations

ACL	alternate concentration limit
bgs	below ground surface
CCR	*Code of Colorado Regulations*
CDPHE	Colorado Department of Public Health and Environment
COPC	constituent of potential concern
CSM	conceptual site model
DOE	U.S. Department of Energy
DWEL	drinking water equivalent level
EPA	U.S. Environmental Protection Agency
EVS	Earth Volumetric Studio
ft	feet
GCAP	Groundwater Compliance Action Plan
GEMS	Geospatial Environmental Mapping System
IC	institutional control
lb	pounds
lidar	light detection and ranging
LM	Office of Legacy Management
LOESS	locally estimated scatterplot smoothing
MCL	maximum concentration limit
mg/L	milligrams per liter
NRC	U.S. Nuclear Regulatory Commission
UMTRCA	Uranium Mill Tailings Radiation Control Act
VMR	Verification Monitoring Report

Executive Summary

This Verification Monitoring Report (VMR) for the Gunnison, Colorado, Processing Site summarizes annual monitoring data through April 2024 and assesses the progress of the current compliance strategy of natural flushing. The site is in Gunnison County, Colorado, approximately 0.5 mile southwest of the city of Gunnison and is managed by the U.S. Department of Energy Office of Legacy Management (LM) under the Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I program. The site is within an institutional control (IC) boundary encompassing an area of approximately 1030 acres. Verification monitoring conducted in 2024 involved routine annual sampling of groundwater and surface water for uranium and manganese, the two constituents of potential concern (COPCs) at the site.

The site compliance strategy was formalized in the 2010 Groundwater Compliance Action Plan (GCAP), whereby the site was anticipated to naturally flush to a condition in which groundwater cleanup objectives would be met within 100 years, the time frame permitted under UMTRCA regulations. To assess the progress of natural flushing, this VMR evaluates (1) temporal trends in groundwater levels and flow directions, (2) COPC concentration trends in groundwater and surface water, and (3) bulk plume metrics relative to baseline conditions. Uranium concentrations in groundwater are compared to the corresponding maximum concentration limit (MCL) of 0.044 milligrams per liter (mg/L). Because manganese is not regulated under UMTRCA (no corresponding MCL), groundwater concentrations for manganese are compared to the 1.6 mg/L drinking water equivalent level (DWEL) established by the U.S. Environmental Protection Agency.

Gravel pit operations adjacent to the former mill site have been occurring since the early 1970s. Most of the contaminated groundwater originating from the former mill site discharges to the adjacent gravel pits, whether pit dewatering is occurring or not. Milling-impacted groundwater is believed to have been discharging to the gravel pits since the first gravel pit was excavated below the water table and dewatering was initiated. Given the proximity of a nearby creek (Tomichi Creek) to the gravel pits and the presence of highly permeable material between these two features, water levels in the gravel-pit ponds are similar to those in the creek during periods when gravel pit dewatering is not occurring. Site groundwater, having a higher elevation than the gravel-pit ponds, discharges to and then migrates through the gravel-pit ponds and surrounding aquifer material to the creek.

While most of the contaminated groundwater emanating from the former mill site discharges to the gravel pits, a portion, at least historically based on downgradient single well detections of uranium and manganese, migrates southwest towards and ultimately discharges to Tomichi Creek. It is likely that the percentage of contaminated groundwater originating from the former mill site and discharging to the gravel pits increased with time as mining expanded towards the mill site. The flow path of site groundwater escaping capture by the gravel-pit ponds also likely changed with time in response to gravel pit expansion.

Uranium and manganese plumes extending from the former mill site to the gravel-pit ponds confirm continuing migration of contamination from the site to the gravel pits. For both COPCs, the temporally consistent plume geometries and concentrations in the vicinity of the site and gravel pits suggest active former mill site uranium and manganese sources.

Consistent with conclusions drawn in the previous VMRs, comparison of the 2010 and 2024 uranium and manganese plumes demonstrates that the higher concentrations of uranium and manganese extend from the former mill site to the gravel pits. The consistent temporal uranium and manganese plume geometries and concentrations in the vicinity of the site and gravel pits suggest active former mill site uranium and manganese sources. The results herein continue to document the relative stability of (in particular) the uranium plume volume and mass within the alluvial aquifer over the past decade, with persistently elevated concentrations in the source area monitoring wells. Given these findings, attainment of the 0.044 mg/L uranium MCL within the 100-year performance period for natural flushing is not likely.

In late 1999, ICs restricting groundwater usage were assigned to an area encompassing the former mill site boundary and a downgradient area partially bounded by Tomichi Creek and U.S. Highway 50. To further restrict groundwater usage within the IC boundary, a water supply system was installed in 1994 to provide drinking water to residents of the Dos Rios neighborhood. Connection of vicinity residences to the Dos Rios water supply system, a component of site ICs, effectively halts the potential public consumption of mill-contaminated groundwater. Currently, only one vicinity residence is not connected to the water supply system and relies on groundwater (well 0667) for domestic consumption. Therefore, location 0667 is sampled annually, and results indicate that uranium and manganese concentrations are below the MCL and DWEL, respectively.

Uranium and manganese concentrations measured in surface water samples in the vicinity of the former mill site have been consistently below acute and chronic Colorado surface water standards. Uranium concentrations in Valco Pond, the surface water monitoring location closest to the site which corresponds to one of the gravel-pit ponds, and immediately downstream in Tomichi Creek (monitoring location 0248) are elevated compared to the other surface water sampling locations, demonstrating that uranium from the former mill site is reaching Tomichi Creek.

In response to previous U.S. Nuclear Regulatory Commission comments, LM is currently conducting additional site analyses and evaluations to support an updated conceptual site model and a revised GCAP.

1.0 Introduction

This Verification Monitoring Report (VMR) provides an update on natural flushing progress at the Gunnison, Colorado, Processing Site, from completion of characterization activities and development of the initial groundwater compliance strategy in 2000 (DOE 2001) to the present. The site is managed by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) under the Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I program and is regulated by the U.S. Nuclear Regulatory Commission (NRC). The site is in Gunnison County, Colorado, approximately 0.5 mile southwest of the city of Gunnison (Figure 1). The site is within an institutional control (IC) boundary encompassing an area of approximately 1030 acres, which includes the former mill site and the area downgradient of the former mill site shown in Figure 1.

The NRC-approved groundwater compliance strategy for the site, documented in the 2010 Groundwater Compliance Action Plan (GCAP) (DOE 2010), is natural flushing with ICs (NRC 2015). Under this strategy, the site was anticipated to naturally flush to a condition in which groundwater cleanup objectives would be met within 100 years, the time frame permitted under UMTRCA regulations. Subsequent reevaluation of the conceptual site model (CSM) indicates that uranium, the primary constituent of potential concern (COPC) at the site, will likely persist in groundwater at concentrations exceeding the corresponding maximum concentration limit (MCL) beyond the 100-year time frame. In 2017, LM submitted a revised GCAP proposing a new compliance strategy consisting of alternate concentration limits (ACLs) and continued implementation of ICs (DOE 2017). In 2019, NRC issued a request for additional information (NRC 2019); LM is currently revising the CSM in response to that request. This VMR focuses on assessing aquifer restoration progress under the current natural flushing compliance strategy.

1.1 Site History

The Gunnison mill was constructed in 1957 and milled locally sourced uranium ore from 1958 to 1962 (DOE 2001) (Figure 2). Milling consisted of mechanically crushing the ore to sand-sized and finer fractions, acid leaching the crushed ore to dissolve uranium, chemically treating the mineral-rich solution to remove uranium, and pumping the tailings and low-pH processing fluids to the tailings impoundment for volume reduction by evaporation and infiltration (Merritt 1971). During its operating lifespan, the mill processed 540,000 tons of ore (FBDU 1981).

Surface remediation of tailings and contaminated soils, building demolition at the former mill site, and removal of radiologic material from vicinity properties occurred between 1992 and 1995 (DOE 2001). Onsite and offsite materials collected during remediation were transported 6 miles east of the former mill site and encapsulated in a 29-acre, engineered disposal cell. Characterization activities following surface remediation began in the 1980s and continued through the 1990s, consisting primarily of monitoring well installation, groundwater and surface water monitoring, and aquifer testing. In the early 1970s, gravel mining operations began on an adjacent parcel of land extending from the southern boundary of the former mill site to Tomichi Creek (Figure 1). Based on available documentation and limited temporally sequential aerial photographs, Pit 1 (also known as Valco Pond) was excavated from approximately 1972 to 1983. Pits 2 and 3 were excavated from approximately 1983 to 1999 and 1999 to 2009, respectively. Following a 4-year hiatus, Pit 4 was excavated from approximately 2013 to 2020.

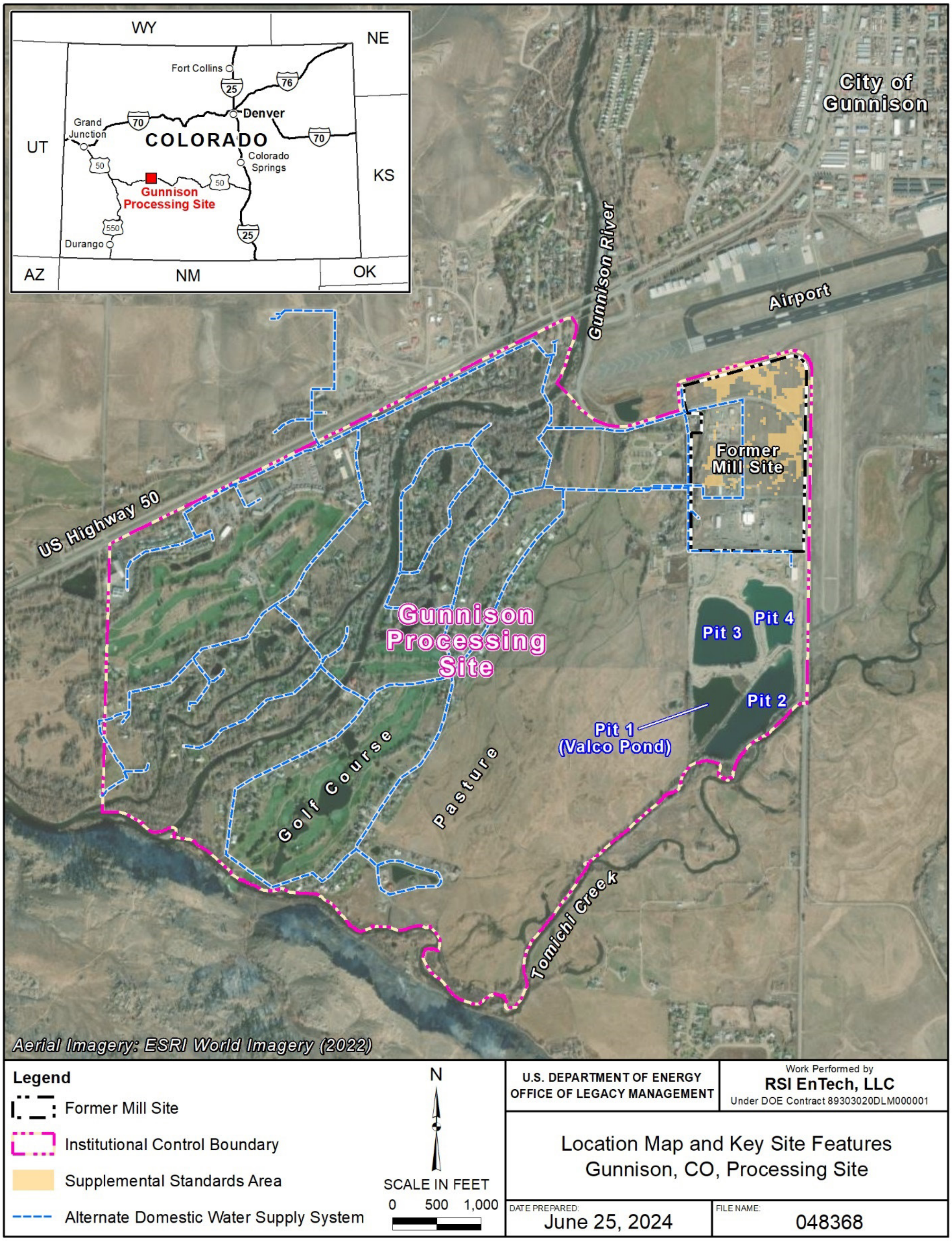


Figure 1. Gunnison Site Location Map and Key Site Features

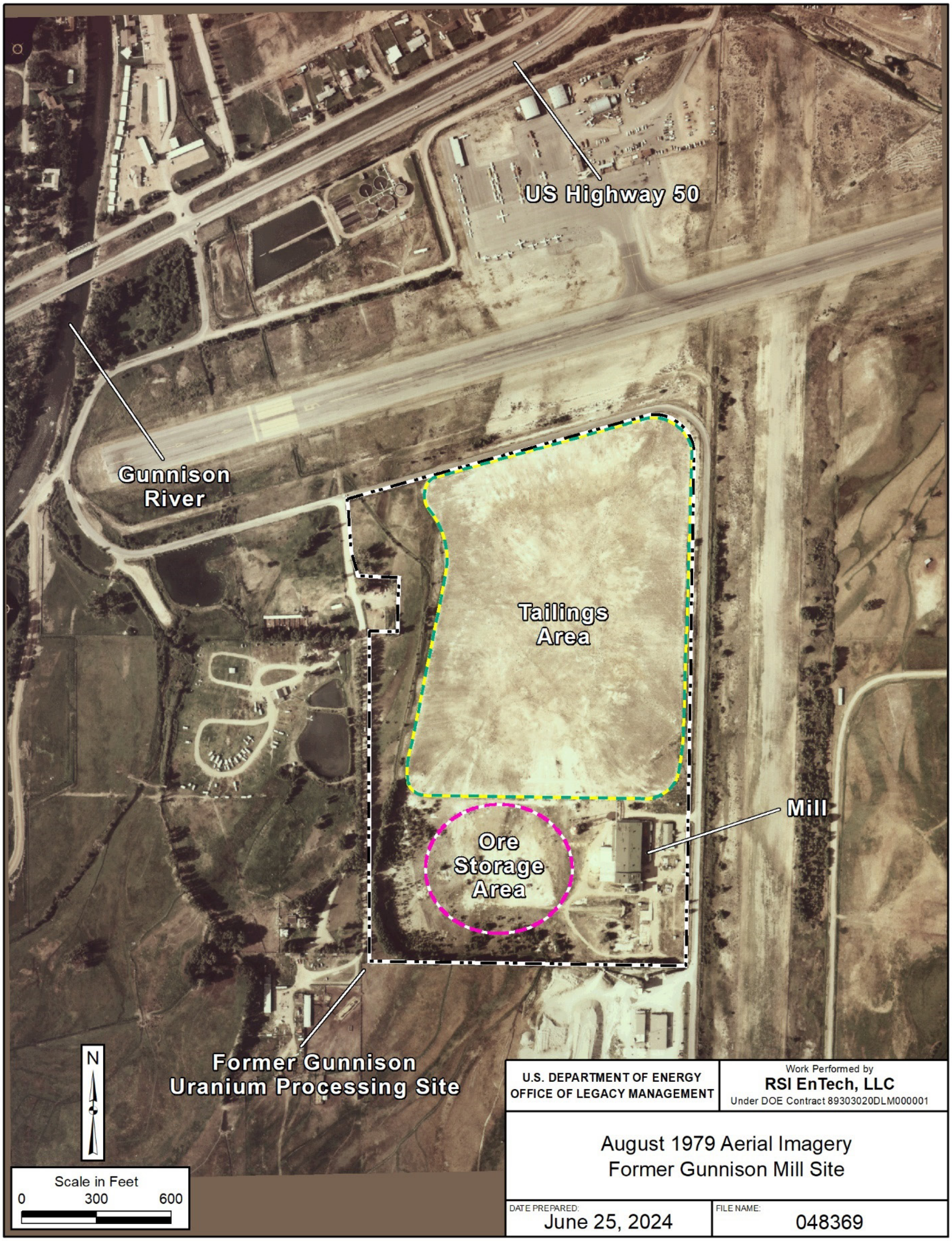


Figure 2. Aerial Photograph of the Former Gunnison Uranium Processing Site, August 1979

Pit 1 (Valco Pond) differs from the other three pits in that the pit is connected to Tomichi Creek by a drainage ditch. Based on Valco Inc.'s mine planning documentation (Gregg 1994), the pits were likely excavated to depths of approximately 40–50 feet (ft). Gravel mining was performed annually from mid-May through August with extracted water being discharged to one of the adjacent mined out gravel pits; dewatering rates ranged from 2000 to 4000 gallons per minute (DOE 2001). Gravel mining typically halts during the winter because of weather-related challenges, causing groundwater levels to recover to ambient conditions.

One-hundred-year natural flushing was selected as the compliance strategy, and ICs restricting groundwater usage were assigned (in 1999) to an area encompassing the former mill site boundary and a downgradient area partially bounded by Tomichi Creek and U.S. Highway 50 (DOE 2010) (Figure 1). To further restrict groundwater usage, the Dos Rios water supply system was installed in 1994 to provide drinking water to surrounding residents. At that time, six residences chose not to connect to the water supply system. Presently, one resident is not connected to the water supply system and relies on groundwater for domestic consumption. Historically, known active domestic wells within the IC boundary have been sampled annually to ensure that groundwater consumed by these households does not contain mill-related contamination above applicable limits or standards. Annual sampling of the single active domestic well will continue until that residence connects to the water supply system.

1.2 Hydrologic Setting

The unconfined alluvial aquifer beneath and downgradient of the former mill site is bounded to the east and south by Tomichi Creek and to the west by the Gunnison River and is underlain by shales of the Morrison Formation (Figure 3). Based on lithologic logs (DOE 2001), the alluvial aquifer, with a thickness of approximately 130 ft, consists primarily of sands and gravels with intermittent, discontinuous layers of silt and clay. In general, the silt and clay layers are more prevalent at greater depths.

In the spring, snowmelt recharges the alluvial aquifer. Following snowmelt, irrigation of the golf course and pastureland (which combined account for a large portion of the alluvial aquifer) is the primary source of recharge to the alluvial aquifer during late spring and summer. Continuous monitoring of groundwater levels indicates that pastureland groundwater levels in the vicinity of the site increase by as much as 10 ft and that those levels are maintained for the entire irrigation season (DOE 2001). In response to elevated water levels caused by irrigation, the vertical hydraulic gradient in the pastureland is downward.

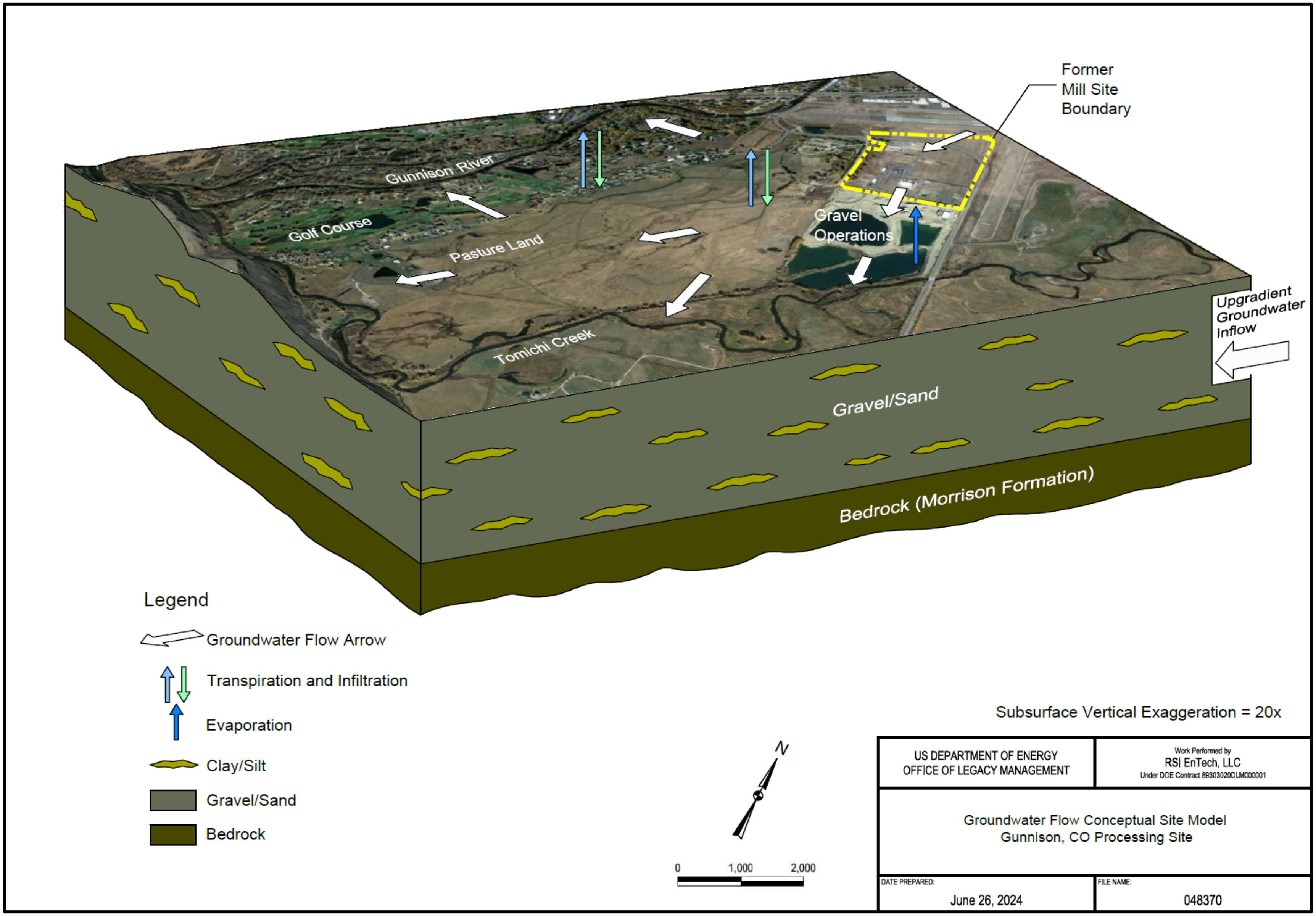


Figure 3. Groundwater Flow CSM

Groundwater in the vicinity of the former mill site discharges to the adjacent gravel pits. When a gravel pit is being dewatered, groundwater levels are maintained at an elevation below the gravel pit excavation depth, which could be as much as 40 to 50 ft (Gregg 1994). Because of the resulting contrast between the water elevations of the gravel pits during dewatering and the surrounding groundwater levels, nearby groundwater flows to the pit being mined. Groundwater continues to flow into the gravel-pit ponds after dewatering halts and pond water levels recover and stabilize. This is because the gravel-pit ponds, have surface water elevations similar to that of the adjacent creek (effectively, they are an extension of the creek surface elevation) but lower than surrounding groundwater elevations. After entering the gravel-pit ponds, water follows the path of least resistance and migrates through the ponds and the underlying aquifer material before discharging to Tomichi Creek, either as groundwater seepage or via the drainage ditch connecting Pit 1 to the creek. Outside the influence of the gravel pit operations, groundwater predominantly discharges to Tomichi Creek. During the warmer months, evaporation removes water from the hydrologic domain, including the gravel-pit ponds that are hydraulically connected to the alluvial aquifer. Evapotranspiration, mostly from pastureland and the golf course, also occurs, mainly during the summer growing season.

1.3 Site Compliance Strategy and Water Quality Monitoring

Groundwater and surface water quality characterization performed in the 1990s identified uranium and manganese as COPCs at the Gunnison site (DOE 2001). Based on evaluations of COPC migration and attenuation potentials, risk assessment, groundwater flow and transport modeling, and COPC trend evaluations, compliance strategies for the mill tailings and raffinate pond areas were developed. Natural flushing with a 100-year duration with ICs encompassing the site and the area downgradient of the site partially bounded by Tomichi Creek and U.S. Highway 50 was selected as the compliance strategy for the mill tailings area (DOE 2010).

1.3.1 COPCs and Compliance Goals

The GCAP requires monitoring of two COPCs: uranium (the primary COPC and the focus of previous natural flushing evaluations) and manganese (DOE 2010). The UMTRCA standard for uranium in groundwater is 0.044 milligrams per liter (mg/L), the MCL established in Title 40 *Code of Federal Regulations* Section 192 (40 CFR 192). Manganese is not regulated under UMTRCA nor under the U.S. Environmental Protection Agency (EPA) “Safe Drinking Water Act” (Title 42 *United States Code* Section 300f [42 USC 300f]). However, EPA has established a drinking water equivalent level (DWEL) of 1.6 mg/L based on a lifetime-exposure concentration protective of adverse, noncancer health effects that assumes the exposure to manganese is from drinking water (EPA 2018). This 1.6 mg/L DWEL is applied as a point of comparison for interpreting monitoring results.

1.3.2 Groundwater and Surface Water Monitoring Schedule and Locations

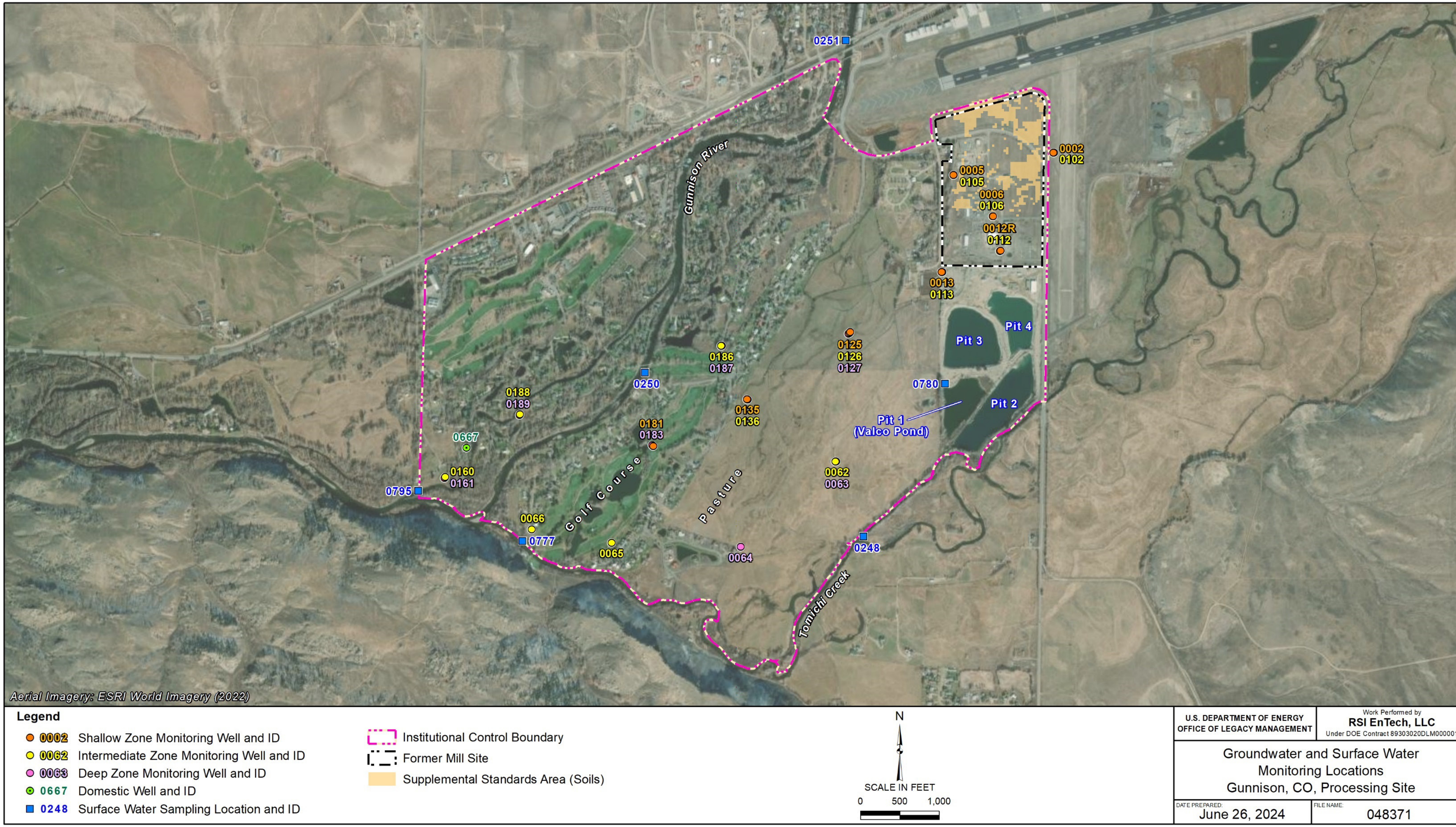
Gunnison site groundwater and surface water samples are typically collected in April from the monitoring locations listed in Table 1 and shown in Figure 4.

Table 1. Gunnison Site Sampling Locations

Monitoring Location	Screened Interval (ft bgs)	Alluvial Aquifer Zone	Location or Description
Groundwater (DOE Monitoring Wells)			
0002 0102	10–15 42–47	Shallow Intermediate	Upgradient (airport).
0005 0105	10–15 42–47	Shallow Intermediate	Former mill site.
0006 0106	10–15 34–39	Shallow Intermediate	Former mill site.
0012R 0112	6–16 40–45	Shallow Intermediate	Former mill site; 0012R replaced 0012 in 2008.
0013 0113	11–16 41–46	Shallow Intermediate	Adjacent to former mill site.
0125 0126 0127	18–23 54–59 94–99	Shallow Intermediate Deep	Pasture.
0062 0063	48–58 88–98	Intermediate Deep	Pasture.
0135 0136	18–23 53–58	Shallow Intermediate	Pasture.
0186 0187	53–58 93–98	Intermediate Deep	Golf course and residential area.
0064	87–97	Deep	Pasture.
0181 0183	18–23 93–98	Shallow Deep	Golf course and residential area.
0065	50–60	Intermediate	Golf course and residential area.
0188 0189	53–58 93–98	Intermediate Deep	West of Gunnison River.
0066	40–50	Intermediate	Golf course and residential area.
0160 0161	51–56 93–98	Intermediate Deep	West of Gunnison River.
Domestic Well			
0667	Not applicable		The only active domestic well as of 2022.
Surface Water			
0780	Not applicable		Valco Pond (Pit 1).
0248			Tomichi Creek, downstream of gravel pit operations.
0777			Tomichi Creek (golf course region, near Gunnison River).
0251			Gunnison River, upstream of IC boundary. Replaced former upstream location 0792 in 2014 to provide safer access for sampling.
0250			Gunnison River (monitor potential aquifer discharge).
0795			Gunnison River, downstream of IC boundary.

Notes:
DOE monitoring wells are listed in general order of increasing distance from the former mill site (Figure 4).
The upgradient wells are listed first, followed by the onsite wells, adjacent offsite wells, and remaining offsite wells.
Colocated monitoring wells (i.e., well pairs or clusters) are listed in the same table cell. Surface water sampling locations are also listed in general order of increasing distance from the former mill site, beginning with the Valco Pond location.

Abbreviation: bgs = below ground surface



Note: At colocated monitoring well locations (i.e., well pairs or clusters), symbols are plotted in order of completion zone. In these cases, the symbol for the well in the shallowest zone obscures symbols for the wells completed in deeper zones.

Figure 4. Groundwater and Surface Water Monitoring Locations at the Gunnison Site

1.4 Current Status and Planned Activities and Evaluations

As discussed in Section 1.0, because LM's more recent evaluations demonstrate that the natural flushing compliance strategy for the site is not performing as expected, LM submitted a draft revised GCAP to NRC on May 1, 2017 (DOE 2017). In lieu of the natural flushing remedy (requiring attainment of the 0.044 mg/L uranium MCL within 100 years), the revised GCAP proposed applying an ACL for uranium of 1.43 mg/L to alluvial aquifer groundwater underlying the former mill site and an ACL of 0.56 mg/L within the downgradient IC boundary (DOE 2017). NRC responded in a letter dated October 30, 2019, determining that "additional information and revisions are necessary for NRC to complete its review and concur on the revised GCAP" (NRC 2019). LM responded to NRC's request for additional information on March 2, 2021 (DOE 2021). In response to NRC's comments and concerns, LM is currently updating the groundwater flow and contaminant transport CSM and identifying data gaps requiring resolution before a revised compliance strategy is selected. In addition to the CSM updates and data gap assessment, the following near-term activities are planned to support LM's ongoing evaluations and a revised GCAP: (1) three-dimensional data visualization and evaluation, (2) development of data quality objectives, and (3) data worth analysis.

2.0 Compliance Remedy Performance

The current groundwater compliance strategy at the Gunnison site is natural flushing within a 100-year duration, with ICs encompassing the former mill site and a downgradient area partially bounded by Tomichi Creek and U.S. Highway 50 (Figure 1). To assess the effectiveness of the compliance strategy, current groundwater flow conditions, with and without adjacent gravel pit mining, were evaluated and compared to groundwater flow conditions assumed when the 2010 GCAP was finalized (DOE 2010). Historical concentrations of uranium and manganese in groundwater and surface water were evaluated to assess localized groundwater trends at and downgradient of the Gunnison site. Maps showing the current (2024) configurations of the uranium and manganese plumes were created and compared to 2010 conditions to evaluate changes in plume geometry over time. To assess temporal plume trends, bulk plume metrics were calculated for both COPCs and compared to 2010 conditions, the conditions on the date when a consistent monitoring well network was initially sampled.

Historical water quality and water level data for the Gunnison site are available on the LM website through the Geospatial Environmental Mapping System (GEMS) at https://gems.lm.doe.gov. A link to the GEMS website can also be found within the "Site Links" tab on the LM website (https://www.energy.gov/lm/gunnison-colorado-disposal-and-processing-sites).

2.1 Gunnison Site Groundwater Flow Directions

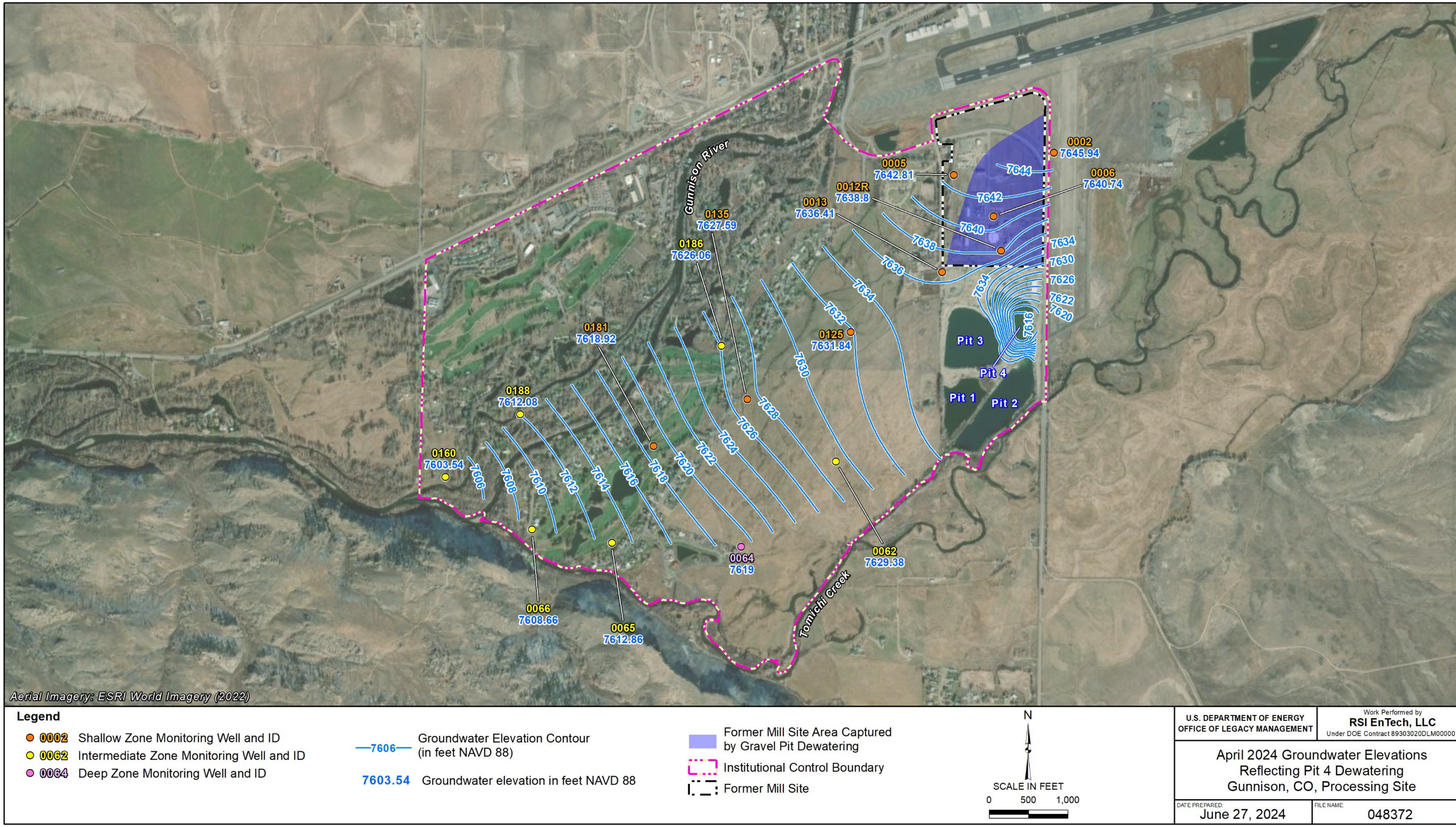
To assess the influence of gravel pit operations on groundwater flow, groundwater elevation maps for the Gunnison site and surrounding area were developed using Earth Volumetric Studio's (EVS's) kriging algorithm, 2024 groundwater levels, and Tomichi Creek and Gunnison River elevations representing baseflow conditions from the 2001 groundwater flow and transport model (DOE 2001). Gravel-pit pond water level elevations were assigned based on the results of a 2019 light detection and ranging (lidar) survey (USGS 2020) that occurred when Pit 4 was being excavated and dewatered. To assess the influence of the gravel pits when dewatering is not occurring, the lidar-determined Pit 3 water level was assigned to Pit 4. Forward particle tracking analysis was performed using the two EVS-determined groundwater elevation surfaces to determine the portions of groundwater flowing through the former mill site that discharge to the gravel pits and to Tomichi Creek when dewatering was and was not occurring.

Figure 5 shows the 2024 water table when Pit 4 adjacent to the site had been excavated to a depth of 30 ft below ground surface (bgs) and was being dewatered to facilitate gravel mining. The contours indicate southerly flow from the former mill site towards the gravel pits. Purple shading at the former mill site (shown in Figure 5 and Figure 6) denotes the portion of the site within the gravel operations capture zone (i.e., the areal footprint within which groundwater is influenced by gravel-pit pond water level elevations). The groundwater within the capture zone discharges to the gravel pits. In Figure 5, groundwater flowing through the portion of the site outside of the purple shading ultimately flows southwest and reaches Tomichi Creek.

Figure 6 shows the 2024 water table when none of the gravel pits were being dewatered. Similar to when gravel pit dewatering is occurring, the contours show southerly flow from the former mill site towards the gravel-pit ponds. This flow direction occurs because the gravel-pit pond water elevations are controlled by adjacent Tomichi Creek water level elevations; the creek and gravel-pit ponds have similar water level elevations. The extent of the purple shaded area for this scenario is smaller compared to when gravel pit dewatering is occurring. Groundwater elevation contours confirm southerly flow into the gravel pits in the absence of dewatering activities. Groundwater flowing through the portion of the site outside of the purple shaded area ultimately flows southwest and reaches Tomichi Creek.

The 1999 groundwater elevation contours (Figure 7) show groundwater flow from the former mill site towards the gravel pits and Tomichi Creek in the intermediate zone of the alluvial aquifer. Flow directions shown in this figure (taken directly from Figure 5-4 of the Site Observational Work Plan [DOE 2001]) suggest that gravel mining operations have likely been influencing groundwater flow since the first gravel pit was excavated below the water table (DOE 2001). Groundwater elevations between the shallow zone and intermediate zone show little variation, suggesting similar flow directions and influence from gravel mining in deeper portions of the aquifer. Similar to conditions in 2024, it is likely that some of the intermediate zone groundwater originating from the former mill site also migrated southwest toward Tomichi Creek.

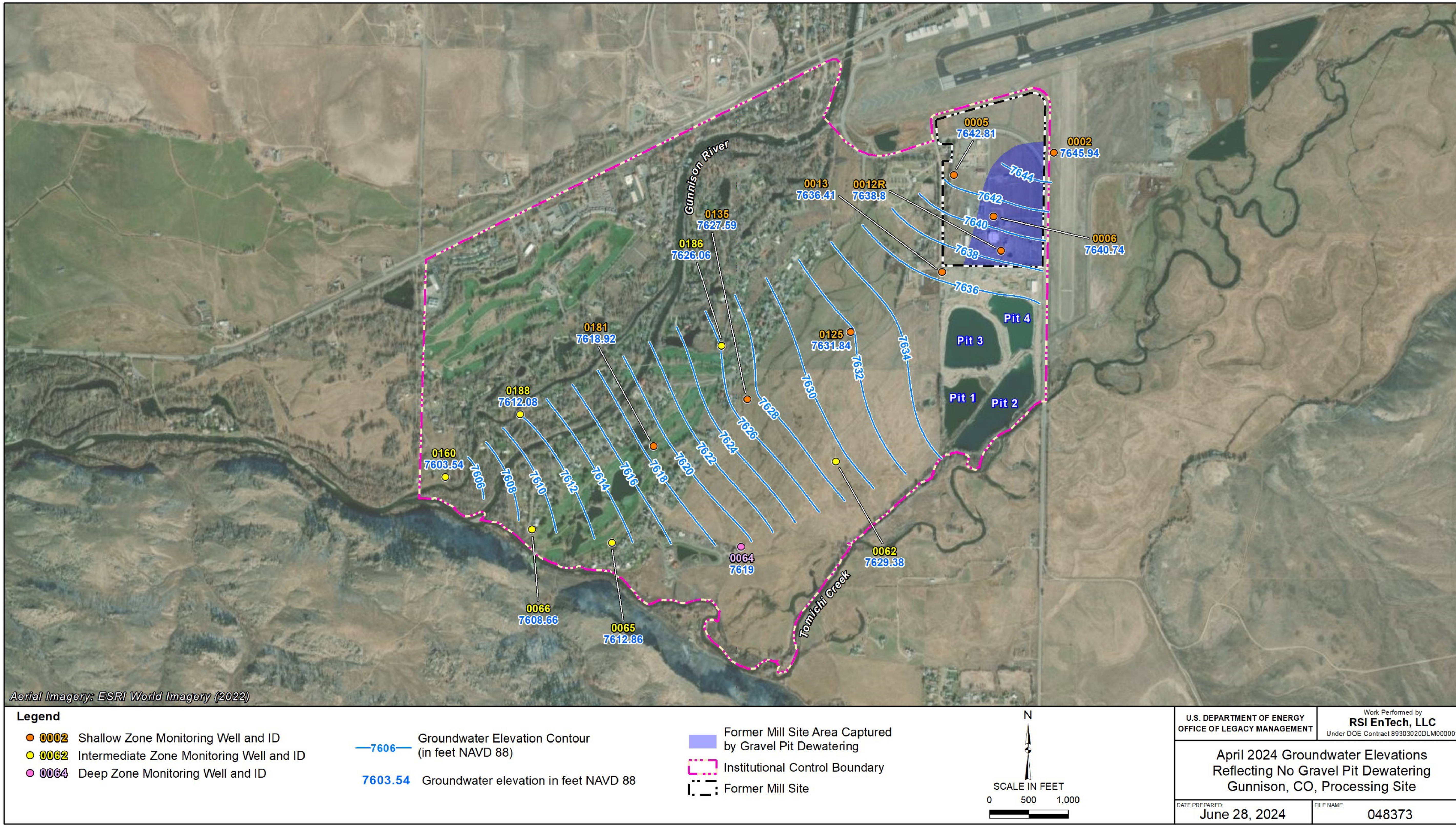
Figure 8 plots groundwater elevations in shallow, intermediate, and deep wells for the period from 1999 through 2024, corresponding to the time period addressed in the preceding three water level contour figures. Of note is the drawdown apparent from approximately 2000 to 2007, with the most significant drawdown measured in 2007, coinciding with the apparent excavation of Pit 3 (as noted in Section 1.1, the specific dates of gravel pit excavations are not known). This drawdown occurred in onsite wells and wells adjacent to the site, suggesting influences from adjacent gravel pit operations. Measurements at wells farther downgradient, closer to Tomichi Creek and the Gunnison River, do not show reduced water levels during the same period, which demonstrates that the drawdown near the gravel pits was not caused by a broader trend in climatic conditions or river levels. Based on these results, the cone of depression from Pit 3 dewatering might have extended as far as wells 0136, 0062/0063, and 0186/0187. In contrast to the drawdown near the gravel pits, the increase in water elevations shown in wells 0181 and 0183 in 2007 might be due to the irrigation of the golf course at that time.



Note: For each well pair or cluster shown in Figure 4, groundwater elevations are shown only for wells screened in the uppermost (shallowest) zone of the aquifer. For the remaining three locations with no corresponding colocated wells (wells 0064, 0065, and 0066), groundwater elevations correspond to the screened zone listed in Table 1.

Abbreviation: NAVD 88 = North American Vertical Datum of 1988

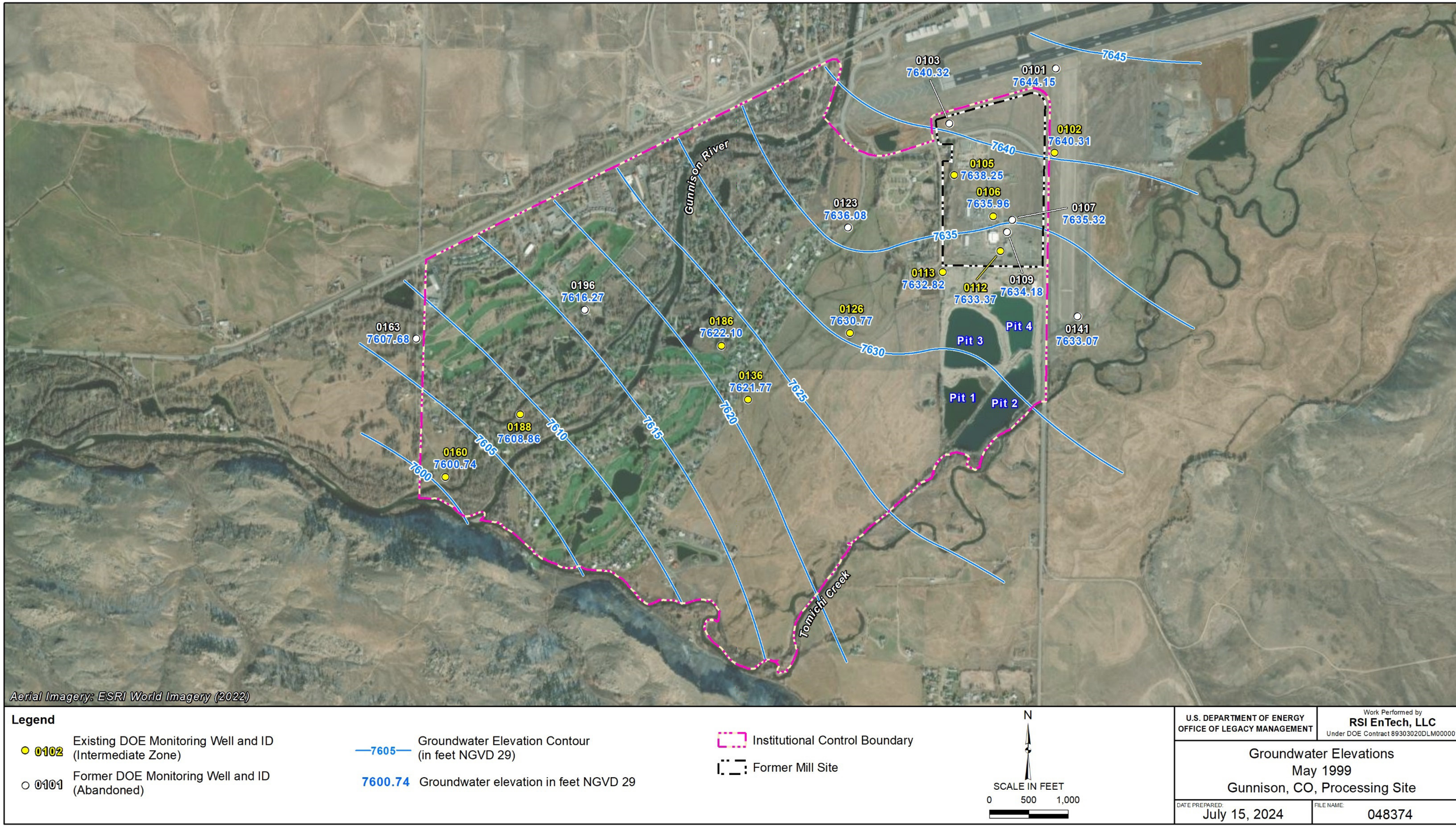
Figure 5. April 2024 Groundwater Elevations Reflecting Pit 4 Dewatering



Note: For each well pair or cluster shown in Figure 4, groundwater elevations are shown only for wells screened in the uppermost (shallowest) zone of the aquifer. For the remaining three locations with no corresponding colocated wells (wells 0064, 0065, and 0066), groundwater elevations correspond to the screened zone listed in Table 1.

Abbreviation: NAVD 88 = North American Vertical Datum of 1988

Figure 6. April 2024 Groundwater Elevations Reflecting No Gravel Pit Dewatering



Note: This figure was adapted from Figure 5-4 of the Site Observational Work Plan (DOE 2001); as such, NGVD 29 is used. All currently monitored wells shown here are completed in the intermediate zone. Remaining wells are no longer monitored and were abandoned in September 2004.

Abbreviation: NGVD 29 = National Geodetic Vertical Datum of 1929

Figure 7. May 1999 Gunnison Site Groundwater Elevations

Notes: Well pairs or clusters are arranged in general order of increasing downgradient distance from the site (locations shown in Figure 4). Data for wells with no corresponding colocated well (wells 0064, 0065, and 0066) are shown individually.
Two erroneous measurements are excluded from this figure. The May 2006 elevation recorded for well 0126 (7493.61 ft) was excluded because it is below the well bottom elevation. The May 2007 elevation recorded for well 0136 (7579.97 ft) was excluded because it represents a magnitude (40 ft) of drawdown that is not likely in a well at this distance from the gravel pits (even though it coincides with drawdowns noted in other wells at the same time).

Abbreviation: NAVD 88 = North American Vertical Datum of 1988

Figure 8. Water Elevations in Shallow, Intermediate, and Deep Monitoring Wells, 1999–2024

2.2 COPC Concentration Trends in Alluvial Aquifer Monitoring Wells

To assess natural flushing progress at the Gunnison site, concentrations of uranium and manganese were plotted for active wells within the monitoring well network for the period from 2000 to the present.[1] Mann-Kendall trend analysis was performed to determine whether COPC concentrations in individual monitoring wells are declining, stable, or increasing. For the wells with COPC concentrations exceeding compliance goals and identified as having a statistically significant decreasing concentration trend, linear regression of the log-transformed concentration data was performed to determine when the COPC concentration in each well is expected to decline below the corresponding compliance goal: the 0.044 mg/L MCL for uranium and the 1.6 mg/L DWEL for manganese.[2]

The following sections discuss concentration trends of COPCs in onsite and offsite monitoring wells screened in shallow (<25 ft bgs), intermediate (30–60 ft bgs), and deep (>85 ft bgs) zones of the alluvial aquifer (see Table 1) and domestic wells, also screened in the alluvium. Time-concentration plots presented in this section were developed using a faceting approach, whereby data are partitioned into a matrix of panels, with each panel plotting data for a single well. In each facet, a nonparametric smoothing method—locally estimated scatterplot smoothing (LOESS)—is used. The surrounding shaded areas in these plots represent the 95% confidence interval. Using this approach, overall trends in the data are more apparent and not obscured by "noise" or random variation.[3] Because of the wide range in contaminant concentrations measured across site wells, most data are plotted using a semilogarithmic scale. For each depth category, individual (well-specific) plots are arranged in general order of increasing distance from the site, consistent with their listing in Table 1. Results labelled in all time-concentration plots and in the corresponding spatial distribution figures are rounded to two significant figures.

2.2.1 Uranium

Shallow Monitoring Wells (Figure 9)

Uranium concentrations in shallow onsite monitoring wells 0006 and 0012R have consistently exceeded the 0.044 mg/L MCL, with the most recent results being 0.32 and 0.20 mg/L, respectively (Figure 9). Although Mann-Kendall trend analysis indicates a significant decreasing concentration trend in both wells, reduction to the MCL is not likely in the near future. Corresponding linear regression predicts attainment of the MCL between 2085 and 2278 and 2043 and 2061, respectively (Table 2). Uranium concentrations in onsite well 0005 and adjacent offsite well 0013 have been consistently at or near the MCL; the most recent results were 0.034 and 0.027 mg/L, respectively. Uranium has not been detected above the MCL in the remaining three shallow downgradient monitoring wells (0125, 0135, and 0181). Uranium concentrations in well 0125 have no trend and have been consistently below the MCL (most recent result was 0.0089 mg/L).

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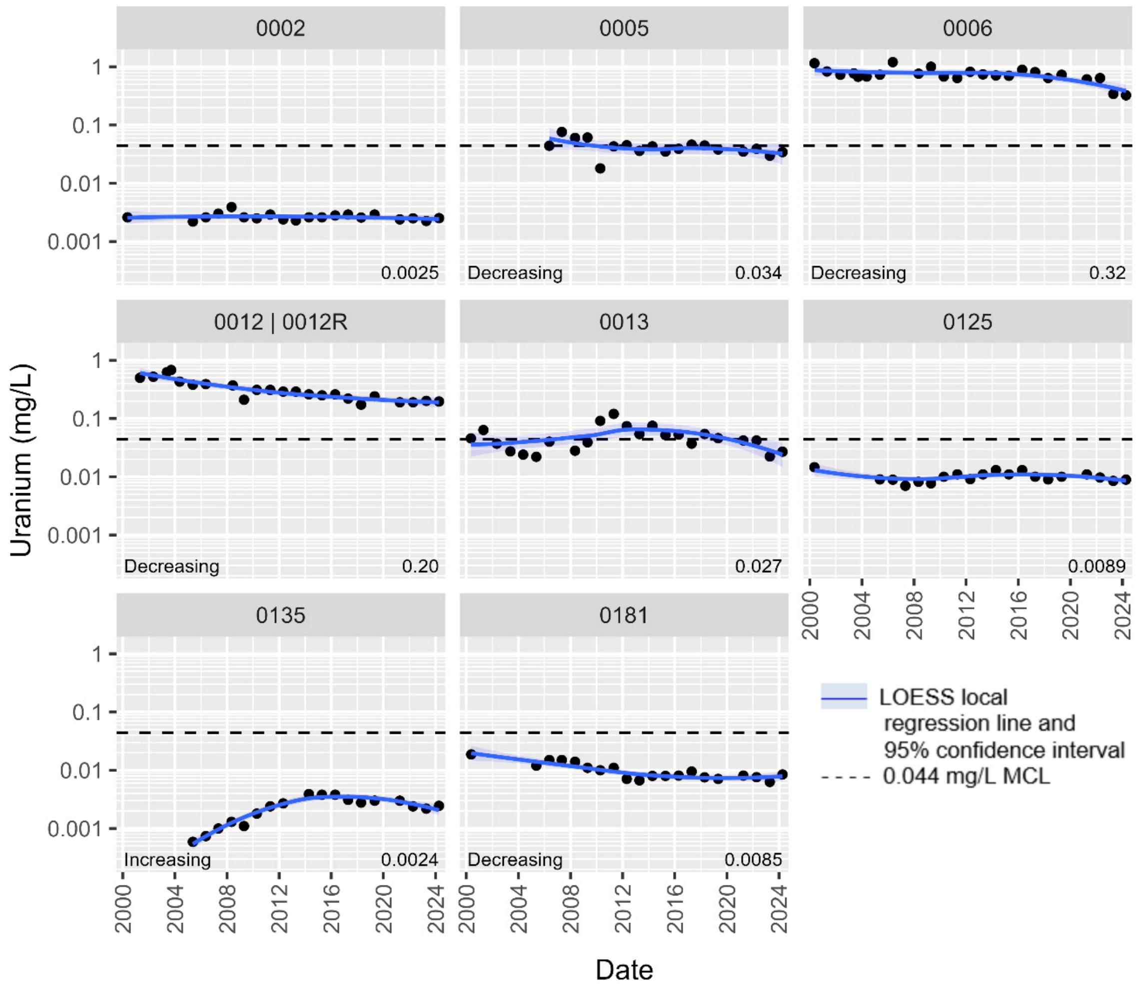
[1] Several wells were sampled infrequently in the 1980s and early 1990s (e.g., shallow wells 0005 and 0135), and monitoring did not resume until 2005 or 2006. For this reason, some individual plots in Figure 9 through Figure 17 do not have data for the entire 2000–2024 time frame. Also, due to the COVID-19 pandemic, the 2020 monitoring event was limited to the sampling of only five domestic wells and six surface water locations.

[2] Both Mann-Kendall and linear regression analyses use a significance (or alpha) level of 0.05.

[3] All temporal plots in this report were developed using R, version 4.3.3 (R Core Team 2024), and the ggplot2 package, version 3.5.1 (https://ggplot2.tidyverse.org).

Although a significant increasing trend was found for well 0135 (Table 2), uranium concentrations in this well have always been low relative to the MCL and have stabilized since 2014. The most recent result of 0.0024 mg/L in well 0135 is equivalent to concentrations measured historically in upgradient well 0002 (Figure 9). While a significant decreasing trend was identified for well 0181 (Table 2), uranium concentrations in this well have also stabilized in recent years.



Notes: The order of facet plots for shallow monitoring wells is consistent with Table 1, in which wells are listed in general order of increasing distance from the former mill site (Figure 4). Former onsite location 0012 (monitored 2001–2006) was replaced with well 0012R in 2008.
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 2), the direction of the trend is indicated on the plot.

Figure 9. Uranium Concentration Trends in Shallow Monitoring Wells

Table 2. Uranium Concentration Trends in Alluvial Aquifer Monitoring Wells and Compliance Strategy Attainment Predictions

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples[b]	Most Recent Result (mg/L)[c]	Kendall's Tau[d]	p-value[d]	Mann-Kendall Concentration Trend	Half-Life (years)			Year 0.044 mg/L MCL is Reached		
								Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Shallow Wells													
0002	5/10/2000	4/10/2024	20	0.0025	−0.16	0.36	None	Not applicable, concentrations less than remediation goal					
0005*	5/15/2006	4/10/2024	18	0.034	−0.44	0.014	Decreasing						
0006*	5/10/2000	4/9/2024	24	***0.32***	−0.41	0.005	Decreasing	28.7	18.3	66.6	2127	2085	2278
0012/ 0012R*	4/26/2001	4/9/2024	23	***0.20***	−0.78	<0.001	Decreasing	13.9	11.4	17.8	2050	2043	2061
0013	5/9/2000	4/9/2024	23	0.027	−0.03	0.87	None	Not applicable, concentrations less than remediation goal					
0125	5/9/2000	4/8/2024	20	0.0089	0.04	0.82	None						
0135	5/18/2005	4/8/2024	18	0.0024	0.41	0.020	Increasing						
0181	5/17/2000	4/9/2024	20	0.0085	−0.56	<0.001	Decreasing						
Intermediate Wells													
0102	5/10/2000	4/10/2024	20	0.0037	−0.03	0.90	None	Not applicable, concentrations less than remediation goal					
0105*	5/20/2005	4/10/2024	19	0.015	−0.33	0.061	None						
0106*	5/10/2000	4/9/2024	24	***0.15***	0.93	<0.001	Increasing	Not applicable, increasing concentrations					
0112*	4/26/2001	4/10/2024	23	***0.12***	0.77	<0.001	Increasing						
0113	5/9/2000	4/9/2024	24	***0.11***	0.13	0.40	None	Not applicable, no trend					
0126	5/9/2000	4/8/2024	24	0.011	−0.16	0.30	None	Not applicable, concentrations less than remediation goal					
0062	5/18/2005	4/8/2024	19	0.0062	−0.53	0.002	Decreasing						
0136	5/10/2000	4/8/2024	20	0.0031	−0.45	0.006	Decreasing						
0186	5/10/2000	4/9/2024	20	0.016	−0.55	0.001	Decreasing						
0065	5/17/2005	4/9/2024	19	0.018	−0.87	<0.001	Decreasing						
0188	5/10/2000	4/9/2024	24	0.022	−0.62	<0.001	Decreasing						
0066	5/17/2005	4/9/2024	19	0.020	−0.62	<0.001	Decreasing						
0160	5/17/2000	4/9/2024	24	0.026	0.56	<0.001	Increasing						
Deep Wells													
0127	5/9/2000	4/8/2024	24	0.015	−0.66	<0.001	Decreasing	Not applicable, concentrations less than remediation goal					
0063	5/19/2005	4/8/2024	19	0.015	0.54	0.002	Increasing						
0187	5/17/2006	4/9/2024	18	0.031	0.28	0.12	None						
0064	5/19/2005	4/8/2024	19	0.012	−0.12	0.50	None						

Table 2. Uranium Concentration Trends in Alluvial Aquifer Monitoring Wells and Compliance Strategy Attainment Predictions (continued)

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	Number of Samples[b]	Most Recent Result (mg/L)[c]	Kendall's Tau[d]	p-value[d]	Mann-Kendall Concentration Trend	Half-Life (years)			Year 0.044 mg/L MCL is Reached		
								Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Deep Wells (continued)													
0183	5/17/2000	4/9/2024	24	0.040	−0.49	<0.001	Decreasing	Not applicable, concentrations less than remediation goal					
0189	5/10/2000	4/9/2024	24	0.0080	−0.21	0.19	None						
0161	5/17/2000	4/9/2024	24	0.023	0.84	<0.001	Increasing						
Remaining Domestic Well Currently Sampled													
0667	4/30/2001	4/9/2024	24	0.0024	0.32	0.030	Increasing	Not applicable, concentration less than remediation goal					

Notes:

[a] For each category, wells are listed in general order of increasing distance from the former mill site, consistent with the order and approach applied in Table 1; wells followed by an asterisk (*) are onsite wells. Data for former well 0012 and current colocated well 0012R were combined for the Mann-Kendall trend analysis and in Figure 10.

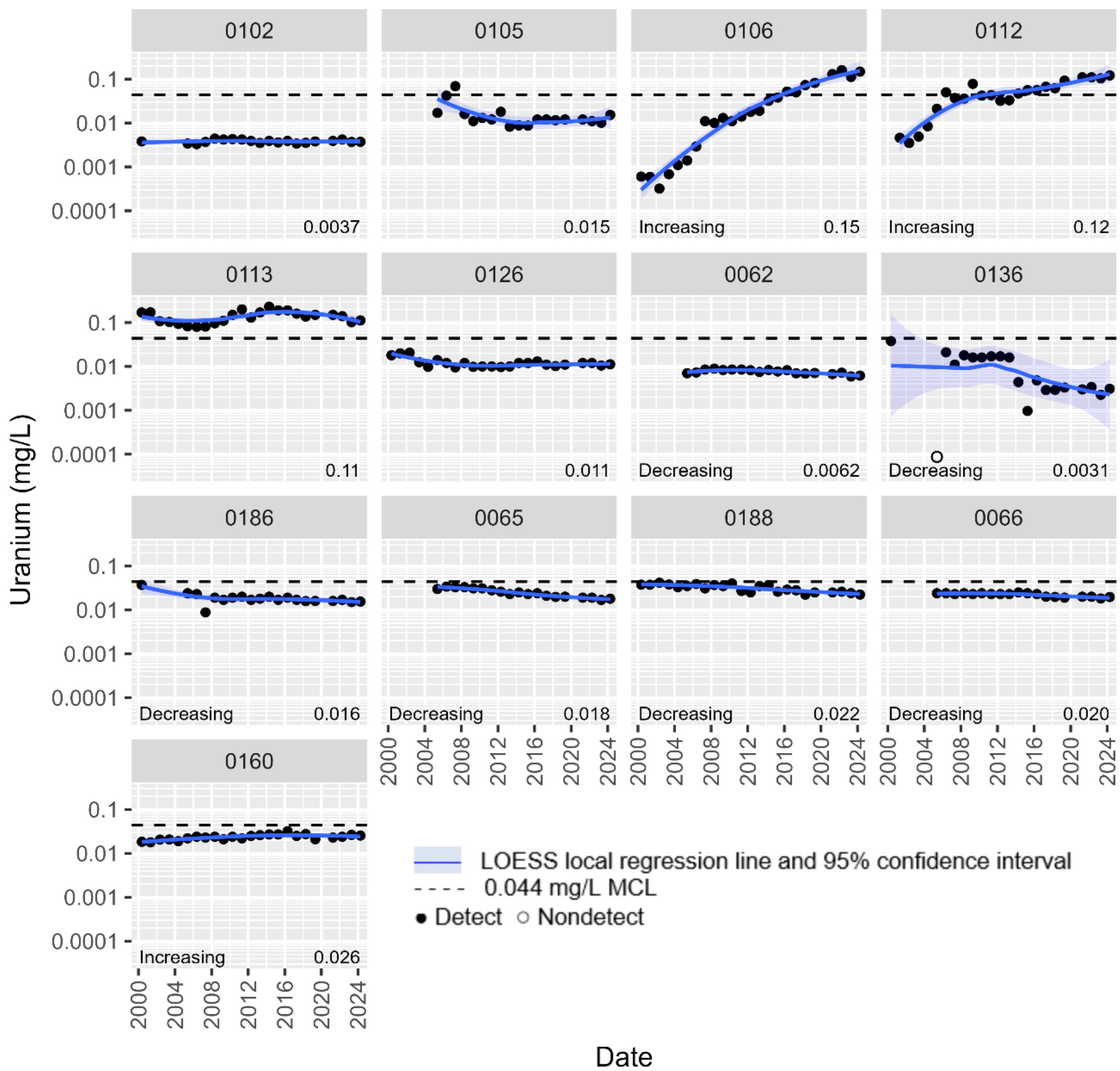
[b] Detection frequencies for uranium in site wells are 100% except for well 0136 with a single nondetect reported in 2005 (Figure 10).

[c] Results shown to two significant figures (refer to the GEMS website [https://gems.lm.doe.gov] for the raw unrounded result). In this column, values in ***red bold italic*** font denote recent uranium concentrations exceeding the 0.044 mg/L MCL.

[d] The test statistic Kendall's tau is a measure of the strength of the association between two variables, with values always falling between −1 and +1. Trend analyses were conducted at the 0.05 significance (or alpha) level using a two-sided test.

Intermediate Monitoring Wells (Figure 10)

Uranium concentrations in intermediate monitoring wells are below the 0.044 mg/L MCL, except for onsite wells 0106 and 0112, which have statistically significant increasing trends, and offsite adjacent well 0113, which has no trend (Table 2). Statistically significant decreasing trends were found for six of the remaining 10 intermediate zone wells. Exceptions include upgradient well 0102, onsite well 0105, and offsite downgradient well 0126, all of which have no trend. A statistically significant increasing trend was identified for well 0160, the farthest downgradient in the intermediate zone (Table 2).

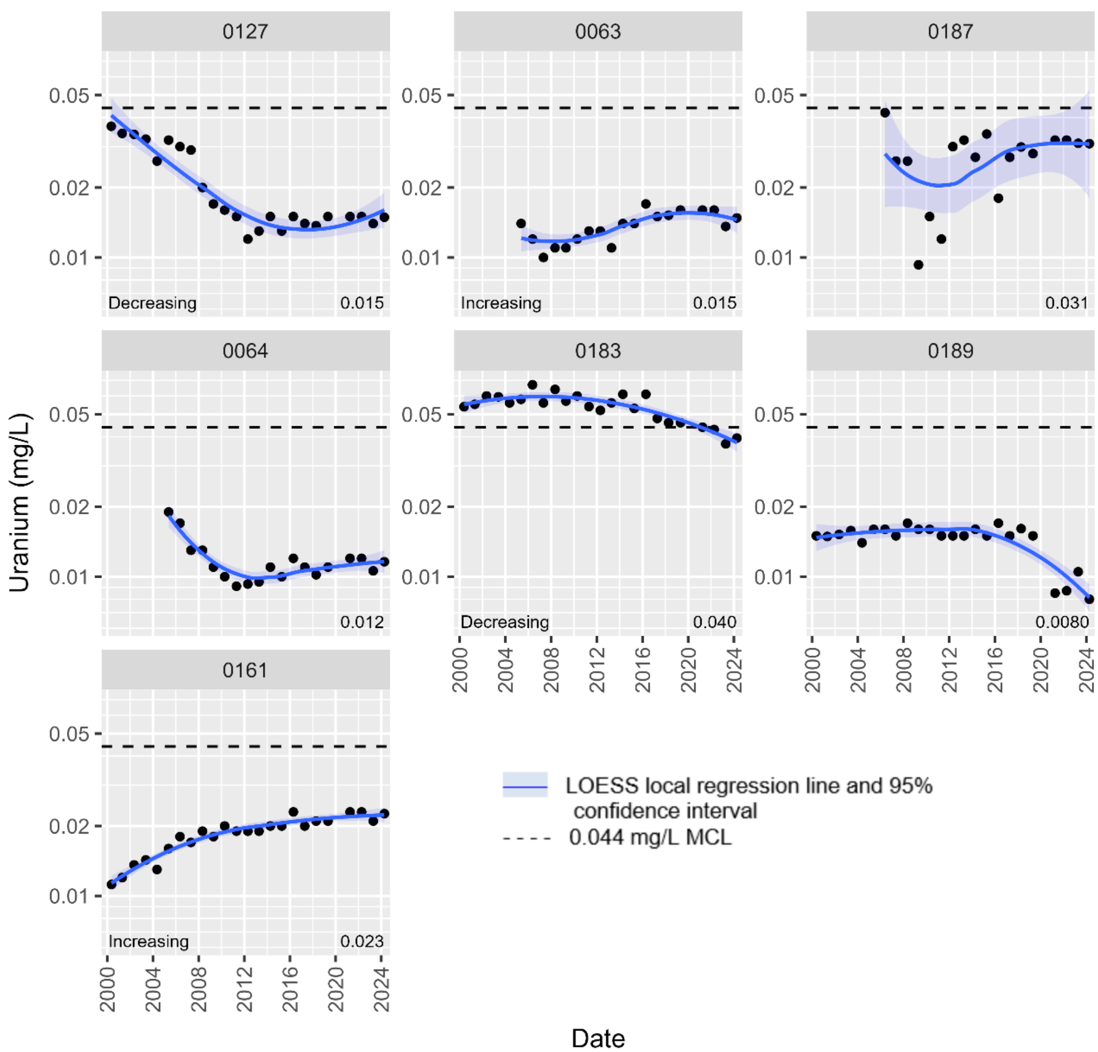


Notes: The order of facet plots for shallow monitoring wells is consistent with Table 1, in which wells are listed in general order of increasing distance from the former mill site (Figure 4).
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 2), the direction of the trend is indicated on the plot.

Figure 10. Uranium Concentration Trends in Intermediate Monitoring Wells

Deep Monitoring Wells (Figure 11)

Consistent with previous sampling results (DOE 2024), uranium concentrations in the deep offsite monitoring wells were below the 0.044 mg/L MCL in 2024. There are no deep onsite monitoring wells (Figure 4). Statistically significant decreasing trends were found for well 0127 (uranium concentrations historically below the MCL) and well 0183, where uranium concentrations exceeded the MCL until 2021 (most recent result was 0.040 mg/L) (Table 2). Mann-Kendall trend analysis identified two deep wells as having statistically significant increasing trends: wells 0063 and 0161 (Table 2). Uranium concentrations in both wells have been below the MCL and have stabilized since approximately 2020. No significant trend was found for wells 0187, 0064, and 0189. Uranium concentrations in well 0187 fluctuated between 2006 and 2016 (0.0093–0.042 mg/L) but have been relatively stable (0.031–0.032 mg/L) the last 4 years.



Notes: The order of facet plots for deep monitoring wells is consistent with Table 1, in which wells are listed in general order of increasing distance from the former mill site (Figure 4).
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 2), the direction of the trend is indicated on the plot.

Figure 11. Uranium Concentration Trends in Deep Monitoring Wells

Monitoring Well Network (Data Plotted by Location and Aquifer Zone) (Figure 12)

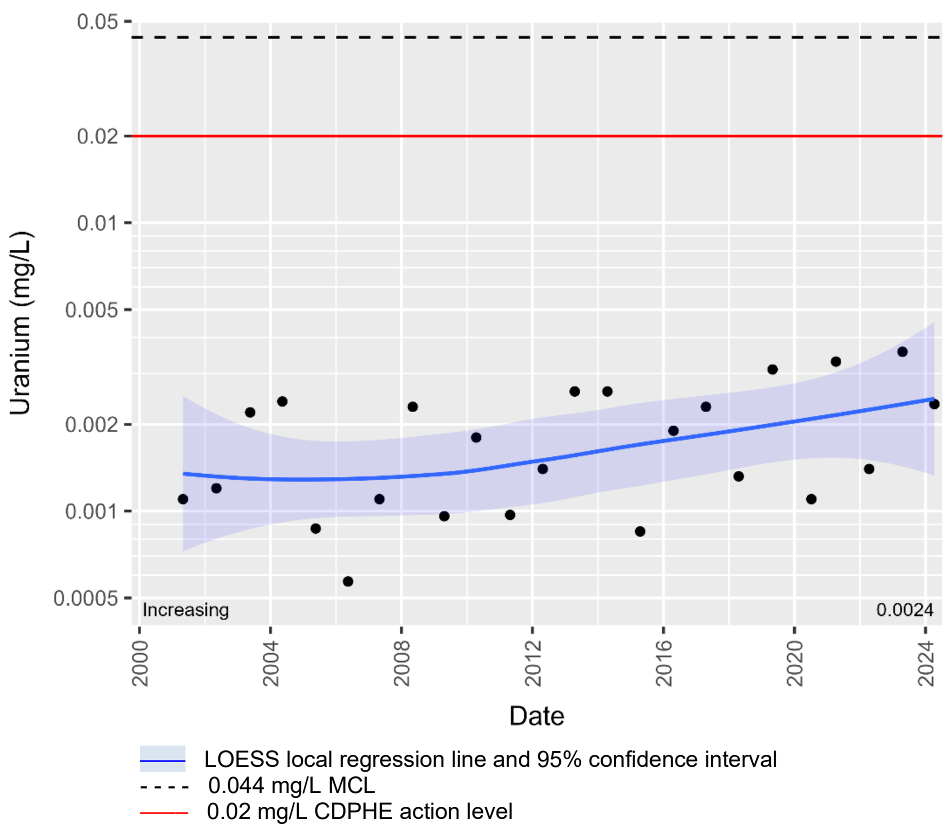
Figure 12 is a compilation of the data previously shown in Figure 9 through Figure 11 for uranium concentrations in shallow, intermediate, and deep wells. Consistent with the presentation of groundwater elevations in Figure 8, the data are plotted by general location, with point symbols color-coded to represent the different screen depth intervals listed in Table 1. For most well pairs or clusters, uranium concentrations are similar across zones. An exception is onsite well pair 0006 and 0106, where uranium concentrations in intermediate well 0106 (screened 34–39 ft bgs) are increasing significantly (Table 2) and approaching current concentrations (0.32 mg/L) in shallow well 0006 (which shows a significantly decreasing trend). A similar but less exaggerated trend is apparent for onsite wells 0012R and 0112. Another exception is shallow and deep well pair 0181 and 0183. In this case, uranium concentrations in the deep zone (currently 0.040 mg/L but historically slightly above the MCL) have consistently exceeded those in the shallow zone.

Notes: Well pairs or clusters are arranged in general order of increasing distance from the site. Data for wells with no corresponding colocated well (wells 0064, 0065, and 0066) are shown individually.

Figure 12. Time-Concentration Plots of Uranium in Shallow, Intermediate, and Deep Monitoring Wells

Domestic Well 0667 (Figure 13)

At the time of completion of the Dos Rios water supply system in 1994, six residences, between the golf course and the Gunnison River (Table 1; Figure 4), chose not to connect to the system. In 2011, one of those residences connected to the water supply system, and sampling of the well on that residence (0479) was discontinued (DOE 2011). Four of the five remaining domestic wells (0476, 0477, 0478, and 0683) were sampled annually until August 2021, when those residences opted to connect to the water supply system. As demonstrated in the 2022 VMR (DOE 2023), uranium concentrations in those four wells were consistently below the 0.044 mg/L MCL (≤0.0041 mg/L). Currently, one residence, relying on well 0667 for domestic consumption, is not connected to the Dos Rios water supply system. Well 0667 continues to be sampled annually as shown in Figure 13. Uranium concentrations in this well, despite having an increasing trend (Table 2), are still an order of magnitude below the MCL and have also been below the 0.02 mg/L Colorado Department of Public Health and Environment (CDPHE) action level established in the 1996 buffer zone monitoring plan (DOE 1996). This action level has been applied in the GCAP (DOE 2010) and subsequent VMRs (DOE 2011; DOE 2024) as a point of comparison for evaluating domestic well results.[4]



Note: The most recent (2024) result is labeled, as is the direction of the trend (Table 2).

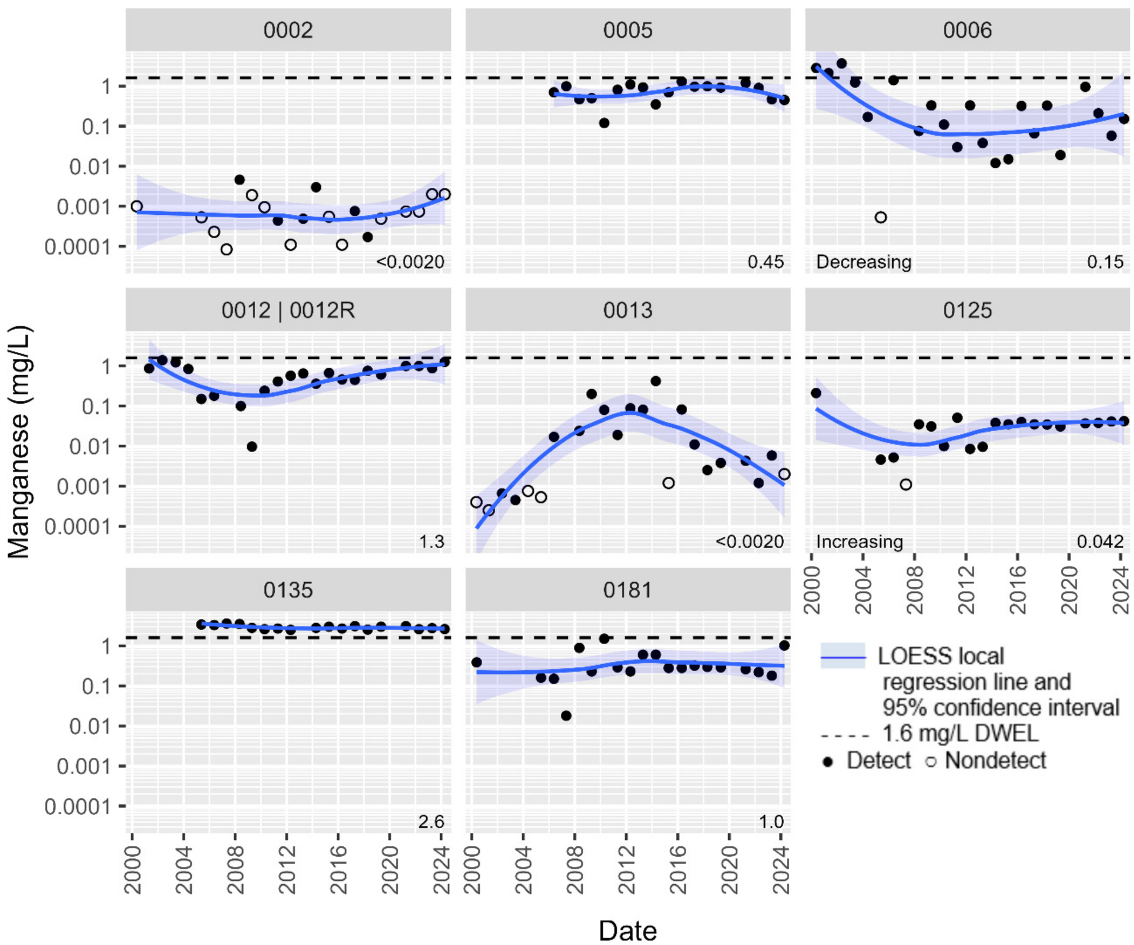
Figure 13. Uranium Concentration Trends in Domestic Well 0667

[4] Section 2.5 of the buffer zone monitoring plan (DOE 1996) states the following: "The DOE will immediately notify CDPHE if the uranium concentration of any well in the buffer zone (Dos Rios subdivision, Unit 2) exceeds 0.020 milligrams per liter (mg/L)."

2.2.2 Manganese

Shallow Monitoring Wells (Figure 14)

Except for the early (2000–2002) results for well 0006, manganese concentrations have been below the 1.6 mg/L DWEL in the shallow onsite monitoring wells. Although a significant decreasing trend was identified for well 0006 for 2000–2024 (Table 3), manganese concentrations in this well (though variable) have no significant trend since 2008. In 2024, the manganese concentration in well 0012R (1.3 mg/L) was just slightly below the DWEL. The increasing trend found for well 0125 reflects the change in manganese concentrations since 2005, from 0.0046 to 0.042 mg/L in 2024. Manganese has been consistently detected above the DWEL in shallow downgradient well 0135, with no trend and results ranging from 2.5 to 3.6 mg/L. Manganese concentrations in the remaining shallow offsite wells have been at or below the DWEL, with no significant trends (Table 3).



Notes: The order of facet plots for shallow monitoring wells is consistent with Table 1, in which wells are listed in general order of increasing distance from the former mill site (Figure 4). Former onsite location 0012 (monitored 2001–2006) was replaced with well 0012R in 2008.
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 3), the direction of the trend is indicated on the plot.

Figure 14. Manganese Concentration Trends in Shallow Monitoring Wells

Table 3. Manganese Concentration Trends in Alluvial Aquifer Monitoring Wells and Compliance Strategy Attainment Predictions

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	No. of Detects/ No. of Samples	Most Recent Result (mg/L)[b]	Kendall's Tau[c]	p-value[c]	Mann-Kendall Concentration Trend	Half-Life (years)			Year 1.6 mg/L DWEL is Reached		
								Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Shallow Wells													
0002	5/10/2000	4/10/2024	6/20	<0.0020	−0.02	0.92	None	Not applicable, concentrations less than DWEL					
0005*	5/15/2006	4/10/2024	18/18	0.45	0.07	0.73	None						
0006*	5/10/2000	4/9/2024	22/23	0.15	−0.30	0.048	Decreasing						
0012/ 0012R*	4/26/2001	4/9/2024	22/22	1.3	0.24	0.12	None						
0013	5/9/2000	4/9/2024	17/23	<0.0020	0.15	0.32	None						
0125	5/9/2000	4/8/2024	19/20	0.042	0.35	0.032	Increasing						
0135	5/18/2005	4/8/2024	18/18	***2.6***	−0.31	0.087	None	Not applicable, no trend					
0181	5/17/2000	4/9/2024	20/20	1.0	0.03	0.87	None	Not applicable, concentrations less than DWEL					
Intermediate Wells													
0102	5/10/2000	4/10/2024	6/20	<0.0020	0.08	0.63	None	Not applicable, concentration less than DWEL					
0105*	5/20/2005	4/10/2024	19/19	***2.5***	0	1	None	Not applicable, no trend					
0106*	5/10/2000	4/9/2024	24/24	***1.9***	−0.95	<0.001	Decreasing	8.2	7.5	9.0	2026	2025	2028
0112*	4/26/2001	4/10/2024	23/23	***3.8***	−0.73	<0.001	Decreasing	14.5	10.8	22.0	2038	2032	2051
0113	5/9/2000	4/9/2024	24/24	1.6	−0.19	0.20	None	Not applicable, no trend					
0126	5/9/2000	4/8/2024	21/24	0.0085	0.04	0.82	None	Not applicable, concentrations less than DWEL					
0062	5/18/2005	4/8/2024	17/19	<0.0020	−0.57	<0.001	Decreasing						
0136	5/10/2000	4/8/2024	19/20	***3.4***	0.55	<0.001	Increasing	Not applicable, increasing concentrations					
0186	5/10/2000	4/9/2024	7/20	<0.0020	0.02	0.94	None	Not applicable, concentrations less than DWEL					
0065	5/17/2005	4/9/2024	19/19	0.031	−0.31	0.068	None						
0188	5/10/2000	4/9/2024	8/24	<0.0020	0	1	None						
0066	5/17/2005	4/9/2024	19/19	0.0024	−0.43	0.012	Decreasing						
0160	5/17/2000	4/9/2024	22/24	0.086	0.34	0.022	Increasing						
Deep Wells													
0127	5/9/2000	4/8/2024	17/24	<0.0020	0.01	0.98	None	Not applicable, concentrations less than DWEL					
0063	5/19/2005	4/8/2024	16/19	<0.0020	−0.67	<0.001	Decreasing						
0187	5/17/2006	4/9/2024	18/18	0.50	−0.75	<0.001	Decreasing						

Table 3. Manganese Concentration Trends in Alluvial Aquifer Monitoring Wells and Compliance Strategy Attainment Predictions (continued)

Well[a]	Initial Trend Analysis Date	Final Trend Analysis Date	No. of Detects/ No. of Samples	Most Recent Result (mg/L)[b]	Kendall's Tau[c]	p-value[c]	Mann-Kendall Concentration Trend	Half-Life (years)			Year 1.6 mg/L DWEL is Reached		
								Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Trend Line	Lower 95% Confidence Interval	Upper 95% Confidence Interval
0064	5/19/2005	4/8/2024	19/19	0.069	0.04	0.83	None						
0183	5/17/2000	4/9/2024	16/24	<0.0020	−0.23	0.12	None						
0189	5/10/2000	4/9/2024	24/24	0.43	−0.55	<0.001	Decreasing						
0161	5/17/2000	4/9/2024	24/24	0.0053	−0.23	0.12	None						
Remaining Domestic Well Currently Sampled													
0667	4/30/2001	4/9/2024	13/24	<0.0020	0.02	0.92	None	Not applicable, concentration less than DWEL					

Notes:

[a] For each category, wells are listed in general order of increasing distance from the former mill site, consistent with the order and approach applied in Table 1; wells followed by an asterisk (*) are onsite wells. Data for former well 0012 and current colocated well 0012R were combined for the Mann-Kendall trend analysis and in Figure 14.

[b] Results shown to two significant figures (refer to the GEMS website [https://gems.lm.doe.gov] for the raw unrounded result). In this column, values in ***red bold italic*** font denote recent manganese concentrations exceeding the 1.6 mg/L DWEL.

[c] The test statistic Kendall's tau is a measure of the strength of the association between two variables, with values always falling between −1 and +1. Trend analyses were conducted at the 0.05 significance (or alpha) level using a two-sided test.

Intermediate Monitoring Wells (Figure 15)

Manganese has been consistently detected at or above the 1.6 mg/L DWEL in four intermediate monitoring wells: onsite wells 0105, 0106, and 0112 and adjacent offsite monitoring well 0113. Mann-Kendall trend analysis continues to indicate no trends for wells 0105 and 0113 and significant decreasing trends for wells 0106 and 0112. If current decreasing trends continue, wells 0106 and 0112 are expected to attain the 1.6 mg/L DWEL between 2025 and 2028 and between 2032 and 2051, respectively (Table 3).

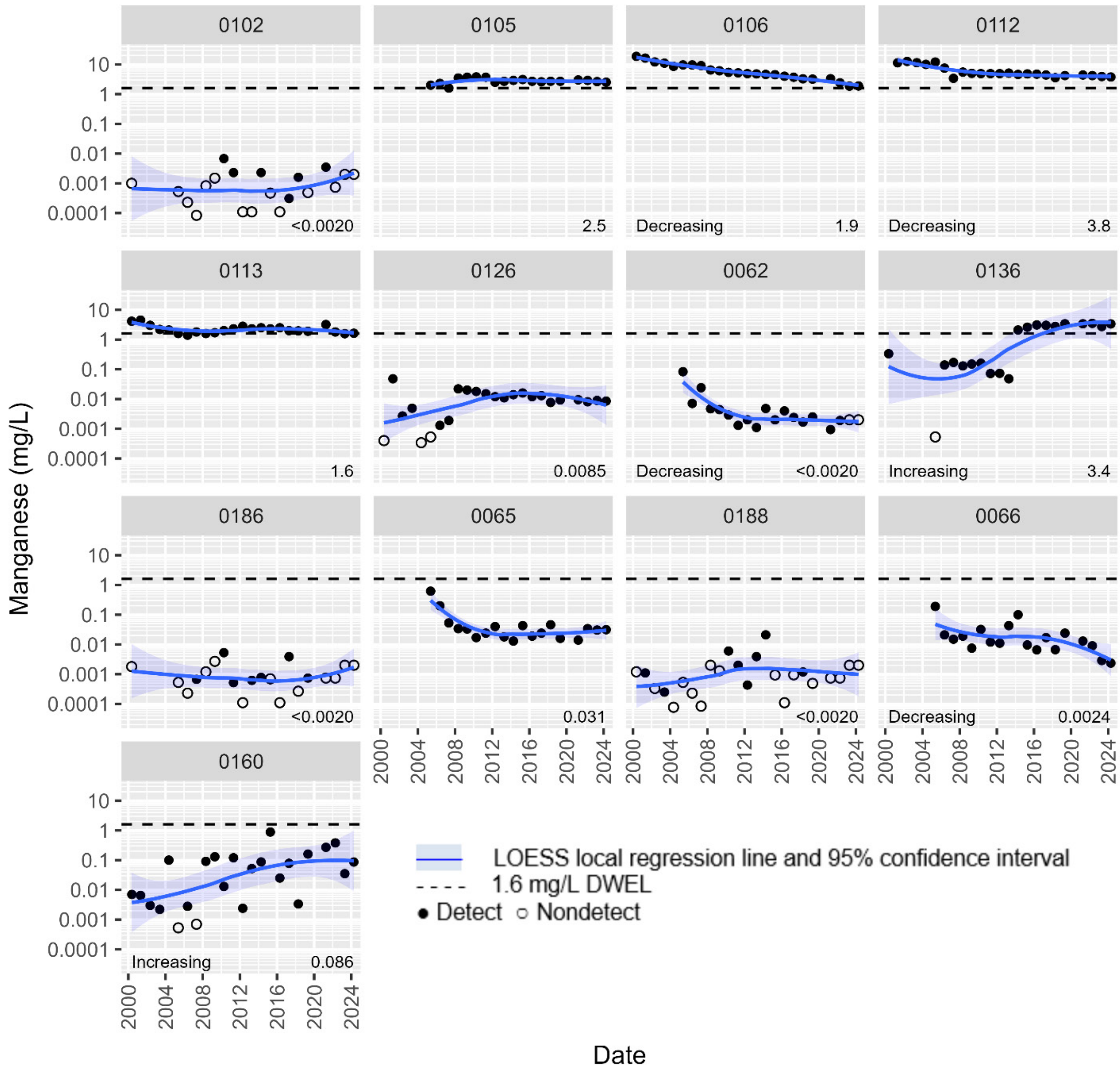
Manganese concentrations in offsite downgradient well 0136 have significantly increased (Table 3), reflecting the shift in 2013–2014, when the concentration increased from 0.048 to 2.1 mg/L. Concentrations have remained relatively stable and above the DWEL since then, ranging from 2.1 to 3.5 mg/L. Although not shown in Figure 15 (only data from 2000–2024 are plotted), manganese concentrations in well 0136 between 1989 and 1992 also exceeded the DWEL, ranging from 2.8 to 4.8 mg/L. A statistically significant increasing trend was found for well 0160, west of the Gunnison River, but results have been below the DWEL (Figure 15). Significant decreasing trends were identified for wells 0062 and 0066 (Table 3). The remaining intermediate monitoring wells were found to have no statistically significant concentration trends.

Deep Monitoring Wells (Figure 16)

None of the deep monitoring wells have manganese concentrations exceeding the 1.6 mg/L DWEL. Consistent with the previous VMR (DOE 2024), Mann-Kendall trend analysis identified statistically significant decreasing trends for three deep wells: 0063, 0187, and 0189 (Table 3). Manganese concentrations in deep well 0187 exceeded the DWEL in 2006 and 2007 but are now below the 1.6 mg/L standard (the most recent result being 0.50 mg/L).

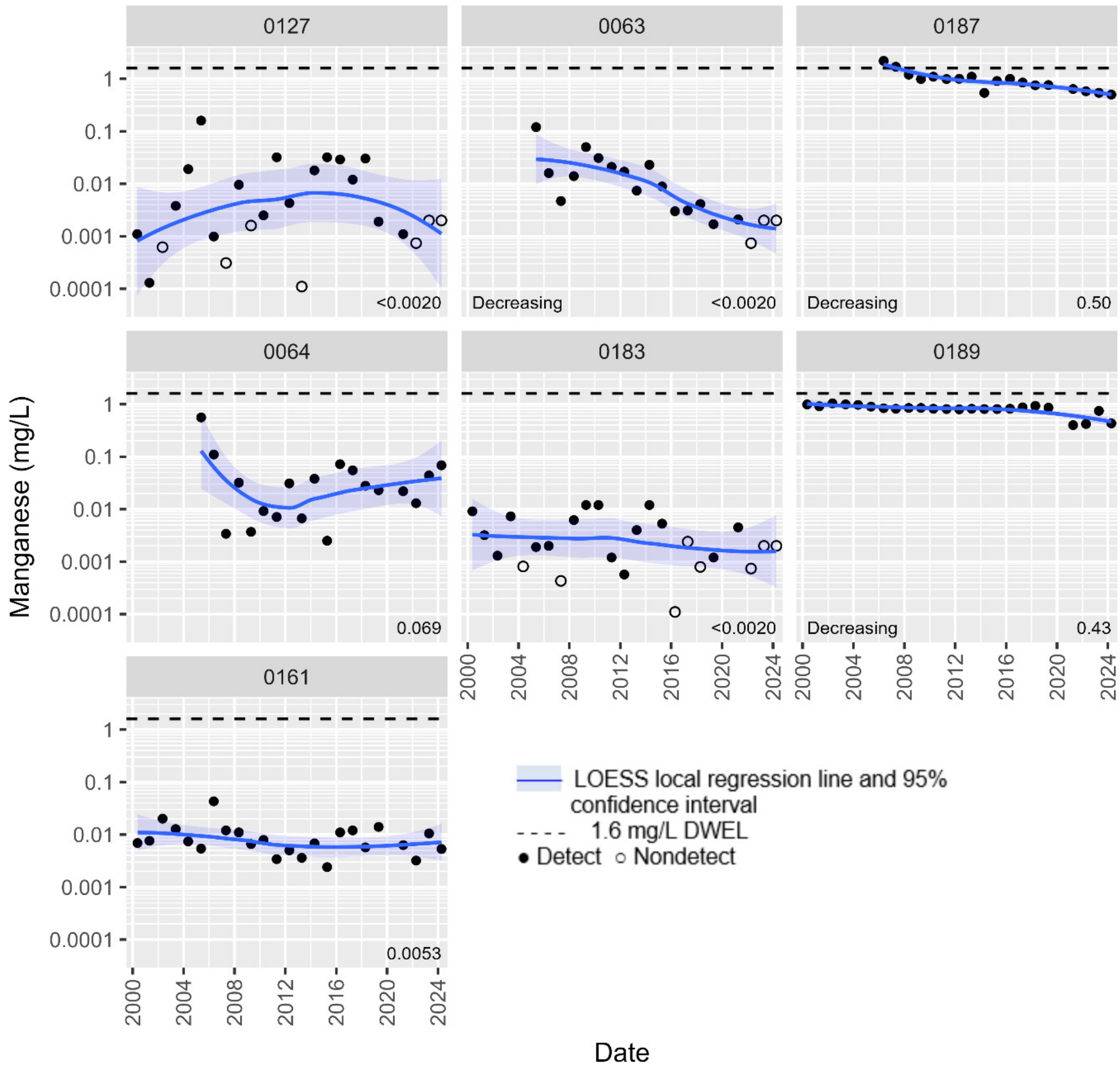
Monitoring Well Network (Data Plotted by Location and Aquifer Zone) (Figure 17)

Figure 17 is a compilation of the manganese data shown previously in Figure 14 through Figure 16. However, in this figure (as in Figure 12), the data are plotted by location, with point symbols color-coded to represent the different screen depth intervals listed in Table 1. In contrast to trends observed for uranium (Figure 12), this figure shows that, in about half of the 12 colocated well clusters, manganese concentrations are higher in the deeper intervals. The most striking examples of this are well pairs 0186/0187 and 0188/0189. In both of these well pairs, manganese concentrations in the intermediate interval are predominantly below detection limits, while those in the corresponding deep interval are one to several orders of magnitude higher.



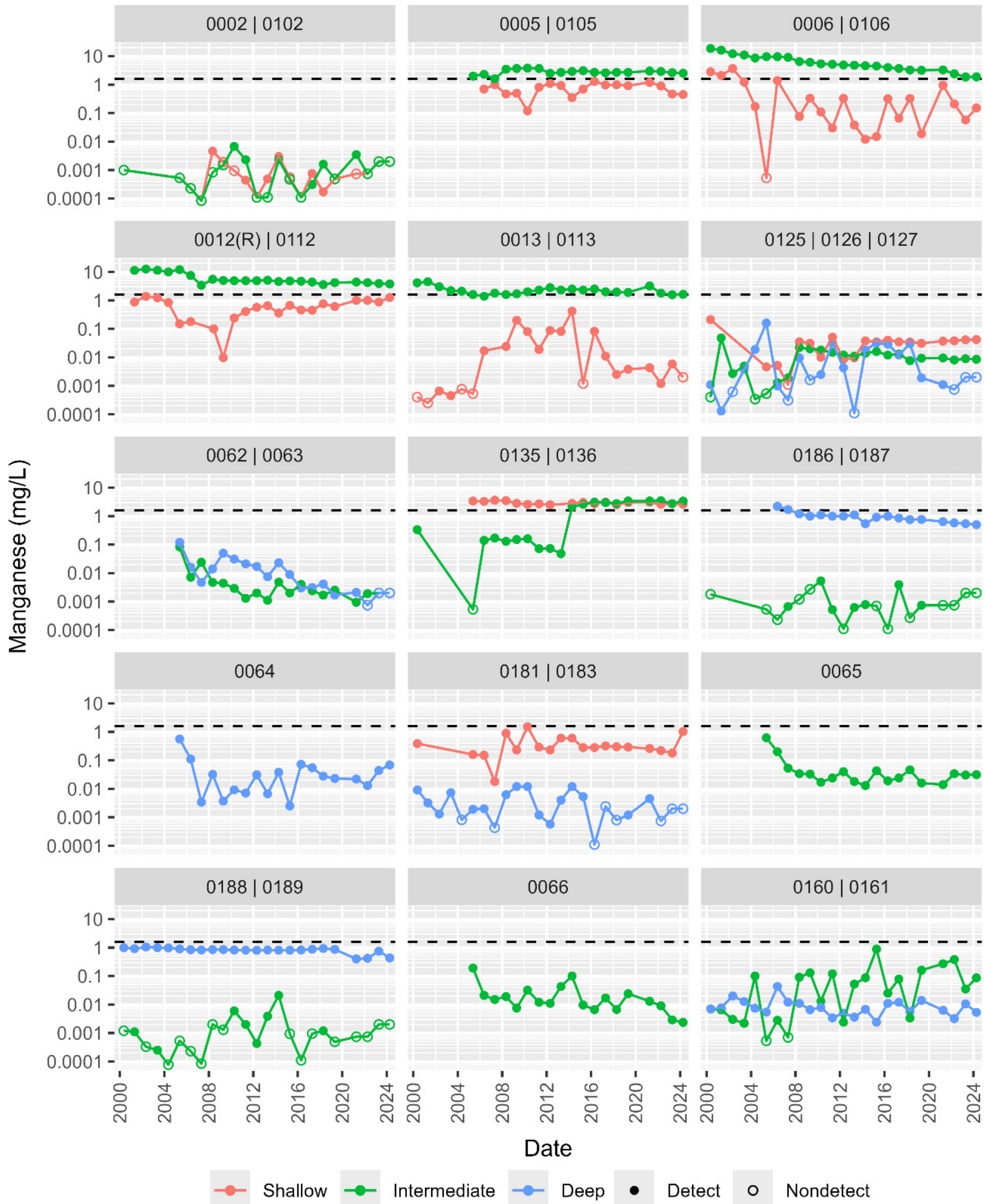
Notes: The order of facet plots for intermediate monitoring wells is consistent with Table 1, in which wells are listed in general order of increasing distance from the former mill site (Figure 4).
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 3), the direction of the trend is indicated on the plot.

Figure 15. Manganese Concentration Trends in Intermediate Monitoring Wells



Notes: The order of facet plots for deep monitoring wells is consistent with Table 1, in which wells are listed in general order of increasing distance from the former mill site (Figure 4).
Values shown in the lower right corner of individual graphs are the most recent (2024) results. For wells with statistically significant trends for the 2000–2024 time frame (Table 3), the direction of the trend is indicated on the plot.

Figure 16. Manganese Concentration Trends in Deep Monitoring Wells



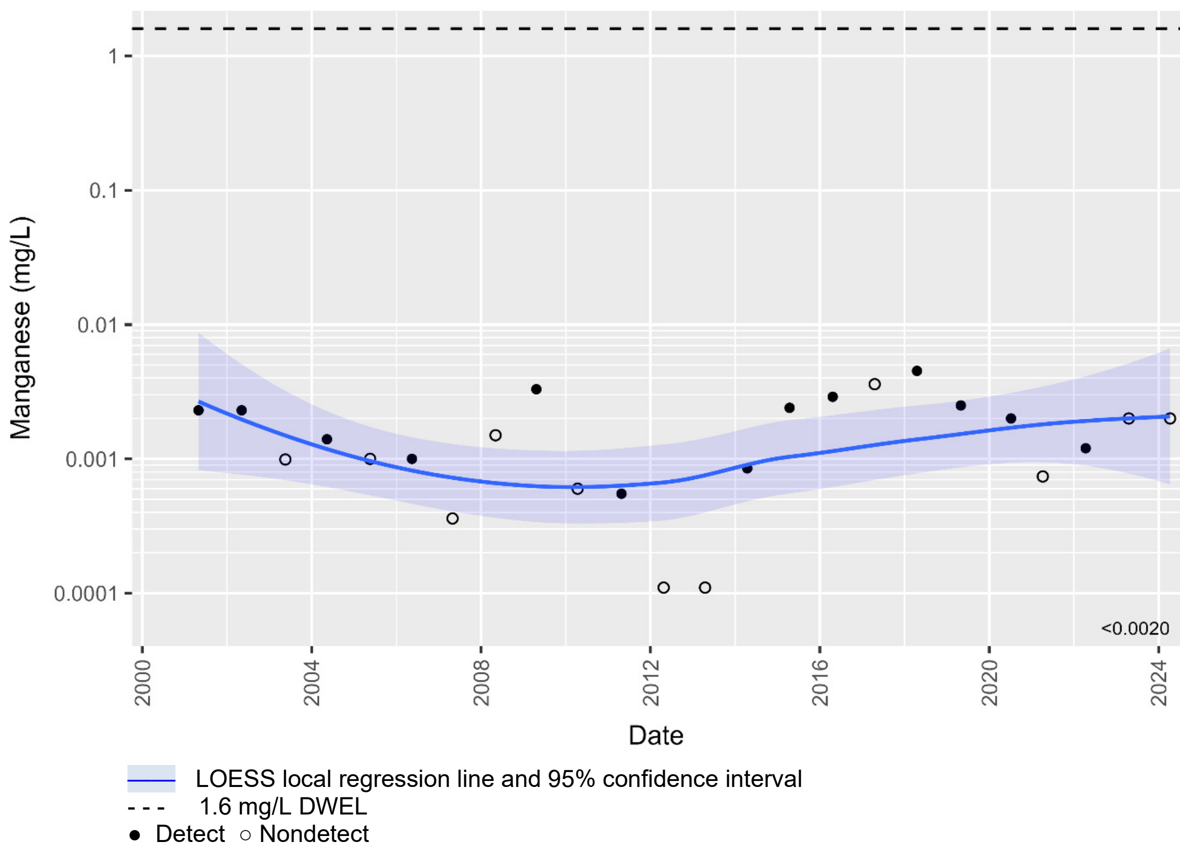
- - - 1.6 mg/L DWEL

Notes: Well pairs or clusters are arranged in general order of increasing distance from the former mill site (Figure 4). Data for locations with no corresponding colocated well (deep well 0064 and intermediate wells 0065 and 0066) are shown individually.

Figure 17. Time-Concentration Plots of Manganese in Shallow, Intermediate, and Deep Monitoring Wells

Domestic Well 0667 (Figure 18)

As described in Section 2.2.1 and in the previous VMR (DOE 2024), at the time of completion of the Dos Rios water supply system in 1994, six residences, between the golf course and the Gunnison River (Figure 4), chose not to connect to the system. One residence connected to the system in 2011, and four others (results documented in the 2022 VMR [DOE 2023]) connected to the system in August 2021. Currently, the one remaining domestic well (0667) is sampled annually. As shown in Figure 18, about half of the manganese results have been below the detection limit, including the most recent (2024) result of <0.0020 mg/L. Manganese concentrations in the remaining samples from well 0667 have been two orders of magnitude below the DWEL.



Note: The most recent (2024) result is labeled; no significant concentration trend was found (Table 3).

Figure 18. Manganese Concentration Trends in Domestic Well 0667

2.3 Alluvial Aquifer Plume Geometries and Concentrations

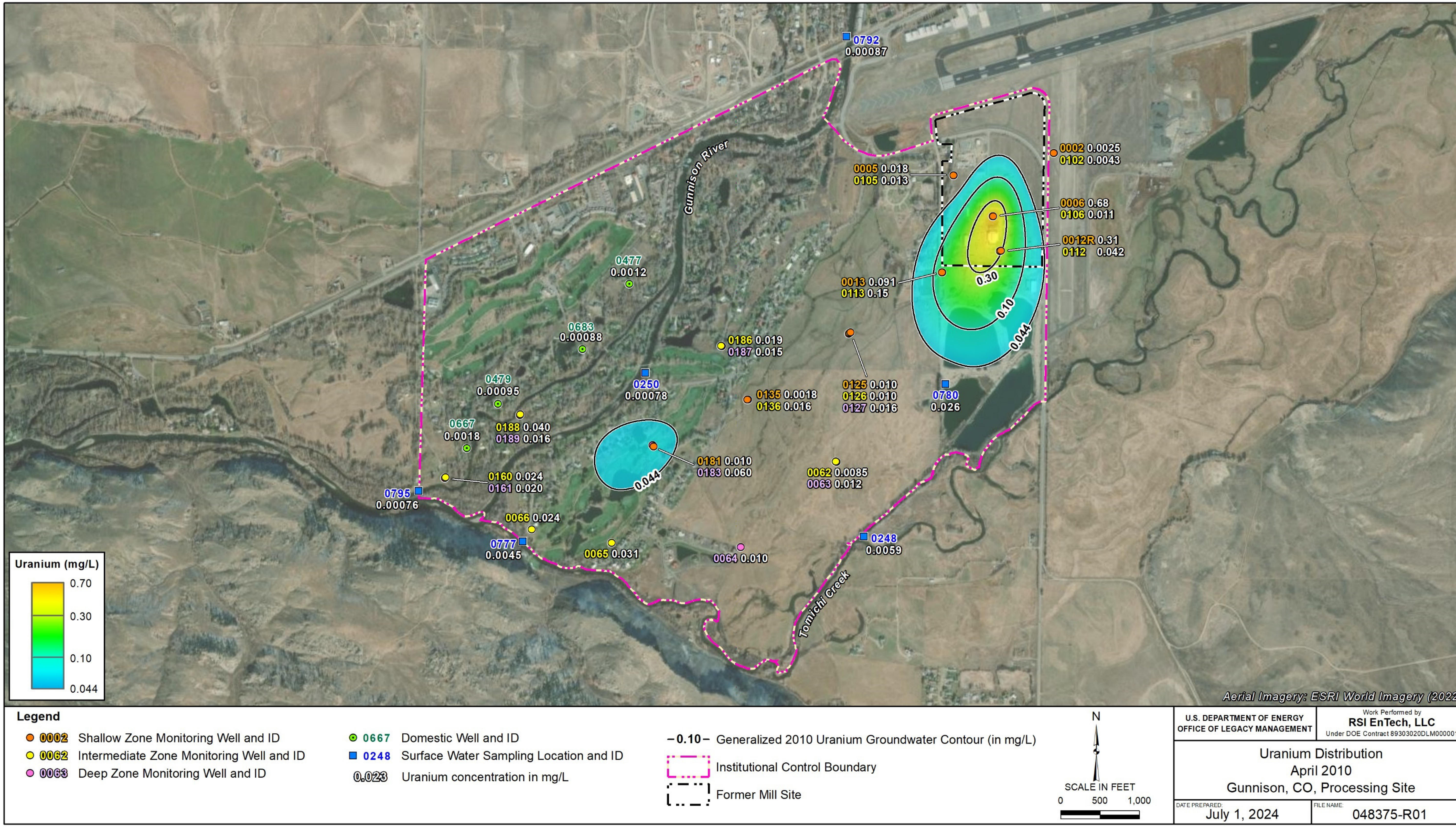
The 2010 and 2024 uranium and manganese plume geometries and concentrations were compared to evaluate aquifer restoration progress at the Gunnison site. During milling (1958–1962) and the subsequent postmilling period preceding the initiation of gravel mining (1963 to approximately 1972), ambient groundwater flow in the vicinity of the mill was to the southwest. Uranium and manganese plumes developed during this time and migrated with the ambient groundwater flow field. The beginning of gravel mining in the early 1970s changed the groundwater flow patterns in the vicinity of the mill site. Instead of flowing southwest, groundwater at the mill site flowed south towards the gravel mining operations. Groundwater outside the gravel mining influence (capture zone) continued to flow southwest. The portions of the uranium and manganese plumes outside the gravel mining capture zone continued to migrate downgradient to the southwest, and portions of the uranium and manganese plumes within the capture zone migrated south into the gravel pits.

2.3.1 Uranium

The 2010 uranium plume consisted of two parts, one extending from the former mill site to the gravel pits, and another centered around deep monitoring well 0183 (Figure 19). The 2024 uranium plume extending from the former mill site to the gravel pits remains similar in geometry and concentrations to the 2010 plume, suggesting a continuing former mill site uranium source (Figure 20). Since 2022, when uranium concentrations in well 0183 declined to levels below the 0.044 mg/L MCL (Figure 11), the downgradient portion of the uranium plume has been absent.

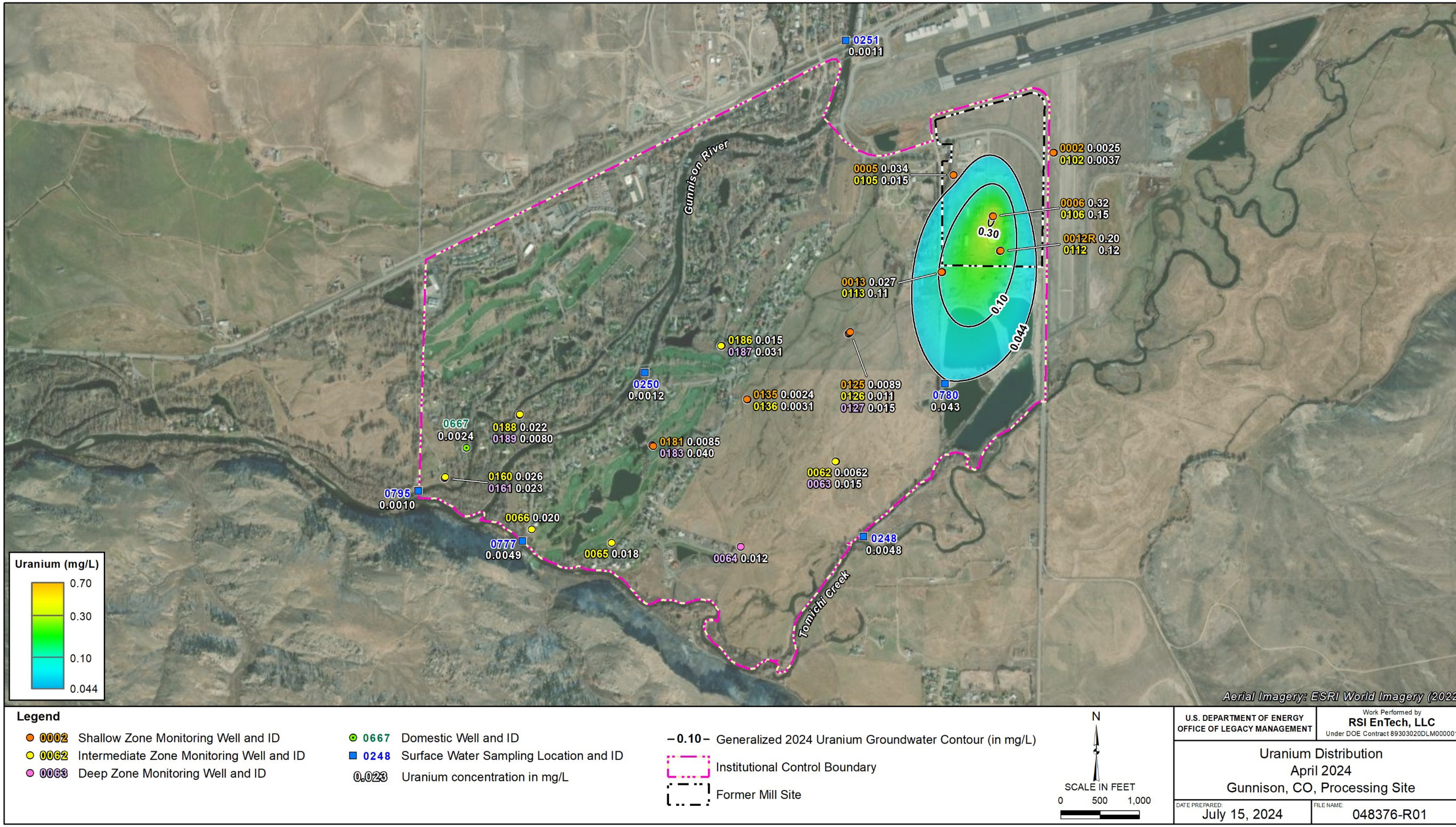
The uranium present in well 0183 likely originated from the site before gravel pit operations started in 1972. Before gravel mining, a continuous plume likely extended from the mill site southwest in the direction of groundwater flow. A current hypothesis is that gravel pit mining changed the groundwater flow direction in the vicinity of the mill site from southwesterly to south (Figure 5 through Figure 7), in turn altering the plume geometry in a similar manner. In response to the change in flow direction, the plume emanating from the former mill site changed trajectory from southwest to south towards the gravel pits.

During this time, a portion of the existing plume (downgradient of the site and outside the influence of the gravel mining operations) continued to migrate southwest. Eventually, a zone of clean water developed between the downgradient portion of the plume and the portion of the plume that discharges to the gravel pits, resulting in the isolated region of historically elevated uranium concentrations in the vicinity of well 0183. To date, uranium has not been detected above the MCL in the remaining monitoring wells southwest of the gravel mining operations area (Figure 12).



Note: At colocated monitoring well locations (i.e., well pairs or clusters), symbols are plotted in order of completion zone. In these cases, the symbol for the well in the shallowest zone obscures symbols for wells completed in deeper zones. Domestic well 0479 was sampled in April 2010; in 2011, the residence was connected to the municipal water supply. Because this well was sampled only once (in 2010), it is not listed in Table 1, nor is the location shown in Figure 4.

Figure 19. April 2010 Uranium Plume Configuration



Note: At colocated monitoring well locations (i.e., well pairs or clusters), symbols are plotted in order of completion zone. In these cases, the symbol for the well in the shallowest zone obscures symbols for wells completed in deeper zones.

Figure 20. April 2024 Uranium Plume Configuration

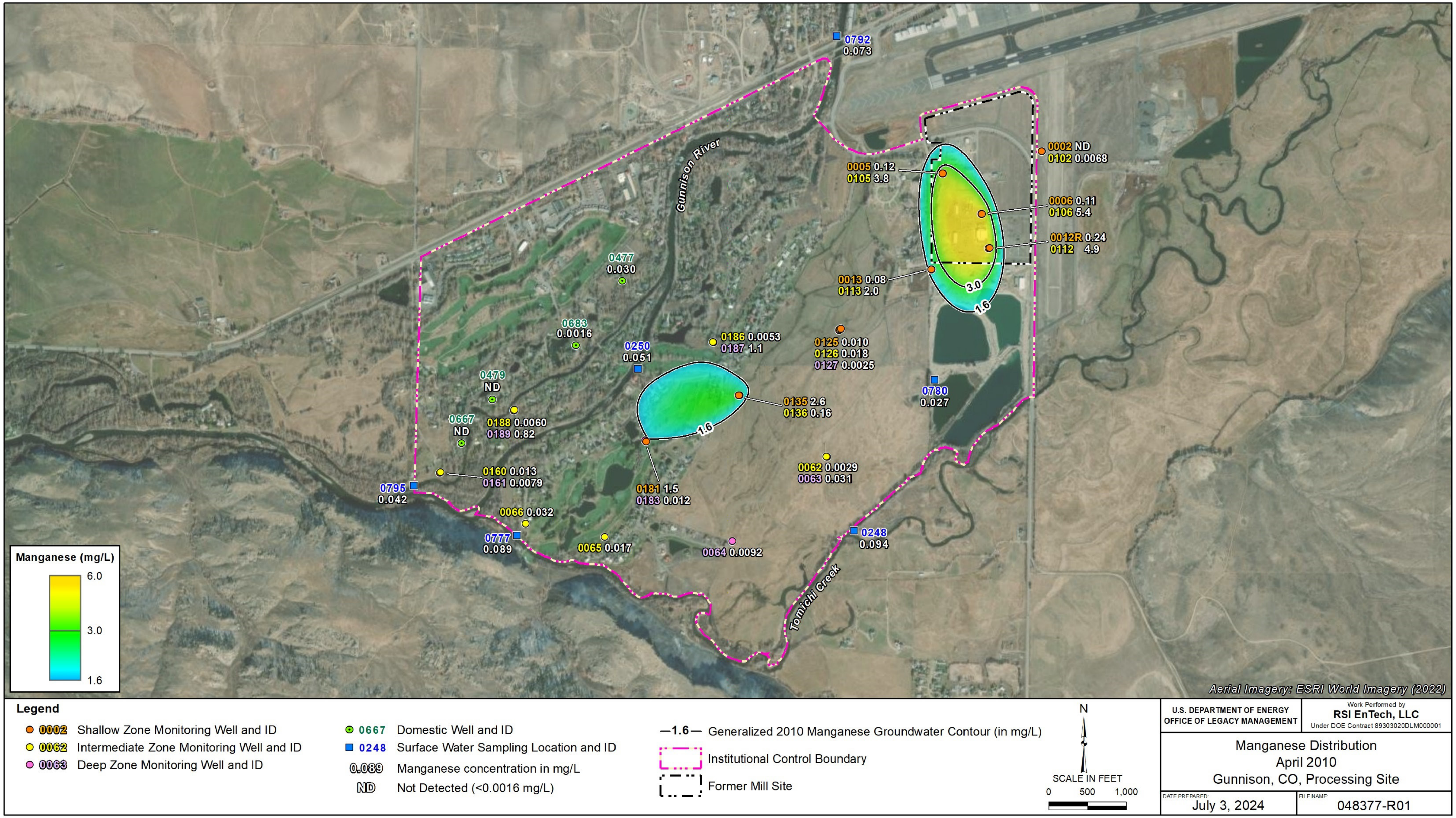
2.3.2 Manganese

The 2010 and 2024 manganese plumes consist of two parts, one extending from the former mill site to the gravel pits and the other southwest of the former mill site in the region downgradient of shallow and deep monitoring well pair 0135 and 0136 (Figure 21 and Figure 22). The 2010 and 2024 plumes near the former mill site remain similar with respect to geometry and concentration distributions, suggesting a continuing manganese source from the former mill site. The elevated manganese present in wells 0135 and 0136 likely originated from the former mill site before gravel mining operations began in the early 1970s. At that time, a continuous manganese plume likely extended from the mill site southwest in the direction of groundwater flow. A likely explanation is that adjacent mining operations changed the groundwater flow direction in the vicinity of the mill site from southwesterly to south. In response to the change in flow direction, the manganese plume emanating from the former mill site changed trajectory from southwest to south towards the gravel pits.

Similar to the evolution of groundwater flow patterns described for uranium, portions of the existing manganese plume downgradient of the site and outside the capture zone continued to migrate southwest. Over time, a zone of clean water developed between the downgradient portion of the manganese plume and the portion of the plume that discharges to the gravel pits, resulting in the isolated manganese plume present today in the vicinity of wells 0135 and 0136. To date, manganese has not been detected above the 1.6 mg/L DWEL in other monitoring wells southwest of the gravel operations area.

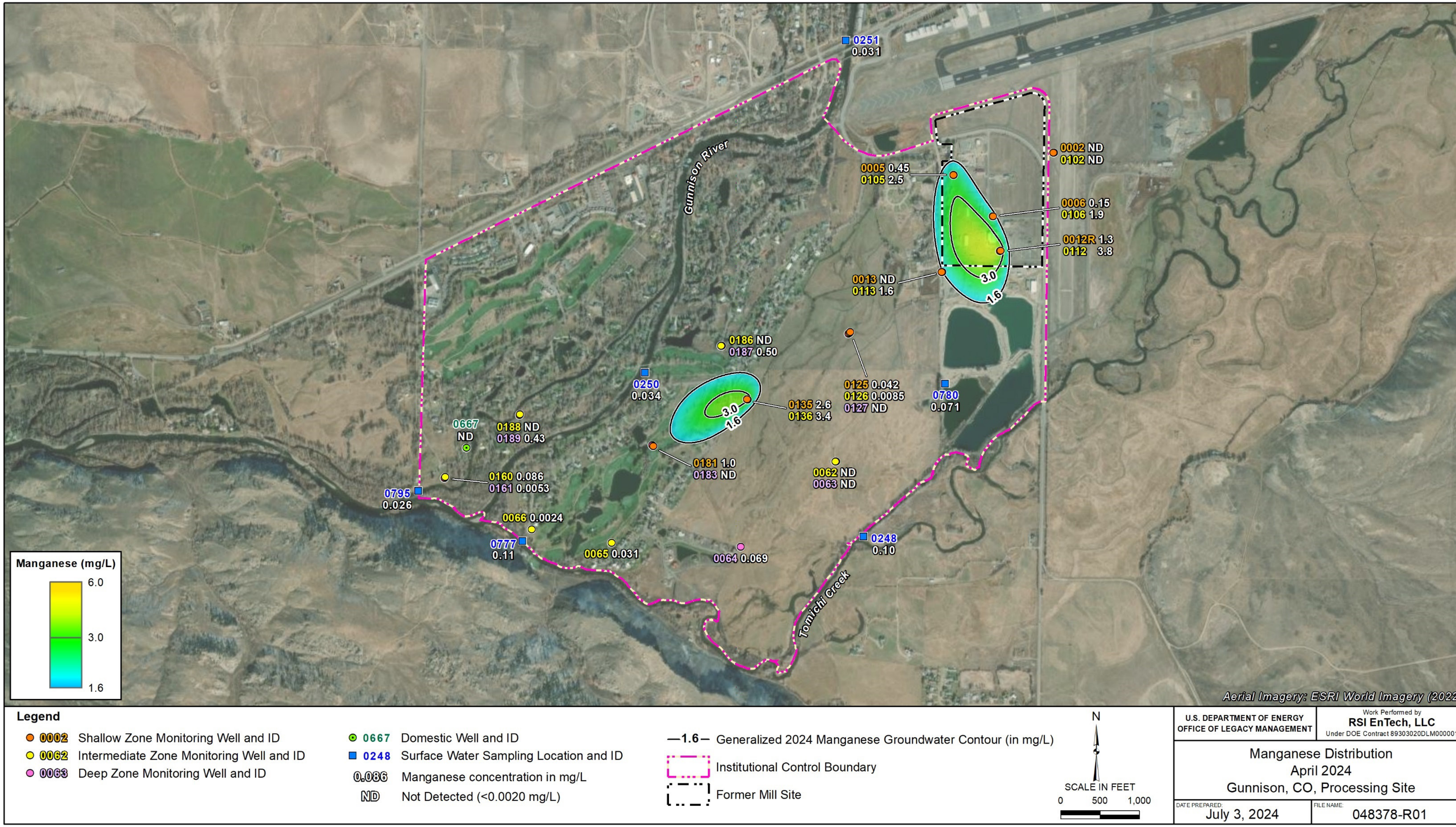
2.4 Bulk Plume Metrics

Bulk plume metrics were calculated using EVS software. The calculation was performed by three-dimensional interpolation of well concentration data using kriging for each recorded sampling event since April 2010, the date after which a consistent set of wells was sampled annually. The DOE monitoring wells shown in Figure 4 were used for the interpolation. The interpolated plume volume was bounded on the bottom by the top of the bedrock surface (assumed to be at a depth of 130 ft bgs; few wells were drilled to bedrock) and bounded on the top by the water table (interpolated from groundwater elevation measurements for each sampling event). A porosity of 0.25 was assumed for pore volume and plume mass calculations. Between the bedrock and the water table, the plume extents were defined by the MCL for uranium and the DWEL for manganese. The resulting three-dimensional representations of the uranium and manganese plumes provide estimates of the plume footprint area, volume, average contaminant concentrations, and corresponding dissolved plume mass. These bulk plume metrics, shown in Figure 23 and Figure 24 for uranium and manganese (respectively), allow an assessment of groundwater restoration progress at the Gunnison site.



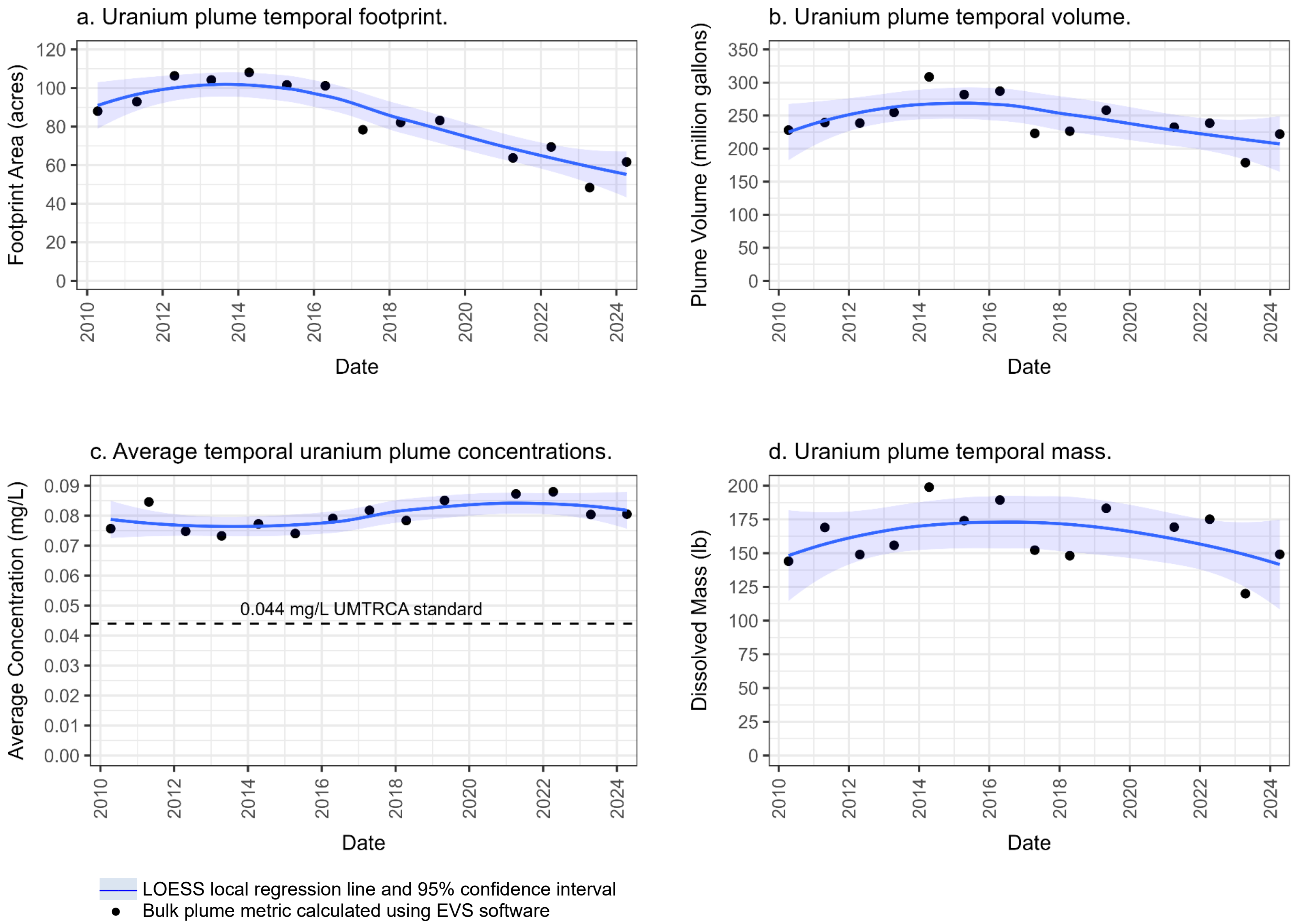
Note: At colocated monitoring well locations (i.e., well pairs or clusters), symbols are plotted in order of completion zone. In these cases, the symbol for the well in the shallowest zone obscures symbols for wells completed in deeper zones. Domestic well 0479 was sampled in April 2010; in 2011, the residence was connected to the municipal water supply. Because this well was sampled only once (in 2010), it is not listed in Table 1, nor is the location shown in Figure 4.

Figure 21. April 2010 Manganese Plume Configuration



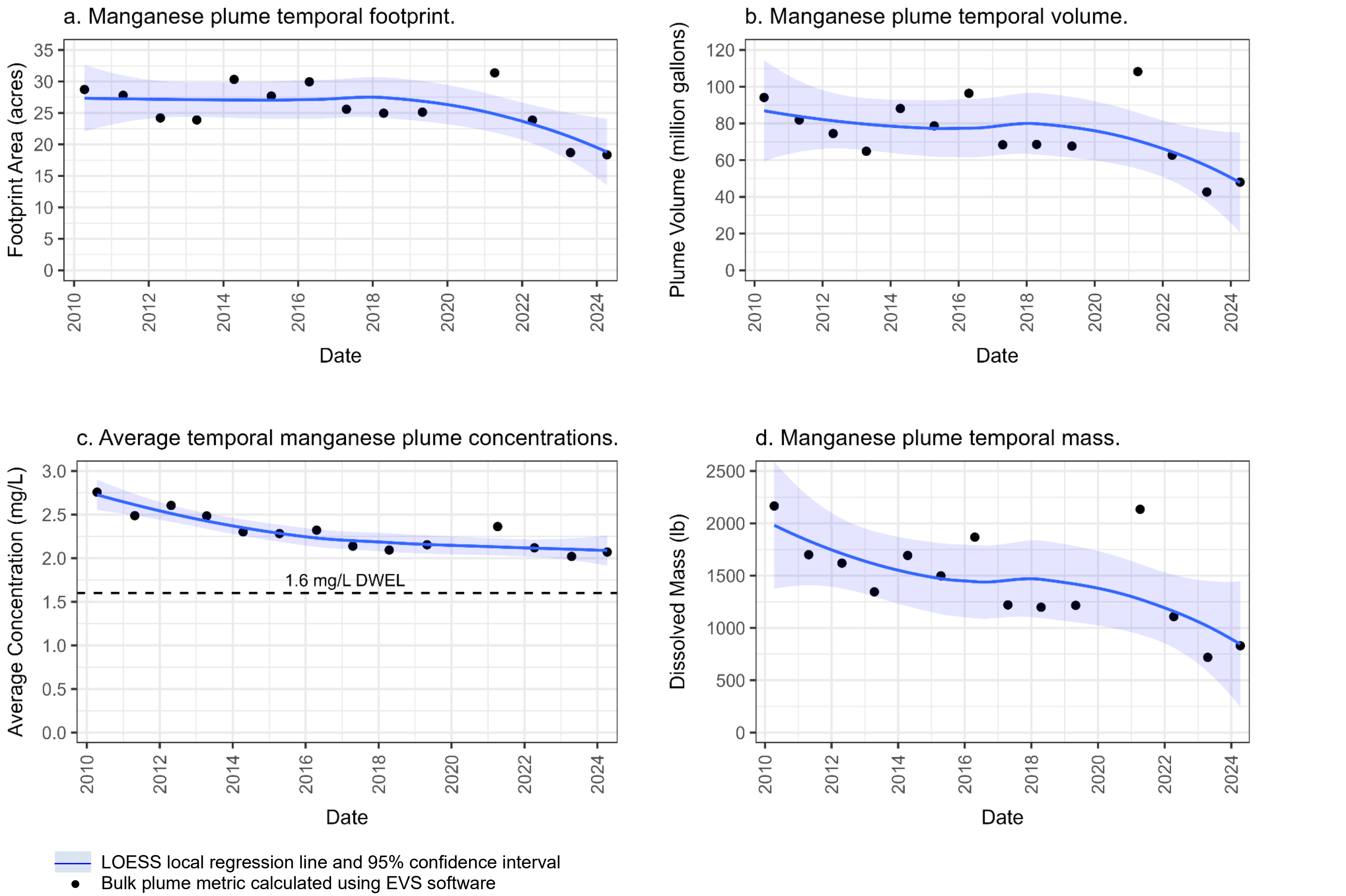
Note: At colocated monitoring well locations (i.e., well pairs or clusters), symbols are plotted in order of completion zone. In these cases, the symbol for the well in the shallowest zone obscures symbols for wells completed in deeper zones.

Figure 22. April 2024 Manganese Plume Configuration



Abbreviation: lb = pounds

Figure 23. Uranium Bulk Plume Metrics



Abbreviation: lb = pounds

Figure 24. Manganese Bulk Plume Metrics

2.4.1 Uranium

The uranium plume footprint has declined since 2010 from a maximum of 108 acres in 2014 to approximately 55 acres in 2024 (Figure 23a). The decline is attributed to declines in uranium concentrations in offsite deep monitoring well 0183 (Figure 11), which, when contoured, result in a footprint reduction. Bulk plume metrics for remaining parameters—plume volume, average concentration, and temporal mass (Figure 23, plots b through c)—have remained relatively constant. The uranium plume volume has remained relatively stable at approximately 210–220 million gallons over the evaluation period (Figure 23b). The average uranium concentration has remained constant at about 0.08 mg/L (Figure 23c). The dissolved uranium plume mass has remained relatively constant overall at approximately 140–150 pounds (lb) (Figure 23d). Given relatively consistent average uranium concentrations and corresponding plume volume and mass in the last 14 years, it is unlikely that the uranium plume will sufficiently attenuate to reach the 0.044 mg/L uranium MCL within the 100-year performance period. NRC (2024) concurred with this conclusion in the recent staff review of the 2023 VMR (DOE 2024).

2.4.2 Manganese

The manganese plume footprint has decreased slightly since 2010, from 27 to approximately 19 acres (Figure 24a). The plume volume reduced from approximately 90 to 50 million gallons over the evaluation period (Figure 24b). The average manganese concentration within the plume has declined just slightly from approximately 2.7 mg/L in 2010 to 2.1 mg/L in 2017 and has remained relatively stable since (Figure 24c). The dissolved plume mass has halved, from approximately 2000 lb in 2010 to roughly 850 lb in 2024 (Figure 24d). Given relatively consistent average manganese concentrations in the last 14 years (Figure 24c), it is unlikely that the manganese plume will sufficiently attenuate to reach the 1.6 mg/L DWEL within the 100-year performance period. As shown in Table 3, in 2024, three of the five wells with elevated manganese (2.5–3.6 mg/L) had no trend or a significant increasing trend (shallow well 0135 and intermediate zone wells 0105 and 0136).

2.5 Surface Water Concentration Trends

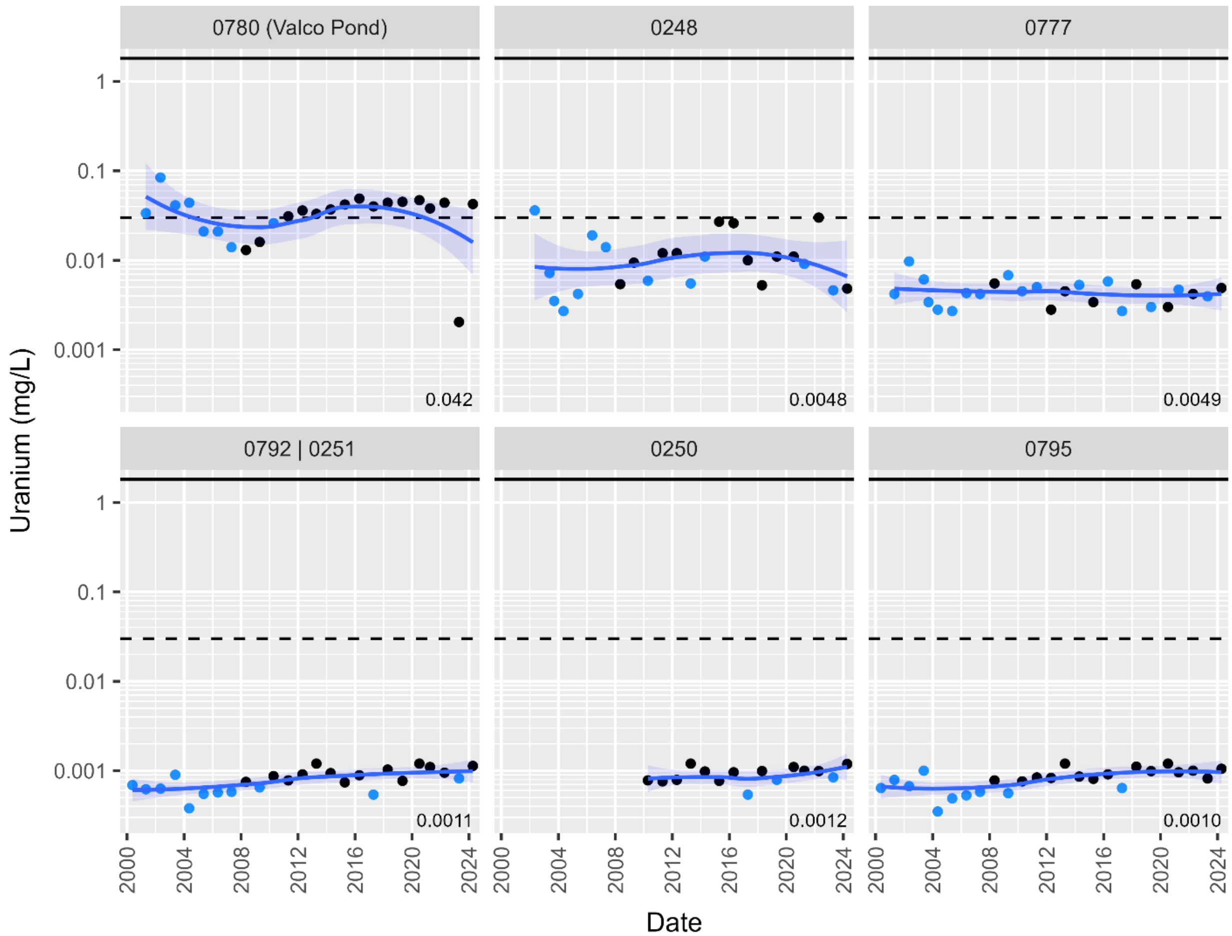
Six surface water samples are collected annually in the vicinity of the former mill site: one from the adjacent Valco Pond (Pit 1), two from Tomichi Creek, and three from the Gunnison River (Figure 4). Table 4 lists the corresponding CDPHE water quality criteria. Figure 25 and Figure 26 plot historical concentrations of uranium and manganese, respectively.

Table 4. State of Colorado Surface Water Regulations for Uranium and Manganese: Gunnison River and Tomichi Creek Watersheds

Parameter	TVS Basis[a,b,c]	TVS Aquatic Life Acute[a,b,c]	TVS Aquatic Life Chronic[a,b,c]	Agriculture (Chronic)[a]	Domestic Water Supply[a,b]
Uranium	Acute = $e^{(1.1021 \times \ln(\text{hardness}) + 2.7088)}$ Chronic = $e^{(1.1021 \times \ln(\text{hardness}) + 2.2382)}$	2.907	1.816	NA	0.0168–0.03[d] (Chronic)
Manganese	Acute = $e^{(0.3331 \times \ln(\text{hardness}) + 6.4676)}$ Chronic = $e^{(0.3331 \times \ln(\text{hardness}) + 5.8743)}$	3.159[e] (Dissolved) (Basis: Solberg et al. 2012)	1.745[e] (Dissolved) (Basis: Solberg et al. 2012)	0.2[f]	0.05[g] (Dissolved chronic)

Notes:
Values are in mg/L.
[a] 5 CCR 1002-31; refer to Table III, "Metal Parameters."
[b] 5 CCR 1002-35.
[c] For both uranium and manganese, CDPHE water quality standards apply only to the dissolved fraction and are dependent on (and directly related to) hardness (as $CaCO_3$), a parameter that has not been measured in site surface water samples. Hardness can be estimated using concentration values for calcium and magnesium, but these analytes have also not been analyzed in Gunnison site surface water samples. In 2012, USGS issued a report addressing water quality in the upper Gunnison Basin (Solberg et al. 2012). The authors reported median calcium and magnesium concentrations of 33.8 and 8.51 mg/L, respectively (see Table 19 of Solberg et al. 2012), corresponding to a hardness value of approximately 119 mg/L (as $CaCO_3$). According to CDPHE, hardness values to be used in equations shall be no greater than 400 mg/L. For consistency with Table IV of 5 CCR 1002-31, acute and chronic TVSs for uranium and manganese are rounded to four significant figures.
[d] The uranium standard is a range. The first number in the range (0.0168 mg/L) is a strictly health-based value, based on the CDPHE Water Quality Control Commission's established methodology for human-health-based standards. The second number in the range (0.03 mg/L) is the MCL defined in 5 CCR 1002-31. These standards apply to the total recoverable fraction.
[e] Acute and chronic TVSs for manganese were calculated using the TVS basis equations listed above and the 119 mg/L hardness values referred to in note c. These values correspond very closely with the acute and chronic standards for manganese cited by USGS in Solberg et al. 2012: 3.159 and 1.745 mg/L (see Table 19 of Solberg et al. 2012). For this reason, the standards cited in Solberg et al. 2012 (3.159 mg/L [acute] and 1.745 mg/L [chronic]) are considered representative of appropriate TVSs for manganese.
[f] This standard applies to the total recoverable fraction. The agricultural standard cited for manganese is only appropriate where irrigation water is applied to soils with pH values lower than 6.0 (5 CCR 1002-31, Table III).
[g] Section 35.6 of 5 CCR 1002-35 states the following: "For all surface waters with a 'water supply' classification that are not in actual use as a water supply, no water supply standards are applied for iron, manganese, or sulfate, unless the Commission determines as the result of a site-specific rulemaking hearing that such standards are appropriate" (5 CCR 1002-35).

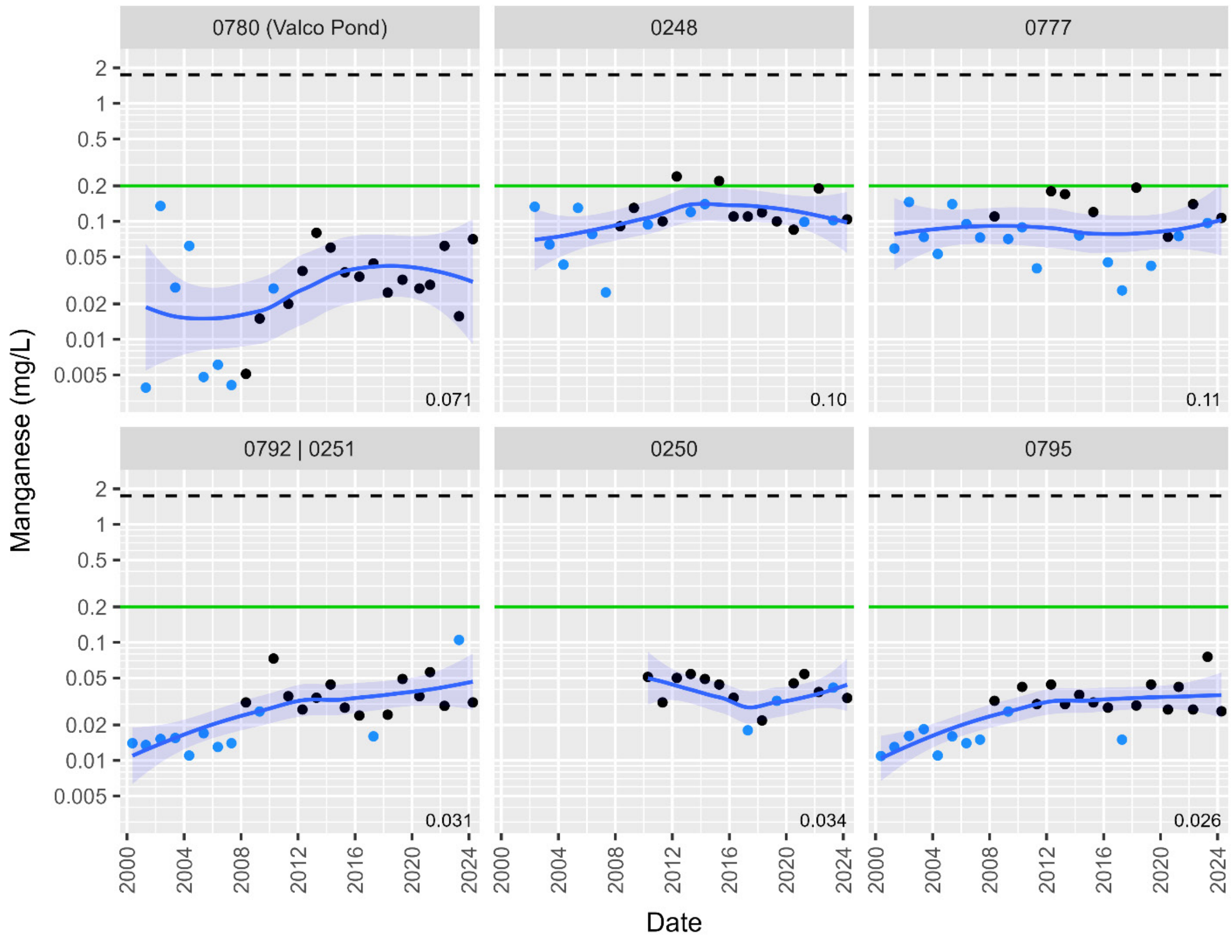
Abbreviations:
$CaCO_3$ = calcium carbonate
CCR = *Code of Colorado Regulations*
ln = natural logarithm
NA = not applicable or available
TVS = table value standard
USGS = U.S. Geological Survey



Fraction: ● Total ● Dissolved
LOESS local regression line and 95% confidence interval
- - - 0.03 mg/L CDPHE domestic use surface water standard (upper bound of range from Table 4)
— 1.816 mg/L chronic table value standard from Table 4 (acute criterion is 2.907 mg/L); applies only to dissolved (●) fraction

Notes: The plots are ordered as follows: the Valco Pond and Tomichi Creek locations, followed by the Gunnison River monitoring locations. Monitoring of current upgradient location 0251 began in April 2014 after sampling at location 0792 was discontinued due to access safety reasons. Data from previous background river location 0792 (monitored 1997–2013) are also plotted with location 0251.
The 2023 Valco Pond result (0.0020 mg/L) was not attributed to laboratory error but is considered an outlier. Values shown in the lower right corner of individual graphs are the most recent (2024) results.

Figure 25. Uranium Concentration Trends in Surface Water Samples



Fraction: ● Total ● Dissolved

LOESS local regression line and 95% confidence interval

- - - 1.745 mg/L chronic table value standard from Table 4 (acute criterion is 3.159 mg/L); applies only to dissolved (●) fraction

—— 0.2 mg/L CDPHE agricultural standard

Notes: The plots are ordered as follows: the Valco Pond and Tomichi Creek locations, followed by the Gunnison River monitoring locations. Monitoring of current upgradient location 0251 began in April 2014 after sampling at location 0792 was discontinued due to access safety reasons. Data from previous background river location 0792 (monitored 1997–2013) are also plotted with location 0251.
Values shown in the lower right corner of individual graphs are the most recent (2024) results.

Figure 26. Manganese Concentration Trends in Surface Water Samples

2.5.1 Uranium

The upper bound of the Gunnison Basin surface water quality standard for uranium, assuming domestic use, is 0.03 mg/L, according to Title 5 *Code of Colorado Regulations* Section 1002-31 (5 CCR 1002-31) and 5 CCR 1002-35. Before 2003, surface water sampling location 0780 (Valco Pond) had measured uranium concentrations above this standard in seven of 11 sampling events.[5] Between 2005 and approximately 2016, uranium concentrations measured at Valco Pond trended upward but then (with one exception) stabilized at about 0.03–0.04 mg/L through 2024. Since 2011, these concentrations slightly exceeded the CDPHE domestic use surface water standard but were well below corresponding acute and chronic CDPHE table value standards for aquatic life (Figure 25; Table 4). The single exception—the 0.0020 mg/L result reported for 2023—deviates markedly from the remaining results.[6]

Uranium concentrations in Valco Pond samples are elevated relative to the other surface water sampling locations because uranium-contaminated groundwater originating from the former mill site continuously discharges to the adjacent gravel pits. Uranium present in Valco Pond discharges to Tomichi Creek and is increasingly diluted as a function of downstream migration distance from the pond (Figure 25). Surface water sampling locations 0248 and 0777 are approximately 1500 and 6000 ft downstream of the pond discharge location, respectively, and show reduced uranium concentration with distance from the pond (Figure 25). In 2024, uranium concentrations measured at these locations were 0.0048 and 0.0049 mg/L, respectively, well below the 0.03 mg/L surface water quality standard.

Uranium concentrations at the three Gunnison River sampling locations have been consistently below 0.03 mg/L (Figure 25). At all six surface water sampling locations, uranium concentrations have been well below the CDPHE acute and chronic aquatic life standards of 2.907 and 1.816 mg/L, respectively.

2.5.2 Manganese

With two exceptions, manganese concentrations in Gunnison site surface water samples have been consistently below the corresponding 0.2 mg/L CDPHE agricultural standard (Figure 26). The two exceptions apply to Tomichi Creek location 0248: the first in 2012 (0.24 mg/L) and the second in 2015 (0.22 mg/L). Both of these results are less than the acute (3.159 mg/L) and chronic (1.745 mg/L) Gunnison Basin table value standards for aquatic life (Table 4; Figure 26). Relative to the baseline (2000) time frame, manganese concentrations have increased at both the upstream and downstream Gunnison River locations (0792/0251 and 0795, respectively) (Figure 26). These increases might reflect the shift in analytical technique from dissolved (filtered) measurements in early years to largely total (unfiltered) measurements circa 2008.

[5] Only two of the 11 results collected before 2003 are shown in Figure 25 because the time-concentration plots in this report are scaled consistently with the development of the Site Observational Work Plan (DOE 2001) and the site compliance strategy (beginning in 2000). Valco Pond was sampled nine times between 1990 and 1995, when uranium concentrations ranged from 0.011–0.075 mg/L and averaged 0.04 mg/L. The pond was not sampled again until 2001. The uranium concentration results for 2000 and 2001 (0.034 and 0.084 mg/L) are shown in Figure 25.

[6] Although data validation eliminated laboratory error from consideration as a possible explanation for this result, it is considered an outlier with respect to previous measurements (DOE 2024).

3.0 Compliance Remedy Performance Summary

Implemented in 2010, the current compliance strategy for the Gunnison site is natural flushing with ICs, whereby the site was anticipated to naturally flush to a condition in which groundwater cleanup objectives would be met within a 100-year time frame. Natural flushing relies on natural physical and chemical processes in soil and groundwater to reduce uranium and manganese mass in the subsurface. The natural attenuation mechanisms available to reduce subsurface uranium and manganese concentrations are discharge to Tomichi Creek and the Gunnison River, dispersion along the plume flow path, strong to irreversible adsorption, and mineral precipitation due to changing geochemical conditions.

This evaluation examined uranium and manganese groundwater concentrations and corresponding bulk plume metrics to characterize attenuation progress (aquifer restoration) and determine whether there are physical and chemical processes that may impede the compliance remedy's efficiency. Lastly, relevant findings from this evaluation period were presented, and implications for aquifer restoration progress were discussed.

Most of the contaminated groundwater deriving from the former mill site discharges to the adjacent gravel pits, whether pit dewatering is occurring or not. After discharging to the gravel pits, site groundwater migrates southward through the gravel-pit ponds and surrounding aquifer material to Tomichi Creek. The flow path of site groundwater to the creek could change with time in response to changing mining operations.

Consistent with conclusions drawn in the previous (2023) VMR (DOE 2024), comparison of the 2010 and 2024 uranium and manganese plumes (Figure 19 through Figure 22) shows that the higher concentrations of uranium and manganese extend from the former mill site to the gravel pits, confirming continuing migration of contamination from the site to the gravel pits. The temporally consistent uranium and manganese plume geometries and concentrations in the vicinity of the site and gravel pits suggest active former mill site uranium and manganese sources. The results herein continue to document the relative stability of (in particular) the uranium plume volume and mass within the alluvial aquifer over the past decade, with persistently elevated concentrations in the source area monitoring wells. Given these findings, attainment of the 0.044 mg/L uranium MCL within the 100-year performance period for natural flushing is not likely.

In 2024, concentrations of uranium (with the exception of Valco Pond) and manganese in surface water samples collected in the vicinity of the former mill site were below corresponding CDPHE water quality standards. Uranium concentrations in Valco Pond (0.042 mg/L in 2024), the closest surface water monitoring location to the site typically having the highest uranium concentrations, continue to slightly exceed the 0.03 mg/L surface water quality standard for domestic use, consistent with most historical observations.

In response to previous NRC comments (e.g., NRC 2019), LM is currently conducting additional site analyses and evaluations to support an updated CSM and a revised GCAP.

4.0 References

Note: Many of the DOE reports cited here are available on the LM website at: https://lmpublicsearch.lm.doe.gov/SitePages/default.aspx?sitename=Gunnison_Processing.

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