Department of Energy
Washington, DC 20585

September 21, 2017

WM-00062

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Deputy Director
Mail Stop T8-F5
Washington, DC 20555-0001

Subject: Draft Groundwater Compliance Action Plan for the Old Rifle, Colorado, Processing Site (RFO/S07857)

To Whom It May Concern:

Enclosed for U.S. Nuclear Regulatory Commission review and concurrence is the draft *Groundwater Compliance Action Plan (GCAP) for the Old Rifle, Colorado, Processing Site*. The current compliance strategy for the alluvial aquifer is a combination of natural flushing for uranium and no remediation with alternate concentration limits (ACLs) for vanadium and selenium. A revised strategy of no remediation with application of ACLs for all three contaminants of concern is proposed. Institutional controls (ICs) enacted by U.S. Department of Energy Office of Legacy Management (DOE-LM), the Colorado Department of Public Health and Environment, the City of Rifle, and Garfield County will be carried forward as an integral component of the revised compliance strategy. The GCAP also provides DOE-LM's plan for compliance monitoring at 8 groundwater, 3 surface water, and 2 seep/surface sampling points.

Please call me at (970) 248-6073 if you have any questions. Please address any correspondence to:

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Sincerely,

Richard P. Bush
Site Manager

Enclosure

NMSS20

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LMS/RFO/S07857

Draft Groundwater Compliance Action Plan for the Old Rifle, Colorado, Processing Site

July 2017

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

ACLs	alternate concentration limits
CDPHE	Colorado Department of Public Health and Environment
CFR	*Code of Federal Regulations*
COCs	contaminants of concern
DOE	U.S. Department of Energy
EC	environmental covenant
EPA	U.S. Environmental Protection Agency
ft	foot/feet
GCAP	Groundwater Compliance Action Plan
ICs	institutional controls
IFRC	Integrated Field Research Challenge
K_d	distribution coefficient
LM	(DOE) Office of Legacy Management
MCLs	maximum concentration limits
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL/g	milliliters per gram
NRC	U.S. Nuclear Regulatory Commission
NRZ	naturally reduced zone
pCi/g	picocuries per gram
POC	point of compliance
Ra-226	radium-226
RBC	risk-based concentration
SC	(DOE) Office of Science
SFA 2.0	Sustainable Systems Science Focus Area 2.0
SOPs	standard operating procedures
SOWP	*Final Site Observational Work Plan for the UMTRA Project Old Rifle Site*
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
UPL	upper prediction limit
USL	upper simultaneous limit

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Executive Summary

This document presents a revised draft groundwater compliance strategy for the Old Rifle, Colorado, Processing site. The Old Rifle site is a former vanadium and uranium ore-processing mill located approximately 0.3 mile east of the city of Rifle in Garfield County, Colorado, on a floodplain of the Colorado River. Mill tailings at the site were cleaned up as required by the Uranium Mill Tailings Radiation Control Act (UMTRCA). However, legacy contamination from the milling resides in sediments and groundwater within a shallow alluvial aquifer that overlies a platform of sedimentary bedrock. The aquifer extends northward to U.S. Highway 6, where resistant sedimentary rock and cohesive older alluvium form a steep cliff face on the highway's north side. The river borders the site on the south, and the alluvial aquifer discharges groundwater to the river along most of the site extent.

In 2001, the U.S. Department of Energy (DOE) received concurrence from the U.S. Nuclear Regulatory Commission on the *Ground Water Compliance Action Plan for the Old Rifle, Colorado, UMTRA Project Site* (GCAP). The compliance strategy presented for the alluvial aquifer was a combination of natural flushing for uranium, the primary contaminant in terms of plume extent, and no remediation with the application of alternate concentration limits (ACLs) for vanadium and selenium, the other two site contaminants of concern (COCs). Flow and transport modeling of contaminants in groundwater, conducted in support of the GCAP, projected that uranium concentrations would decrease within 10 years to the maximum concentration limit (MCL) for uranium of 0.044 milligram per liter (mg/L). However, monitoring of the aquifer in following years indicated that concentrations were not decreasing as predicted. DOE undertook an effort to characterize the alluvial aquifer in 2010 and reviewed findings from research sponsored by the DOE Office of Science (SC) under the Rifle Integrated Field Research Challenge (IFRC). Subsequent updating of the site conceptual model along with multiple investigations of the biogeochemical processes in the site's subsurface led to recognition that compliance with the uranium MCL within 100 years (the time frame permitted under UMTRCA regulations) of initiating the natural flushing strategy was unlikely. This guided the decision to propose a revised compliance strategy.

This GCAP describes the justification for a compliance strategy, based on current monitoring data, findings from IFRC work up to 2011, and results of SC site-specific research from 2011 to present. The additional research has been conducted under continued IFRC projects, and a new program called Sustainable Systems Science Focus Area 2.0, or SFA 2.0. SFA 2.0 led to identification of geochemical processes that strongly inhibit the mobility of subsurface uranium, and thus prevent concentrations from decreasing as expected in the 2001 GCAP. SC-sponsored research in the past three years provides evidence presented in this report for why uranium at the site remains at concentrations that have stabilized and remain above the MCL standard. The SFA 2.0 investigations, in tandem with progress made over the past decade in characterizing contaminant diffusion from low-permeability alluvium, identify why the alluvial aquifer will likely prevent uranium concentrations from meeting the standard for hundreds of years.

The combination of past site characterization efforts by DOE, continued monitoring of site groundwater, SC-sponsored research, and improved characterization of transport in alluvium provides a more complete understanding of local groundwater flow, water chemistry, the legacy impacts to groundwater from mill-related contaminants, and intrinsic biogeochemical processes. Whereas earlier modeling of uranium transport was based on assumed uniform hydraulic properties and steady-state flow for the aquifer, it is now recognized that heterogeneity of the alluvium and transient flow conditions profoundly affect the rate at which legacy uranium is mobilized and flushed to the Colorado River.

Spring snowmelt runoff increases the site groundwater levels several feet (as flow and level in the Colorado River increase), which in turn promotes chemical reactions that convert solid-phase uranium in organic-rich deposits into a dissolved form. Additional phenomena contributing to persistently elevated concentrations in groundwater include slow diffusion of uranium from silt and clay sediments, slow diffusion of desorbed uranium from cracks and dead-end pores in sediment grains, seasonal mobilization of mill-related constituents in the vadose zone, natural inflow of uranium in recharge zones north of the site, and both steady and episodic release of contaminants leached from mill tailings (supplemental standards areas) present beneath a highway embankment north of the site. The SFA 2.0 work has concluded that seasonal and chemically induced release of uranium residing in naturally reduced zones can cause elevated uranium concentrations in groundwater that may persist for up to 1000 years. Collectively, the flow and transport processes in the alluvial aquifer suggest that neither natural attenuation nor active remediation will reduce uranium concentrations in groundwater to background levels or the uranium MCL within the 100-year timeframe prescribed in UMTRCA regulations.

The only point of exposure to site-related contamination is the Colorado River. Constituent concentrations in samples of river water collected adjacent to and downstream of the former mill site are indistinguishable from those in background samples collected upstream of the site. Geologic barriers prevent the spread of contamination in any direction except toward the river.

Protection of human health and the environment is achieved through a combination of favorable geological conditions and institutional controls (ICs). Three rigorous ICs (a zone overlay, a quitclaim deed, and an environmental covenant) are in place at the Old Rifle site and each addresses the entire area of contamination. These overlapping measures restrict a number of activities at the site and limit access to the subsurface and groundwater without written permission from the Colorado Department of Public Health and Environment (CDPHE) and DOE. The ICs are expected to remain implemented, monitored, and enforced in perpetuity. Residual groundwater contamination poses no unacceptable risk as long as use restrictions are maintained.

COC values are as low as reasonably achievable considering reasonable cleanup alternatives. The recommended compliance strategy is no remediation and the application of ACLs for the three COCs: uranium, vanadium, and selenium. ACLs proposed in this GCAP revision are based on observed rather than model-predicted values and therefore differ somewhat from previously approved ACLs. Proposed ACLs for uranium, vanadium, and selenium are 0.36 mg/L, 1.0 mg/L, and 0.122 mg/ respectively.

ICs and continued monitoring are required components of this compliance strategy. DOE proposes to monitor the three COCs annually for 5 years following regulatory concurrence on this GCAP. After 5 years, DOE proposes to reevaluate the monitoring requirements. Assuming observed trends exhibit stable behavior, DOE may propose to reduce the frequency of monitoring to once every 5 years for the next 30 years, followed by further reevaluation of the monitoring strategy after 30 years at the reduced frequency.

1.0 Introduction

This revised draft Groundwater Compliance Action Plan (GCAP) serves as a stand-alone modification to Section E.3.6 of the *Final Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Sites at Rifle, Colorado* (DOE 1992) and is the concurrence document for compliance with Subpart B of Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192) for the former Old Rifle, Colorado, Site. The revised plan has been developed in accordance with compliance guidelines for sites administered under the Uranium Mill Tailings Radiation Control Act (UMTRCA).

The Old Rifle site is one of two former uranium-ore processing sites at Rifle, Colorado, assigned to the U.S. Department of Energy (DOE) Office of Legacy Management (LM). Previously, a GCAP was submitted for regulatory review with natural flushing as the compliance strategy for uranium. Alternate concentration limits (ACLs) were established as the appropriate cleanup standards for selenium and vanadium (DOE 2001).

The results of continued groundwater monitoring over the last 15 years suggest that natural flushing processes are unlikely to achieve the cleanup goal for uranium within a reasonable time. A DOE study of the natural flushing remedy after the initial 12 years of monitoring (DOE 2011) concluded that ambient processes in the site's groundwater system were unlikely to reduce uranium concentrations to below the maximum concentration limit (MCL) of 0.044 milligram per liter (mg/L) by the year 2098. This study, referred to herein as the 2011 remedy review or the 2011 remedy evaluation, was based in part on findings by DOE Office of Science (SC) researchers who had been investigating uranium transport and biogeochemistry in Old Rifle groundwater since the early 2000s. In accordance with DOE's compliance framework for UMTRCA sites (Figure 16), DOE has taken into consideration the remedy review in developing a new compliance strategy for uranium.

Subsequent to the 2011 remedy evaluation, SC researchers have conducted several studies of local subsurface processes to specifically identify geochemical reasons for the slow release of uranium from remnant contaminant sources. Reports and published papers stemming from the research indicate that successful natural flushing of uranium from site groundwater will require several hundreds of years (e.g., Janot et al. 2016). Moreover, simultaneous work reported in pertinent scientific literature sheds more light on universal causes of the persistence of metals like uranium in groundwater systems at contaminated sites (e.g., Adamson and Newell 2014, Hadley and Newell 2014, Parker et al. 2008, Sale et al. 2013). DOE has used the observations gained from site monitoring and contaminant behavior, the work by SC researchers on the Old Rifle site, and similar recent work within the literature as a basis for developing a revised strategy for addressing groundwater, and uranium in particular, under the UMTRCA compliance framework. Section 2.0 contains technical site information. Section 3.0 discusses the selection process and rationale for the revised compliance strategy. Section 4.0 describes implementation measures for carrying out the remedy.

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2.0 Site Information

Extensive site characterization data are presented in a number of site documents, including the Remedial Action Plan (DOE 1992), the Site Observational Work Plan (SOWP) (DOE 1999), annual verification monitoring reports (e.g., DOE 2012, 2014) and numerous research papers based on studies conducted at the site. The 2011 groundwater remedy evaluation, as described in *Review of the Natural Flushing Groundwater Remedy at the Old Rifle Legacy Management Site, Rifle, Colorado* (DOE 2011), was based partly on studies conducted by LM personnel and partly on studies conducted by SC researchers between 2001, at the start of the natural flushing compliance strategy (DOE 2001), and 2011. Though that earlier research was administered under several different SC labels, it has generally been identified as part of the Rifle Integrated Field Research Challenge (IFRC) (Long 2012). Since 2011, additional SC studies conducted as part of Sustainable Systems Scientific Focus Area 2.0 (SFA 2.0) (Hubbard and Hawkes 2013) have shed greater light on groundwater flow and geochemical and biological processes that impact the attenuation of contaminant concentrations in the alluvial aquifer. Many of the processes have been identified as further impediments to the flushing of uranium from the aquifer, as summarized in key findings presented in this GCAP.

2.1 Location

The Old Rifle site is located approximately 0.3 mile east of the city of Rifle in Garfield County, Colorado (Figure 1). The site, which is accessible by U.S. Highway 6, is the location of a former vanadium and uranium mill that operated for two separate periods between 1924 and 1958. Its location, on the north bank of the Colorado River, is near the northeastern edge of the Colorado Plateau physiographic province.

2.2 Site Background

The Old Rifle site occupies 22 acres of a crescent-shaped floodplain in an erosional meander of the ancestral Colorado River. The alluvial aquifer maintains a relatively uniform thickness of approximately 20 to 25 feet (ft). Well logs from across the site indicate that aquifer sediments mostly consist of sand and gravel horizons, with distinct, fine-grained layers, lenses, and zones interspersed with the coarser materials (DOE 2011). Depth to groundwater ranges from 5 to 15 ft below land surface. The alluvium directly overlies an 8 to 13 ft thick zone of weathered Wasatch Formation claystone that appears to be hydraulically connected to the unconsolidated alluvium. The weathered bedrock is underlain by several hundred feet of unweathered Wasatch Formation rock with hydraulic conductivities that are typically two to three orders of magnitude lower than the conductivities for the alluvium. Thus, the claystone bedrock is considered a local and regional aquitard, and the alluvial sediments compose the uppermost aquifer at the site. Resistant, cliff-forming beds of the Wasatch Formation control the western, northern, and eastern extent of the alluvium at the site. Groundwater beneath the site generally flows in a south-southwest direction with a hydraulic gradient ranging from approximately 0.003 to 0.006 ft/ft. Recharge to the alluvial aquifer is attributed to leakage from drainage ditches on the north side of U.S. Highway 6, groundwater inflow from sedimentary formations on the north side of the highway, leakage from an open ditch that extends north to south across the site, and infiltration of precipitation on the site. The Colorado River bounds the site on the south, and the alluvial aquifer discharges groundwater to the river along most of the site extent. Figure 2 shows the key current and historical features of the Old Rifle site. Figure 3 provides a corresponding 3-dimensional schematic depicting the main physiographic features of the site.

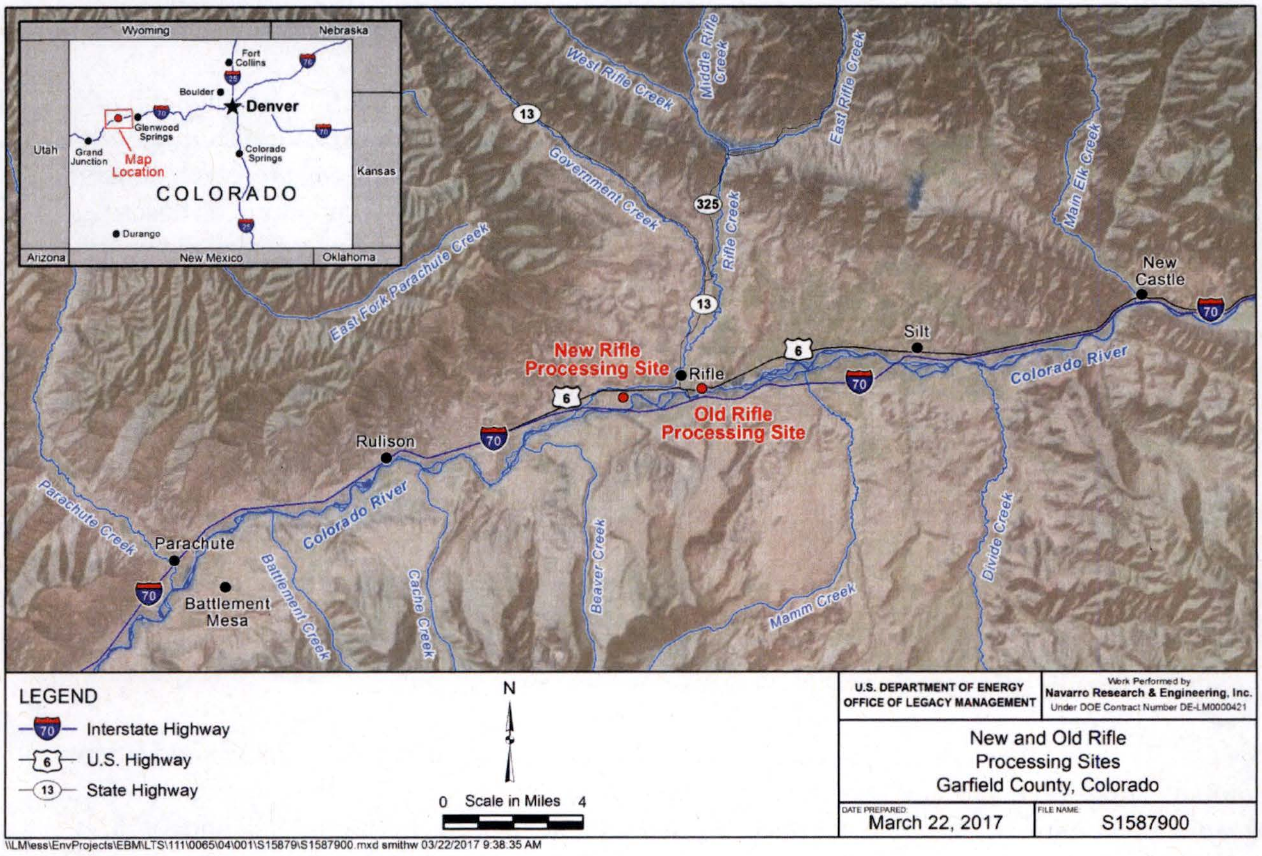

Figure 1. Location of the Old Rifle Site

The Old Rifle milling facility operated from 1924 to 1932 and from 1942 to 1958, and was idle during the interim. The west portion of the site was mostly covered with tailings, and the mill and ore storage area occupied the east part of the site. By the time processing activities ceased, the tailings pile covered a little more than half of the site. Old photos show that during operations tailings piles and raffinate ponds occupied the west portion of the site (Figure 4), and disturbance of the entire site by milling features was clear. Most of the tailings were moved to the New Rifle site after 1958 for reprocessing. Approximately 13 acres of tailings were stabilized at the site in 1967 in accordance with State of Colorado regulations. Stabilization consisted of covering the pile with approximately 6 inches of soil and installing a sprinkler system to promote the growth of grasses. River water was used for irrigation (DOE 1992).

Surface remediation started in spring 1992 and was completed in October 1996. This resulted in the removal and offsite disposal of mill tailings and contaminated soils from the entire site to meet the 40 CFR 192 activity standard of 5 picocuries per gram (pCi/g) for radium-226 (Ra-226) averaged over the first 15 centimeters of soil below the surface. Because removal of soils and alluvial sediments generally stopped at the water table due to difficulties in excavating below this level, some soils exceeding the Ra-226 standard were left in place under the supplemental standards provision of UMTRCA.

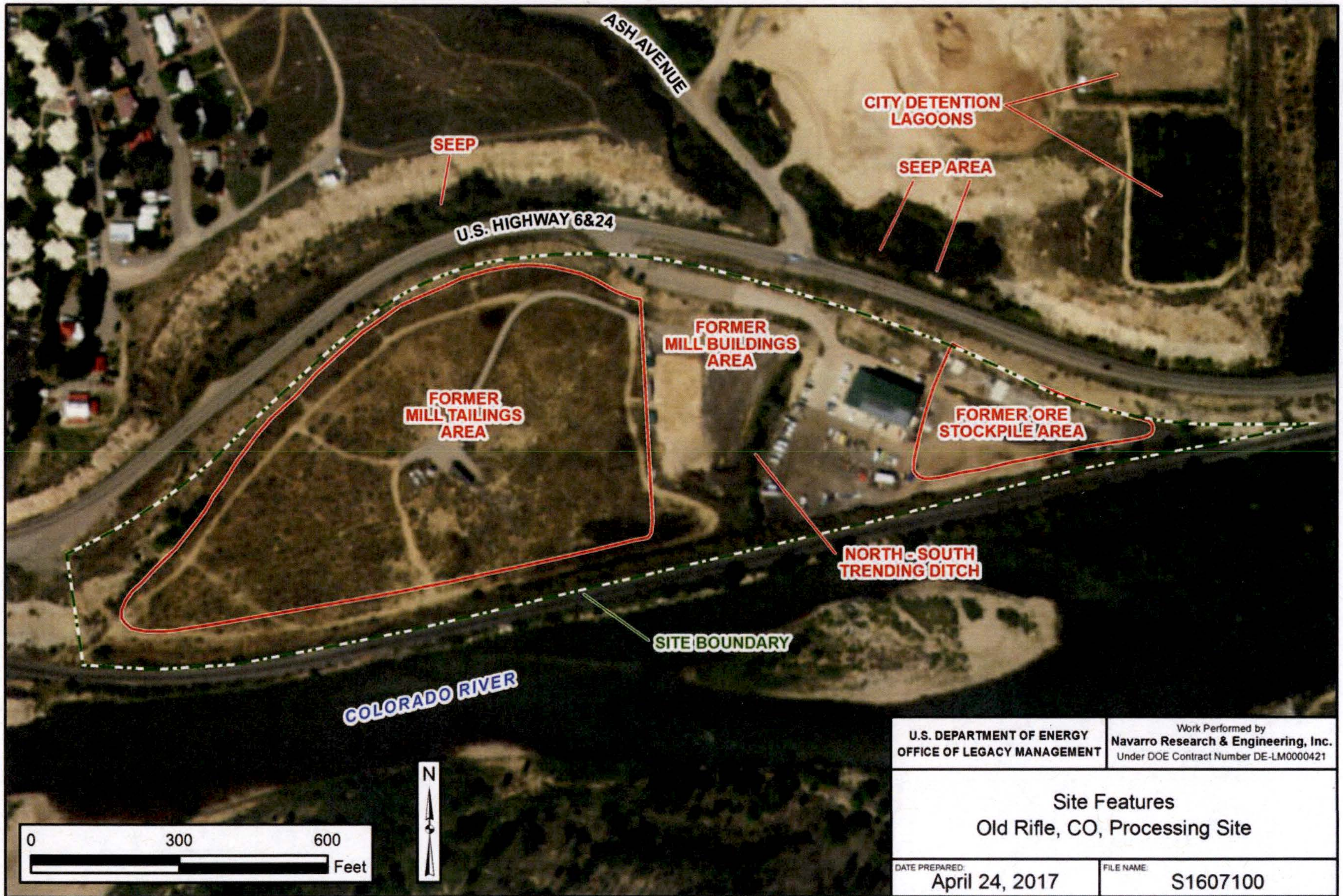

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Figure 2. Site Features, Old Rifle, Colorado, Site

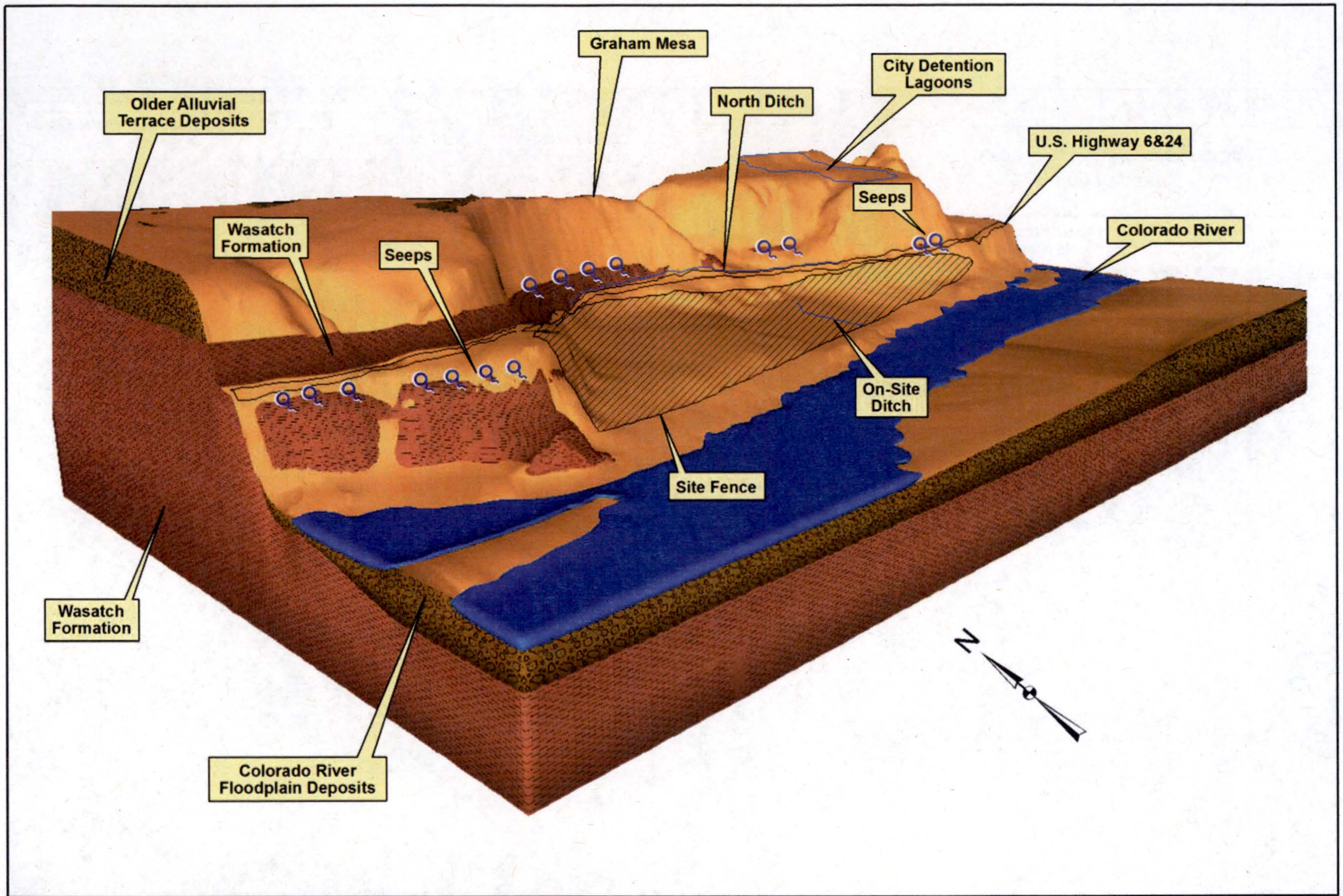

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Figure 3. Depiction of Physiographic Features at the Old Rifle Site

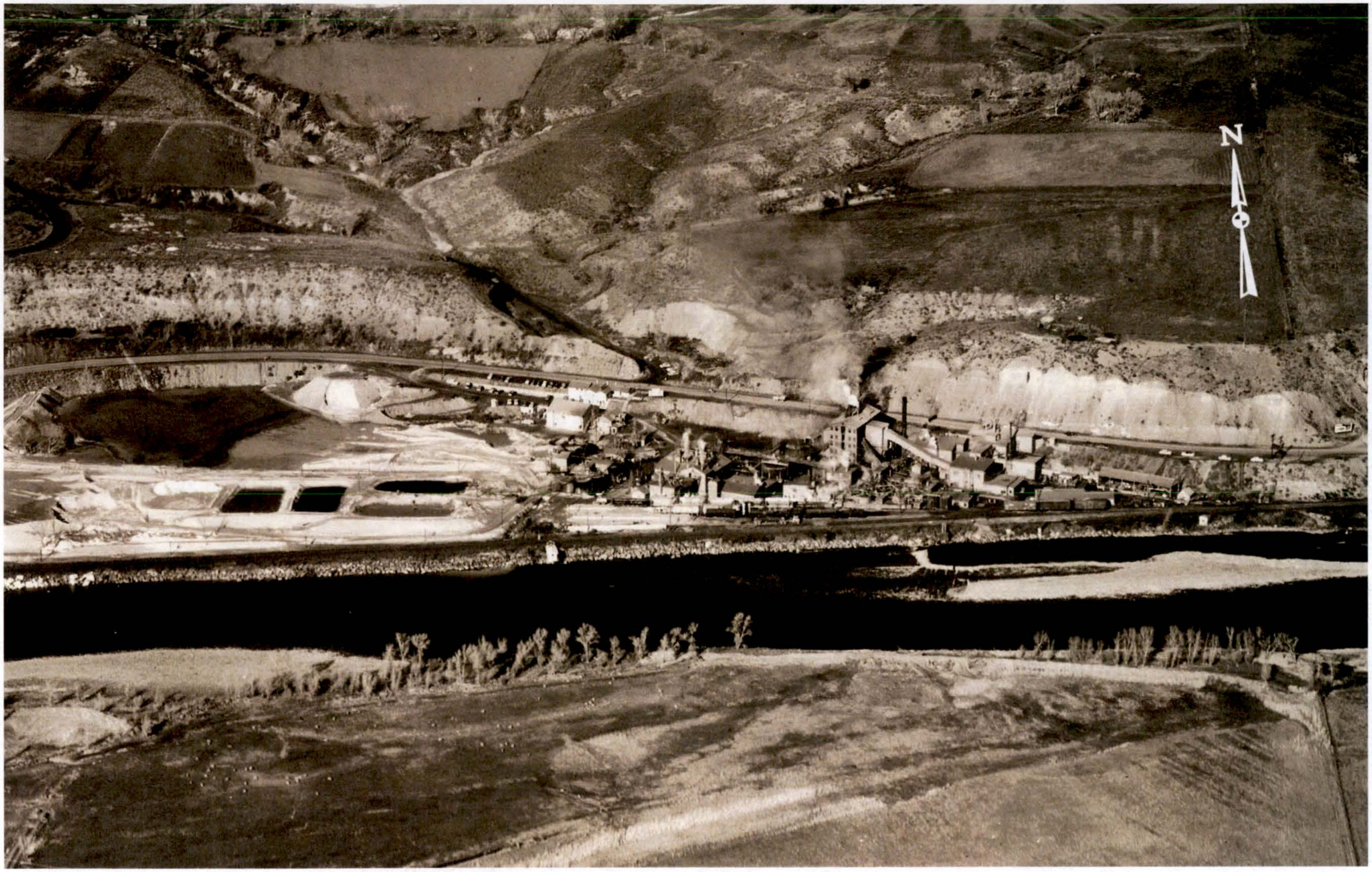

Figure 4. Old Rifle Site During Milling Operations
(Tailings and raffinate ponds occupy the west side, mill buildings the east. Circa 1955, Union Carbide photo.)

Residual soils and sediments are also known to contain contamination from other metals (e.g., uranium and vanadium). In addition, an estimated 24,000 cubic yards of tailings qualified for supplemental standards because of concerns about worker safety and were left in place on adjoining vicinity properties north of the site, beneath U.S. Highway 6, and beneath the embankment on the highway's south side (Figure 5; Appendix J of DOE 1997). Other supplemental standards areas exist under the railroad right-of-way and along the riverbank south of the site. Residual solid-phase activity concentrations for Ra-226 in the supplemental standards areas ranged as high as 1320 pCi/g, and averaged about 150 pCi/g (DOE 1992). Limited subpile soil sampling conducted as part of the SOWP identified residual uranium concentrations in sediments beneath the former ore stockpile area as high as 12 milligrams per kilogram (mg/kg), and an average residual uranium concentration less than 2 mg/kg (DOE 1999). Fine-grained fill was applied and mechanically compacted during surface remedial action across most of the site and makes up the uppermost 5 to 10 ft of surficial material.

A GCAP for site groundwater was prepared and submitted to the U.S. Nuclear Regulatory Commission (NRC) in 2001. The GCAP identified three constituents—uranium, selenium, and vanadium—as having elevated concentrations in groundwater and requiring the selection of a cleanup compliance strategy (DOE 2001). Although arsenic was historically elevated above background levels at a single location in the footprint of the tailings pile, concentrations for this constituent at all other monitoring well locations were below the UMTRCA standard of 0.05 mg/L; therefore, arsenic was eliminated as a COC at the site in the 2001 GCAP. However, subsequent monitoring conducted by SC researchers showed that arsenic in some non-DOE wells still persists at concentrations exceeding the UMTRCA standard.

Modeling of constituent transport in the alluvial aquifer indicated that uranium concentrations under background conditions would decline to levels below the UMTRCA standard of 0.044 mg/L within 10 years after 1998, and that selenium would drop below its primary drinking water standard of 0.05 mg/L within 50 years. The primary drinking water standard was proposed as an ACL for selenium because background concentrations were higher than the corresponding UMTRCA standard of 0.01 mg/L. Natural flushing was selected as the compliance strategy for achieving the uranium and selenium standards. Because neither a groundwater nor drinking water standard exists for vanadium, an ACL was also proposed for this constituent. A concentration of 1.0 mg/L was proposed as the vanadium ACL, which is higher than the maximum observed concentration at the site. All onsite wells, shown in Figure 6, were considered to be point-of-compliance (POC) wells for the ACLs. The Colorado River, where groundwater discharges from the site, was considered to be the point of exposure for mill-related contamination.

In July 2002, NRC concurred on DOE's proposed compliance strategy for the Old Rifle site, contingent on the transfer of the site to the City of Rifle and the formalization of institutional controls (ICs) (NRC 2002). The site was transferred from the Colorado Department of Public Health and Environment (CDPHE) to the City of Rifle by quitclaim deed in January 2003. The City of Rifle constructed an operations and maintenance facility on the east end of the property in 2007.

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Figure 5. Supplemental Standards Areas Remaining after Surface Cleanup

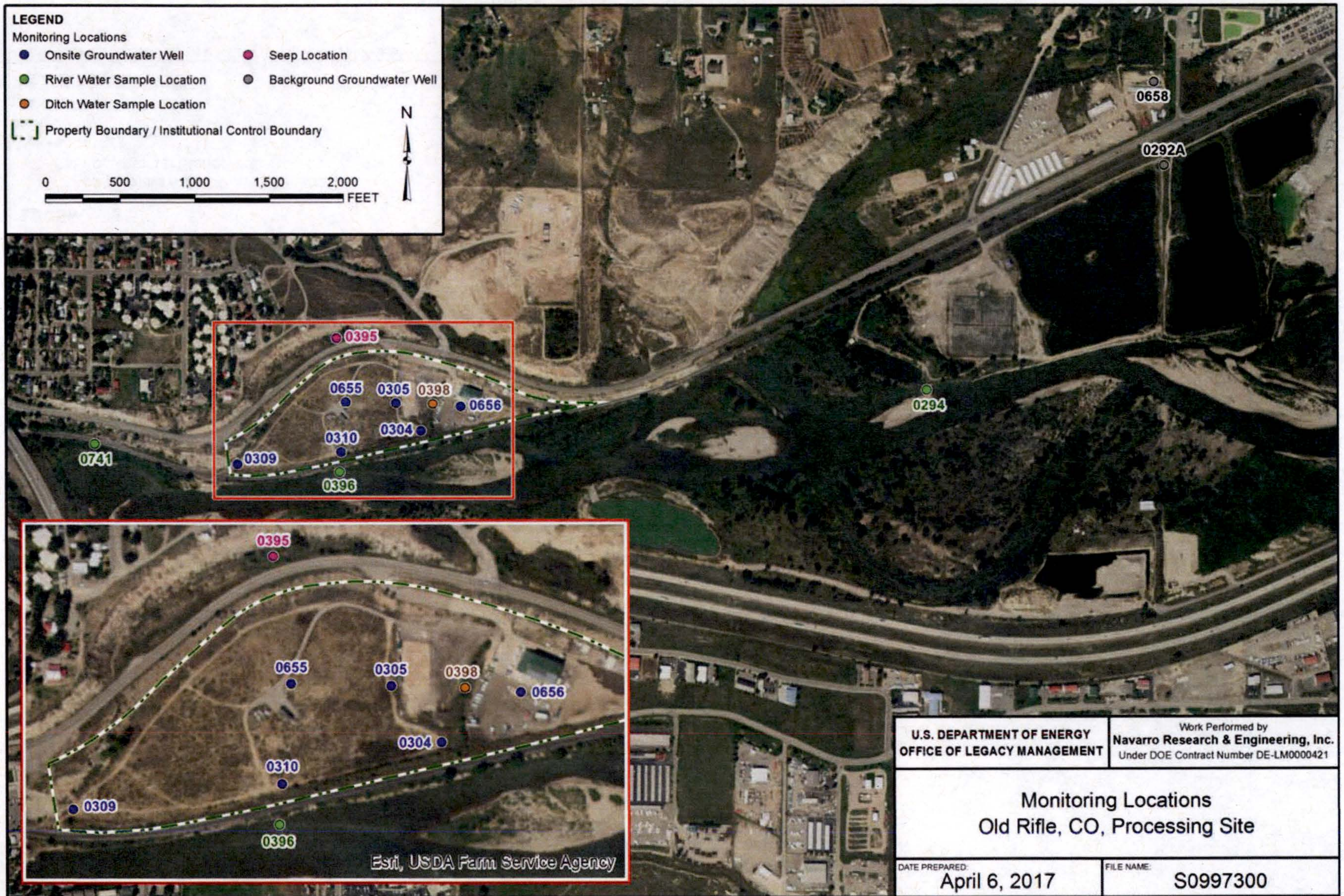

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Figure 6. Monitoring Locations for the Old Rifle Site

On the west half of the site, SFA 2.0 personnel have conducted biogeochemical research that characterizes the controls on mobility of uranium and other constituents in the alluvial aquifer. Several ICs are in place on the property that put certain constraints on land use, including restrictions on groundwater use. The ICs are described in greater detail in Section 4.2.

2.3 Site-Related Contamination

2.3.1 Constituent Concentrations at Site Wells

Uranium is the most prevalent mill-related contaminant occurring in the alluvial groundwater. With the exception of well 0309, in the southwest corner of the site (Figure 6), samples from all locations have had uranium concentrations that exceeded the background value of 0.067 mg/L and the UMTRCA standard of 0.044 mg/L at some point during their monitoring histories (Figure 7). Uranium concentrations in samples from wells 0304 and 0305 have occasionally dropped below these values. Concentrations in wells 0310, 0655, and 0656 have remained consistently elevated over the last decade.

A comparison of pre-surface-remediation levels for uranium (prior to 1992) at site wells with concentrations beginning in 1998 at the same locations (Figure 7) suggests that the remediation resulted in an order-of-magnitude reduction in groundwater concentrations. Maximum uranium concentrations reported in the Remedial Action Plan for the site during the 1987–1990 time period were on the order of 1 to 2 mg/L (DOE 1992), as compared with current maximum concentrations of around 0.1 to 0.3 mg/L. Wells in the vicinity of existing well 0309 had pre-remediation concentrations of 0.11 to 0.13 mg/L (DOE 1992), whereas levels of about 0.01 to 0.03 mg/L have been more common at well 0309 since 2000 (Figure 7). Such results suggest that source control (i.e., removal of tailings and other residual radioactive materials) produced rapid and significant improvements in the quality of water in the alluvial aquifer. However, since the drop in uranium concentration following source removal, the average uranium level across the site has shown no further decline (Figure 8) and has remained well above both background concentrations and the UMTRCA standard. (Average uranium values shown in Figure 8 are the arithmetic means of data from the same six monitoring wells over time.)

In contrast to uranium, selenium concentrations have exceeded relevant benchmarks in only two wells—0305 and 0655 (Figure 9). Both of these locations are close to the center of the former tailings area (Figure 6) and west of the north-south trending ditch that conveys surface runoff from north of the site to the Colorado River (Figure 2). Selenium concentrations in well 0305 fluctuated widely between 1998 and 2006, often exceeding the 0.05 mg/L ACL level, but have since decreased to levels below 0.05 mg/L and the 0.041 mg/L background value. An opposite pattern is observed for well 0655, where selenium concentrations were mostly below the ACL until 2010; since that time concentrations have varied widely, both above and below the ACL (Figure 9).

Based on U.S. Environmental Protection Agency (EPA) regional screening-level tables for May 2016 (EPA 2016), a current risk-based concentration (RBC) for vanadium in drinking water is 0.15 mg/L. Vanadium concentrations have almost consistently remained above the RBC at wells 0305 and 0655 for the last several years, contrasting with vanadium levels uniformly below the RBC in all remaining wells (Figure 10). Concentrations in all site wells have remained below the current vanadium ACL of 1.0 mg/L.

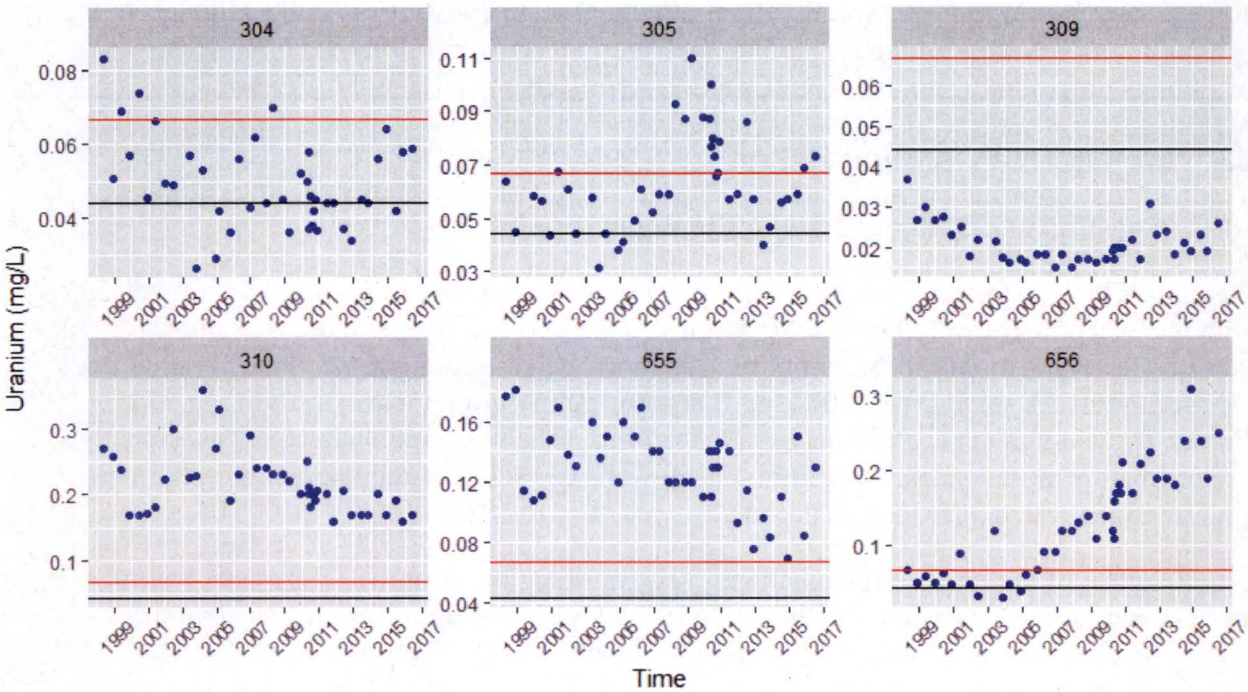

Figure 7. Uranium Time-Concentration Scatterplots for Old Rifle Onsite Wells
(red line denotes maximum uranium background concentration of 0.067 mg/L; black line is UMTRCA standard of 0.044 mg/L)

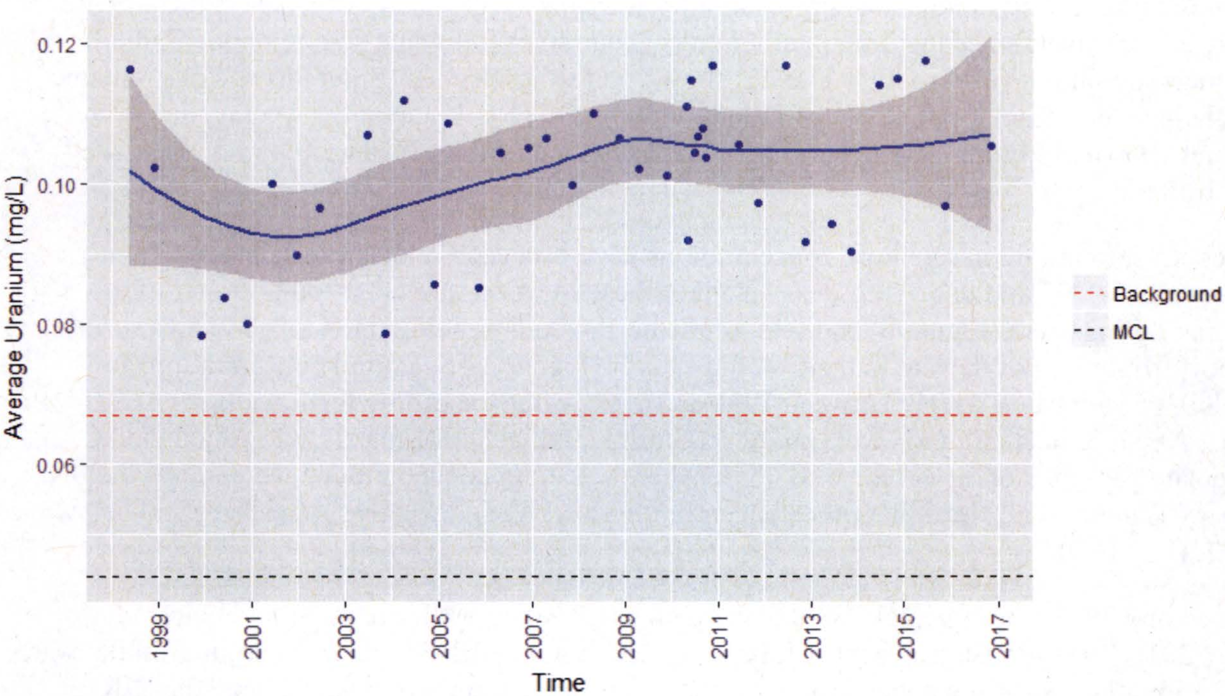

Figure 8. Average Uranium Concentration at Onsite Wells Versus Time for the Old Rifle Site
(—— blue line is loess local regression line; shaded area is the corresponding 95% point-wise confidence interval)

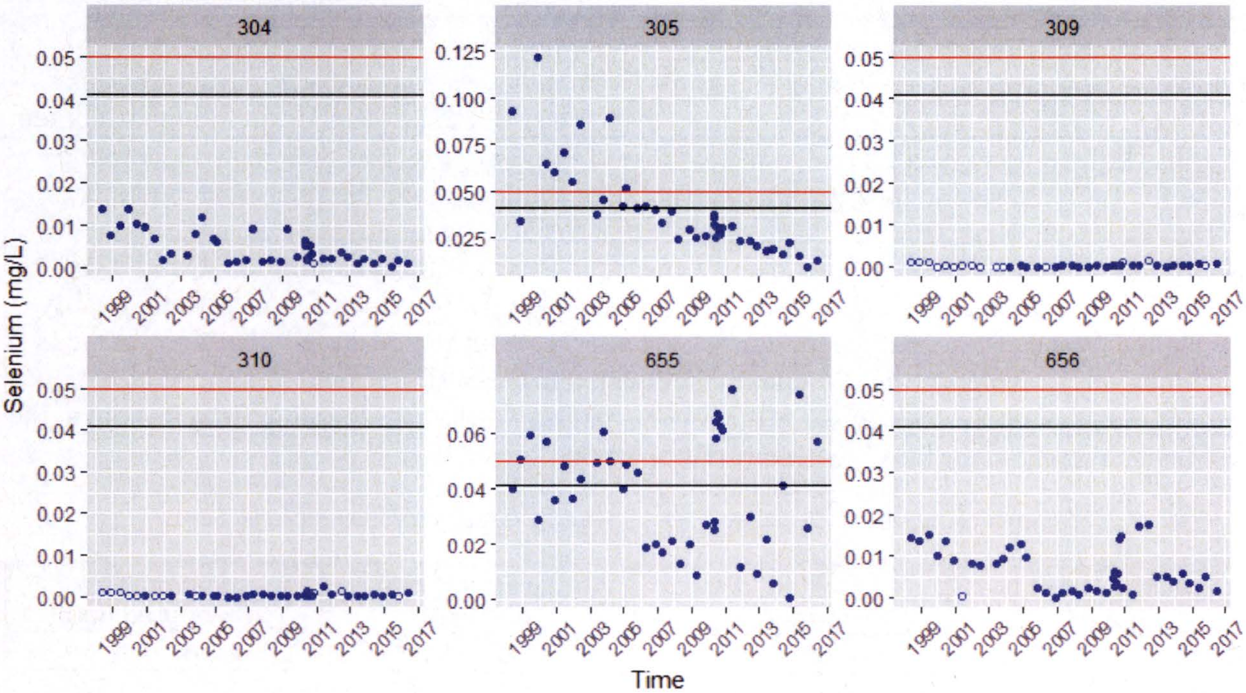

Figure 9. Selenium Time-Concentration Scatterplots for Old Rifle Onsite Wells
(red line denotes selenium ACL of 0.05 mg/L; black line is maximum selenium background concentration of 0.041 mg/L)

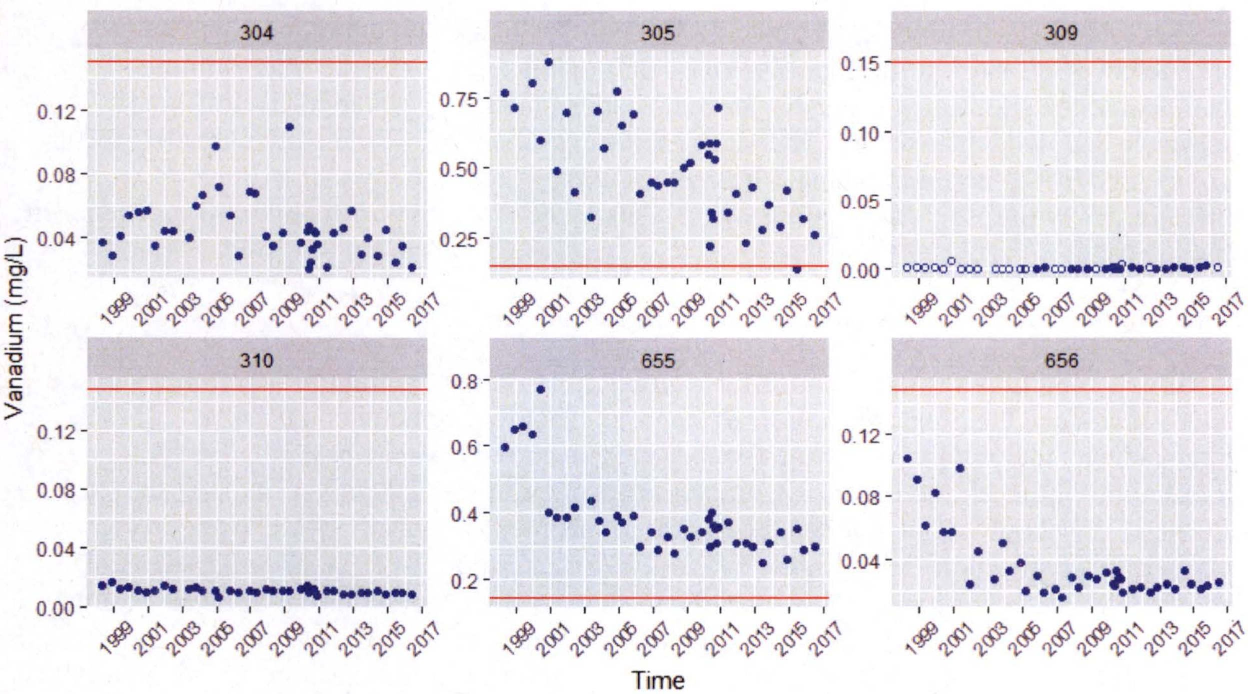

Figure 10. Vanadium Time-Concentration Scatterplots for Old Rifle Onsite Wells
(red line denotes current vanadium RBC of 0.15 mg/L)

2.3.2 Potential Site Impacts on the Colorado River

Despite the persistence of uranium in site groundwater at levels that exceed the MCL for this constituent (e.g., DOE 2012, 2014), it appears that discharge of site groundwater to the Colorado River has little to no impact on river water quality. Table 1 summarizes the range of sampling results for uranium, selenium, and vanadium at three locations along the river in the vicinity of the site (Figure 6). Based on their locations adjacent to and downgradient of the site, respectively, it is possible that water quality measured at two of the locations, 0396 and 0741, could reflect contaminant discharge from site groundwater. However, the surface-water quality data for the river indicate that the influence of contaminated-groundwater discharge from the alluvial aquifer is insignificant. Calculations provided in the SOWP show an estimated dilution factor of approximately 3×10^{-5} for contaminants in groundwater discharging from the site to the river under average river flow conditions (DOE 1999).

Table 1. Summary of Colorado River Sampling Results for the Old Rifle Site

Constituent (mg/L)	Location 0294 (Upgradient)	Location 0396 (Adjacent)	Location 0741 (Downgradient)
Selenium	0.0002–0.001	0.0002–0.0017	0.0001–0.0008
Uranium	0.0007–0.0027	0.001–0.0028	0.0008–0.0027
Vanadium	0.0003–0.0045	0.0004–0.0026	0.0001–0.007

2.3.3 Focus on Uranium

The discussion in the remainder of this GCAP primarily focuses on uranium, which has been the main subject of research at the site. Moreover, uranium is likely to be the most limiting constituent at the site from a groundwater remediation standpoint due to its demonstrated persistence and wide distribution. The locations where selenium and vanadium are elevated are encompassed by the uranium plume. Therefore, a compliance strategy that ensures protectiveness with respect to uranium will also likely be protective with regard to additional site constituents.

2.3.4 Spatial Distributions of Uranium Contamination

Color-flood contour maps in Figure 11 through Figure 14 show uranium concentrations in site groundwater since the initial reductions in response to surface remediation occurred. These figures indicate that mild to moderate changes have occurred over the past 18 years. As illustrated in Figure 11 and Figure 12, uranium concentrations in 2007 over much of the site were generally about the same magnitude as those recorded earlier in 1998. Changes were subsequently observed in 2012 (Figure 13), when concentrations in the west half of the site, particularly at wells 0655 and 0310, appeared to decrease by about a third to one-half of uranium values at the same locations in 2007. Though the 2012 map was based on fewer monitoring wells than used during 1998 and 2007, the respective measured concentrations at wells 0655 and 0310 provided sufficient evidence of a moderate decrease in uranium concentrations beneath the former tailings area. In contrast, some evidence of a mild increase in uranium levels between 2007 and 2012 was seen on the mill (east) side of the site, as a concentration of 0.19 mg/L was recorded for well 0656 in the latter year (Figure 13) in comparison to a value of 0.12 mg/L in the earlier year (Figure 12).

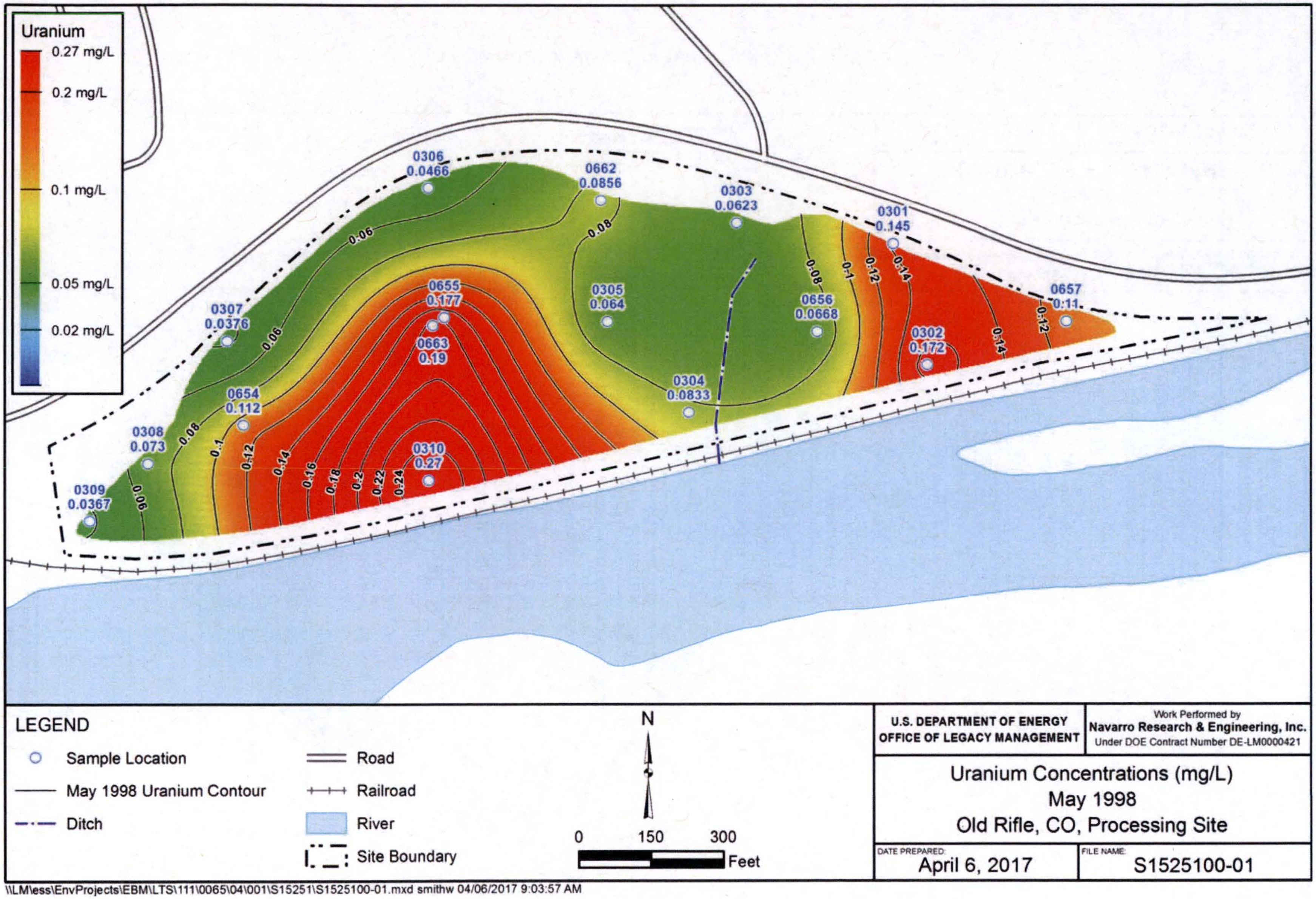

Figure 11. Uranium Concentrations, May 1998

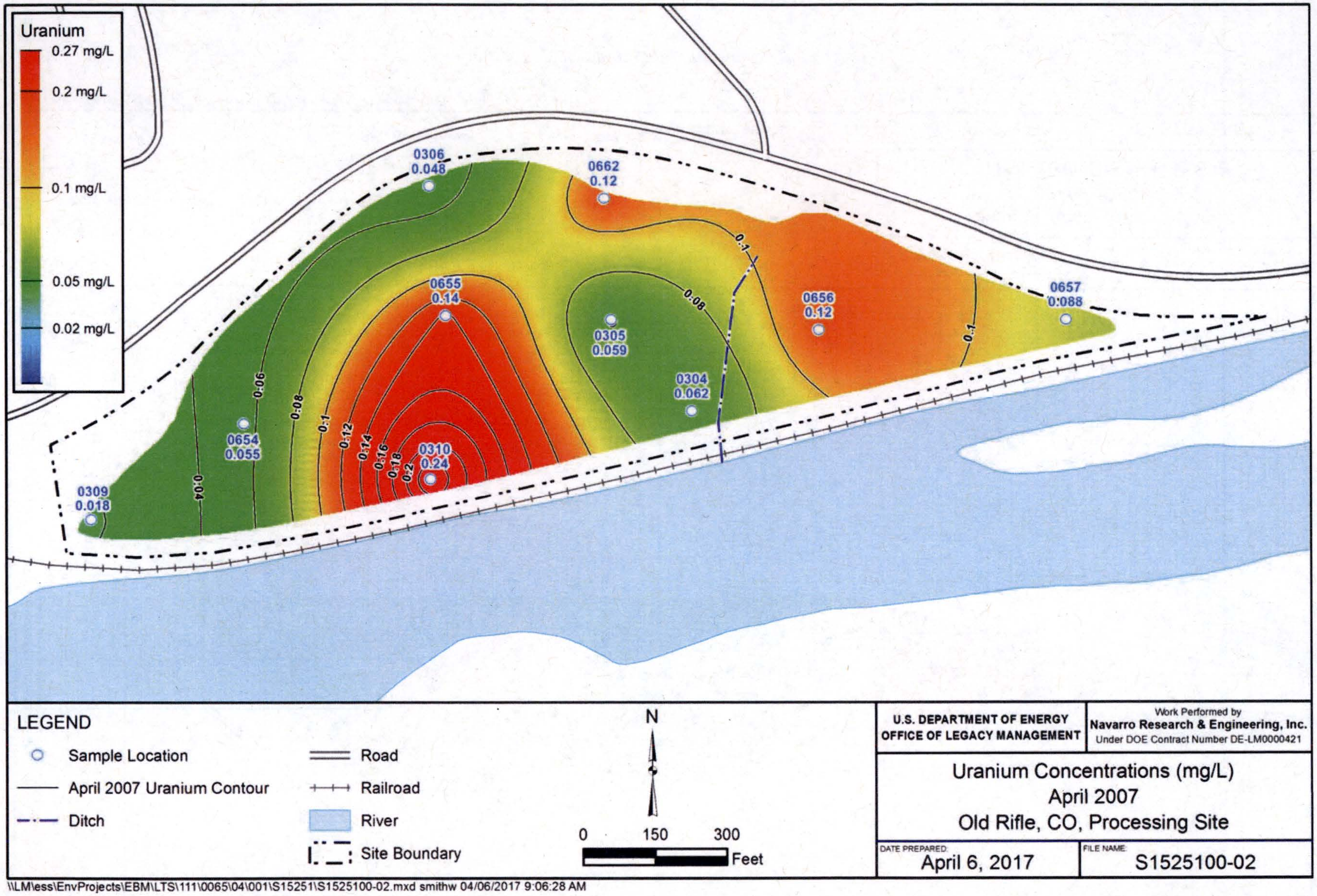

Figure 12. Uranium Concentrations, April 2007

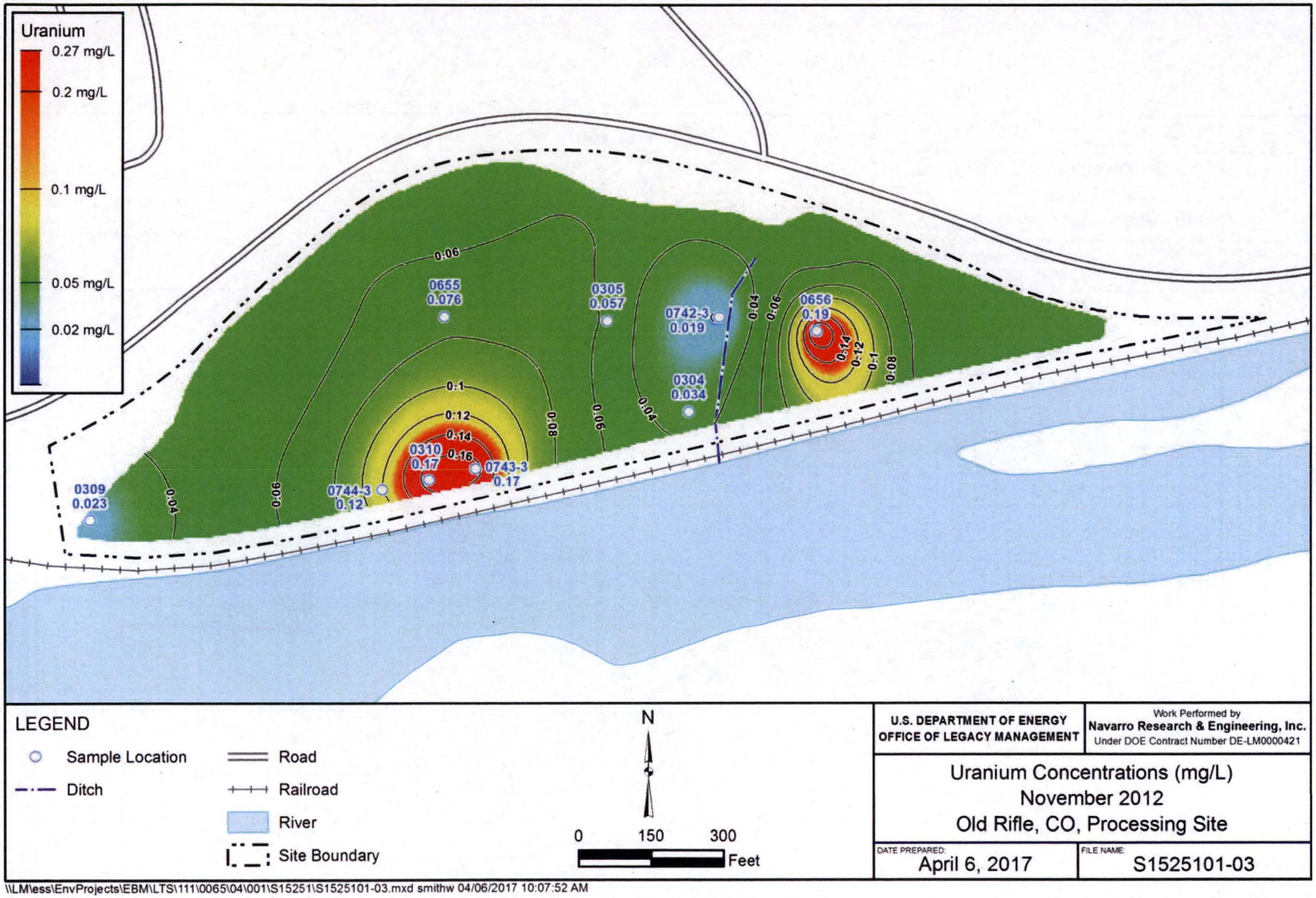

Figure 13. Uranium Concentrations, November 2012

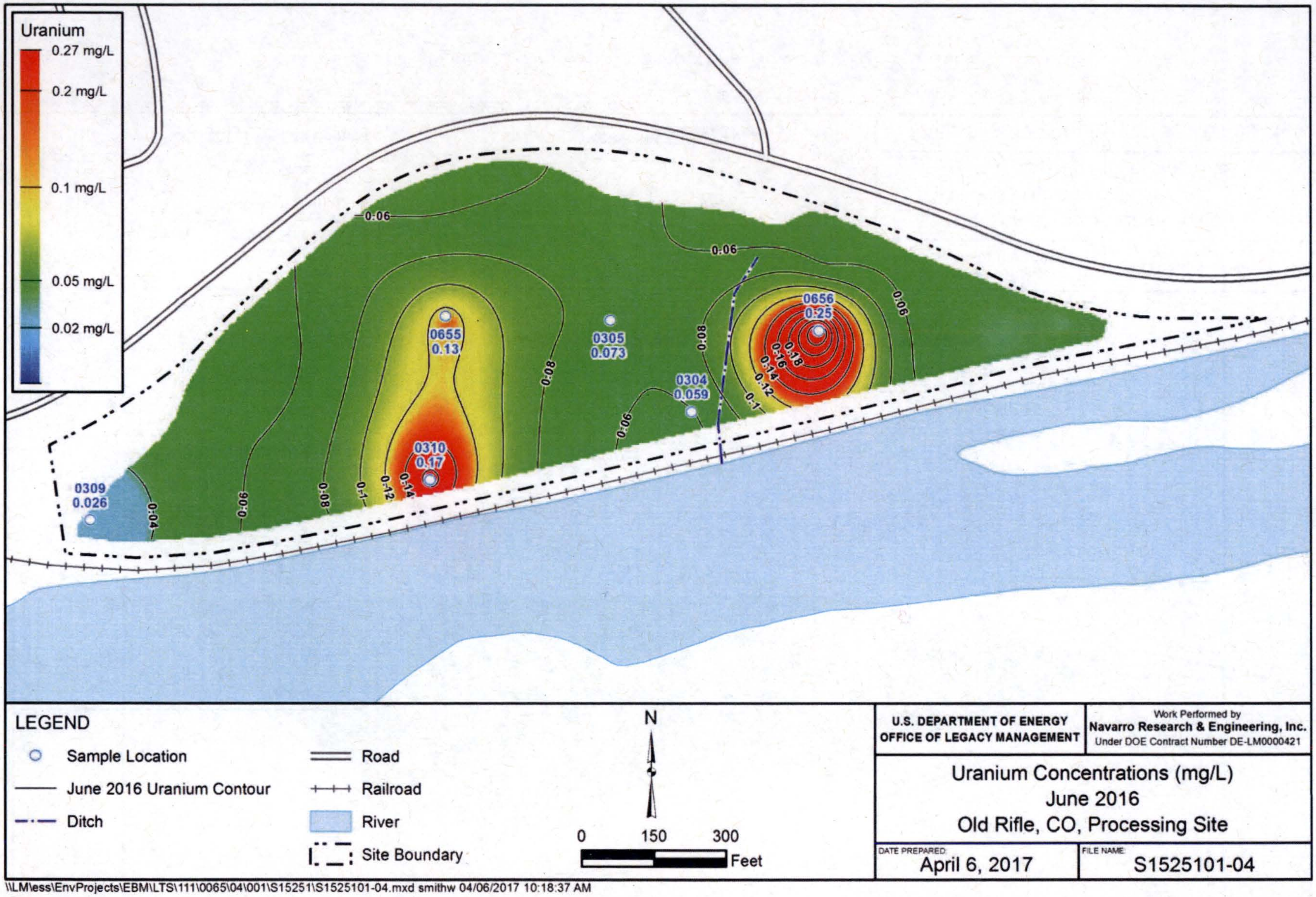

Figure 14. Uranium Concentrations, June 2016

Moderate changes in the spatial distribution of uranium were again observed in 2016 (Figure 14) in comparison to levels from preceding years. Notably, the uranium concentration at well 0655 increased to 0.13 mg/L from 0.076 mg/L in 2012, returning to a level relatively close in magnitude to those at this location in 2007 (0.14 mg/L) and 1998 (0.19 mg/L). Given that contaminants are transported primarily in a south-southwest direction across the site, the increased uranium concentration at well 0655 presented the possibility that concentrations at well 0310, located farther downgradient, would also eventually recover to levels seen in earlier years. The uranium concentration in 2016 at well 0310 (0.17 mg/L) did not change from the concentration observed in 2012. Note that the uranium level at well 0656, on the mill side of the site, continued to climb in 2016 to 0.25 mg/L (Figure 14).

Generally, both temporal plots of uranium concentration and mapped representations of its distribution indicate that, though mild to moderate changes in concentration can occur at specific wells, no significant trend in uranium values across the Old Rifle Site is observed. This supports previous findings (DOE 2011) that uranium is unlikely to flush from site groundwater within the 100-year period permitted for natural flushing.

2.4 Hydrogeology and Uranium Transport

This section presents a review of studies at the Old Rifle site that help explain why cleanup of uranium in the alluvial aquifer is unlikely to be achieved for hundreds of years. The review begins with a description of the work performed for the SOWP in the late 1990s (DOE 1999). Much of this section is focused on investigations conducted by researchers funded by SC. As mentioned in Section 2.0 and discussed below, the SC research was carried out under two separate efforts: the IFRC and SFA 2.0.

2.4.1 SOWP Modeling

DOE developed both a conceptual model and a numerical model of groundwater flow and contaminant transport in the alluvial aquifer as part of the 1999 SOWP. The decision to adopt a natural-flushing groundwater remedy at the site was based on the modeling results.

2.4.1.1 Conceptual Model

The conceptual model of groundwater flow and transport at the Old Rifle site developed in support of the SOWP (DOE 1999) assumed that the fate of uranium in the subsurface was controlled by three processes: advection, mechanical dispersion, and sorption. The first two processes were determined by the hydraulic characteristics of the alluvial aquifer, leaving sorption as the only chemical-specific process that had the potential to impact both aqueous-phase and solid-phase uranium concentrations. It was further assumed that adsorption of uranium on aquifer sediments was an equilibrium phase-partitioning process that could be accurately modeled using a linear soil-water distribution coefficient, or K_d.

SOWP characterization work showed that both groundwater elevation and groundwater flow direction varied with time, particularly in response to rising water levels in the Colorado River each May and June due to snowmelt runoff in the Rocky Mountains. Water elevations were shown to rise by as much as 5 to 6 ft and flow directions to vary by 90 degrees or more. Nonetheless, groundwater flow was conceptualized as being a steady process that was confined to a single layer. Flow was to the south-southwest, from the site's north boundary to the Colorado River. Adoption of these ideas meant that advection could only occur along distinct streamlines that never varied between seasons and successive years. Lateral spreading of uranium on the west side of the site, where the highest concentration of uranium mass is located, was solely attributable to transverse dispersion and not caused by a temporally varying flow orientation. The conceptual model also assumed that the capacity to convey groundwater (i.e., permeability) could be represented as if the aquifer were homogeneous, with a single, uniform value of hydraulic conductivity.

2.4.1.2 Numerical Models

A steady-state version of the finite-difference flow model for the Old Rifle site was calibrated using a uniform hydraulic conductivity of 110 ft/day, a value that was considered representative of the more permeable alluvial sediments, such as gravelly sands and clean, coarse-grained sands. With this approach, aquifer heterogeneity and the lower hydraulic conductivities, low water velocities, and slow contaminant migration occurring in finer-grained portions of the aquifer (silty sands, sandy silts, silts and clays) were ignored. The use of a high hydraulic conductivity in the model indicated that transport of water from the upgradient portions of the aquifer to discharge locations along the Colorado River occurred in less than 5 years. Calibration was achieved by assigning constant head boundary conditions to multiple nodes on the north border of the steady flow model, which facilitated inflow of water from offsite that helped sustain the steady groundwater levels employed as calibration targets.

The basic elements of this homogenous flow model were subsequently combined with a transport simulator that made it possible to simulate uranium transport for 100 years beyond 1998, the starting year in the SOWP model. The combined flow and transport modeling system was then used to perform 100 probabilistic simulations, in which flow was considered steady in each simulation, and hydraulic conductivity and K_d were allowed to vary between simulations. The K_d values used in the probabilistic modeling were relatively low, ranging from 0.0 to 0.2 milliliter per gram (mL/g), as determined from laboratory batch tests indicating that uranium sparingly adsorbs to the aquifer sediments. Thus, uranium migration through the aquifer was only mildly retarded in the numerical simulations.

Initial concentrations of uranium employed in each model run were based on a plume map generated from concentrations measured at several site wells in May 1998. The total inventory of uranium (dissolved and sorbed) in the aquifer at the start of each simulation (in 1998) was dictated by this set of initial concentrations and the K_d value used in the simulation, with larger K_d values signifying a larger inventory. The transport model assumed that an overlying vadose zone contributed no uranium to groundwater.

All of the probabilistic model runs conducted for the SOWP (DOE 1999) indicated that dissolved uranium concentrations in the aquifer would decrease to levels less than the MCL (0.044 mg/L) within 10 years of the 1998 starting time. Groundwater monitoring during the period 1998–2011 did not confirm this optimistic projection of uranium flushing (see, for example, Sections 2.3.1 and 2.3.4). This observation suggested that the conceptual and numerical models developed to support the SOWP were in need of revision.

2.4.2 Remedy Review Through 2011

DOE began assessing the progress of the natural flushing remedy at the Old Rifle site in 2010, using both LM monitoring results and findings of the SC researchers under the IFRC. This resulted in the development of a new conceptual model of flow and transport processes at the site, which was described in Section 6 of the 2011 groundwater remedy review (DOE 2011).

2.4.2.1 DOE Assessment

The new conceptual model of groundwater processes in the alluvial aquifer indicated that there were multiple sources of uranium mass other than those accounted for in the original conceptual model based solely on observed 1998 uranium concentrations in groundwater and an estimated K_d (DOE 1999). New sources of uranium were posited, including leaching from vadose zone sediments and slow release from lower-permeability sediments in the alluvium to higher-permeability materials in the aquifer. The conceptual model also included uranium sources in the form of inflow of uranium-containing groundwater from offsite areas near the site's north boundary. These offsite sources were attributed to (1) groundwater seeps from older alluvial terrace deposits overlying the Wasatch Formation in the cliff face on the highway's north side (Figure 3); (2) infiltration of runoff collected in drainage ditches on the north side of the highway, and (3) southward-moving groundwater in the weathered Wasatch Formation found in both the cliff face and beneath the highway. In some areas, the inflowing water from the offsite sources appeared to contain uranium concentrations that were higher than accounted for in the SOWP model (DOE 1999), and at times exceeded the MCL.

As discussed in Section 2.4.2.2, IFRC researchers determined that some of the lower-permeability sediments in the aquifer were also chemically reducing, stemming from the local presence of natural organic carbon that facilitated oxidation-reduction (redox) reactions mediated by resident microbes. These sediments were referred to as naturally reduced zones, or NRZs (Qafoku 2009), and contained reduced tetravalent uranium [U(IV)] in a solid phase. Oxidation of the U(IV), resulting in dissolved hexavalent uranium [U(VI)] that was available for transport in groundwater, was identified as a mechanism for mobilizing uranium for delivery to the river. However, the rate of mobilization was considered very slow, and the exact manner at which oxidation reactions occurred in the NRZs had not been completely determined as of 2011. IFRC researchers hypothesized that the NRZs were important contributors to uranium plume persistence (e.g., Qafoku 2009) and were added to the list of potential subsurface sources of uranium in the site conceptual model.

In contrast to a homogeneous aquifer with uniform hydraulic and transport parameters (as assumed in the SOWP), the revised conceptual model treated the aquifer as a dual-domain system, in which preferential flow paths (mobile domain) were interspersed among less-permeable (immobile domain) zones. Hydraulic conductivities in the preferential pathways were described as being as much as 3 or 4 orders of magnitude higher than the conductivities of fine-grained sediments that constitute the immobile domain (DOE 2011). Adoption of dual-domain phenomena meant that groundwater flow paths were more tortuous than expected in a homogeneous system, and that disparate contaminant transport rates would result, with uranium migration being relatively rapid in high-permeability, preferential flow paths and much slower in low-permeability sediments. Parts of the groundwater system where contaminant migration was so slow that it was effectively dominated by molecular diffusion, rather than advection, were identified as long-lived contaminant sources that slowly feed uranium into the mobile domain over time.

2.4.2.2 Integrated Field Research Challenge

The SC has conducted research at the Old Rifle site since the early 2000s. Though the scientific studies for the initial 11 years were carried out under a few different programs, the projects conducted up through 2011 are referred to in this document as the IFRC studies. A primary thrust of this research was to evaluate the feasibility of immobilizing uranium in the subsurface using enhanced bioremediation technology. The technology makes use of biostimulation, in which organic carbon in the form of acetate is injected into the site's alluvial aquifer to promote a chemical redox reaction that leads to conversion (precipitation) of dissolved U(VI) to solid-phase U(IV). The redox process is facilitated by indigenous iron-reducing and sulfate-reducing microbes. The IFRC research involved numerous experiments and subsurface characterization activities focused on understanding the physical, geochemical, and biological processes in the aquifer, both under background conditions and as a result of the biostimulation.

The IFRC studies were carried out on the west half of the site within several rectangular areas, or biostimulation test plots, with each plot encompassing less than 0.1 acre. Multiple experiments were performed in each area. Tens of wells were located within each plot, with some of the wells being used for acetate injection and others for monitoring the results of the experiment (see Section 4.0 of the remedy evaluation, DOE 2011). Figure 15 shows the locations of the rectangular areas, the names of many of the individual experiments conducted within them, and the density of wells that have been installed to facilitate the biostimulation experiments and other research projects. A numerical model that simulated groundwater flow and the transport of uranium and other constituents was typically developed for each test, and validation of the models was performed using experimental results. Each experiment and model typically synthesized multiple hydraulic, chemical, and microbial processes and chemical data that affect uranium behavior in groundwater.

The IFRC studies differed from the site characterization and modeling performed in support of the SOWP in that the experiments were conducted in a manner that allowed researchers to observe groundwater-system behavior at a relatively fine scale and over short time intervals. The distances separating monitoring wells in the biostimulation experiments tended to range between 6 and 24 ft, and water samples were collected at intervals ranging from a few weeks to a few months. In addition, samples of aquifer sediment were sometimes collected, during both pre- and post-test phases of individual experiments, and subsequently analyzed to better understand the solid-phase chemistry of the aquifer. Similarly, various indigenous microbial populations that influence aqueous-phase and solid-phase chemistries were extensively characterized.

In addition to better describing the geochemistry of uranium in site groundwater, the IFRC researchers used aquifer testing techniques to characterize the spatial variation of hydraulic conductivity across individual test plots. In general, the largest hydraulic conductivities were on the order of 50 to 100 ft/day (Williams et al. 2009, Long 2012), of the same general magnitude (110 ft/day) used to conduct the earlier DOE modeling (DOE 1999). However, examination of data from multiple studies of the tests revealed a large range of hydraulic conductivities varying over 4 to 5 orders of magnitude (e.g., Li et al. 2010, Yabusaki et al. 2011, Zachara et al. 2013),

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Figure 15. Integrated Field Research Challenge (IFRC) Experimental Plots and Selected Monitoring Wells for Science Focus Area 2.0 (SFA 2.0)

with the lowest conductivities approximating 0.01 ft/day. These values, which conform to the results of detailed characterization activities in alluvial aquifers (e.g., Fogg et al. 2000, Labolle and Fogg 2001), indicated that the aquifer was more heterogeneous than assumed in the SOWP, and capable of exhibiting dual-domain behavior.

The IFRC investigations also showed that, in addition to physical heterogeneities, the sorption, geochemical, and biological processes controlling uranium dissolution and mobility in the alluvial aquifer were heterogeneous (e.g., Li et al. 2010). In contrast to the DOE transport modeling that assumed sorption could be simulated using a single uniform K_d, the SC research found that adsorption and desorption of contaminants like uranium were strongly affected by pH and the concentrations of dissolved inorganic carbon and calcium. To account for such influences, Hyun et al. (2009) developed a surface complexation model that allowed the proportion between adsorbed and aqueous concentrations of uranium to vary over time and location. The model identified K_d values that, depending on ambient water chemistry, ranged from 0.5 to 20 mL/g. Because the values on the low end of this range were noticeably larger than the K_ds (0.0 to 0.2 mL/g) used in the earlier DOE simulations (DOE 1999), the minimum time required to flush all uranium mass residing in the subsurface was expected to span several decades. Surface complexation models were incorporated in several transport models (e.g., Li et al. 2010, Yabusaki et al. 2010, Fox et al. 2012) used to evaluate the effectiveness of IFRC biostimulation tests. All of the transport simulators demonstrated that processes governing the adsorption and desorption of uranium in alluvial sediments were much more varied and complex than assumed in preceding DOE assessments of contaminant flushing.

Some IFRC projects continued beyond 2011. These later experiments resulted in more-detailed descriptions of aquifer biogeochemistry, as well as quantification of the relationships between various subsurface processes under both background and stressed (biostimulated) conditions. The findings from the 2011 groundwater remedy review, the IFRC experiments, and semi-annual sampling events conducted by DOE have been complementary, and collectively provide multiple lines of evidence that dissolved levels of uranium in the alluvial aquifer are unlikely to decrease to the MCL within 100 years.

2.4.3 Sustainable Systems Science Focus Area 2.0

The SC-supported research in recent years, conducted mostly under SFA 2.0 (along with a few continued IFRC projects), has largely focused on characterization of hydrological and biogeochemical processes in both the vadose and saturated zones. This work has identified the sizes and physical and chemical properties of NRZs, and the chemical reactions that lead to the dissolution of reduced uranium phases for transport to the river. Two previously unrecognized sources of uranium contamination along the north boundary of the site have also been identified.

Following on the earlier work of Qafoku (2009), Campbell et al. (2012) characterized the mineralogy, solid-phase chemistry, aqueous geochemistry and microbiology of several samples collected from site NRZs. In addition to confirming the relative abundance of organic carbon that is typically seen in these natural deposits, this characterization process indicated that they are composed of more fine-grained sediments (clays and silts) than are commonly associated with the alluvium. Correspondingly, the NRZs are expected to have a low hydraulic conductivity. The NRZs also contain relatively large amounts of solid-phase constituents in the form of U(IV), adsorbed U(VI), iron oxides and ferrous sulfides, all of which are expected in a chemically reducing environment and appear to play a role in generating dissolved U(VI) that is eventually mobilized in flowing groundwater.

Qafoku et al. (2014) also conducted a geochemical and mineralogical investigation of uranium in site NRZs, confirming the NRZ composition described by Campbell et al. (2012) while using alternative analytical techniques. The Qafoku et al. (2014) assessment reported that some of the solid-phase U(IV) present consisted of both crystalline uraninite and non-crystalline, monomeric U(IV). Of the two, uraninite was identified as being more resistant to mobilization in groundwater and, therefore, a more enduring contributor to uranium plume persistence over multiple decades and centuries. Both Campbell et al. (2012) and Qafoku et al. (2014) concluded that molecular diffusion of the dissolved uranium derived from oxidation of U(IV) in the NRZs further slows the release of U(VI) to the preferential flow paths that convey most of the contaminant mass discharging to the Colorado River. Both authors also posited that seasonal changes in hydraulic and chemical processes in the vadose zone played an important role in the release of uranium from the NRZs.

Column leaching tests by Mouser et al. (2015) using NRZ materials from the site further elucidated the slow release of uranium from naturally reduced sediments to through-flowing water. Measured uranium concentrations in the column effluent remained relatively stable and higher than the MCL over a 70-day time period. Results of the column testing also suggested that NRZs act primarily as long-term contaminant sources rather than potential sinks for any inflowing uranium from upgradient parts of the aquifer. Janot et al. (2016) characterized the sediment particle size and biogeochemistry of five cores containing NRZ materials and concluded that the reduced sediments were likely buried soil horizons similar to those observed today in near-river areas in the Colorado River Basin. A calculation in this study concluded that one of the described NRZs could sustain a uranium plume with concentrations equal to the MCL for somewhere between 259 and 1375 years. Both the Mouser et al (2015) and Janot et al. (2016) investigations indicated that oxidative conversion of U(IV) to dissolved U(VI) in naturally reduced sediments at Old Rifle was seasonal in nature and probably involved associated changes in vadose zone geochemistry.

The column tests by Mouser et al. (2015) presented evidence of rate-limited, or nonequilibrium, mass transfer of uranium from solid-phase materials to flowing groundwater, which was attributed to either molecular diffusion, as discussed above, or kinetically controlled desorption from aquifer sediments. As with diffusion, kinetic sorption processes further slow the natural flushing of uranium from the aquifer.

SFA 2.0 investigations from 2013 through 2016 have revealed a clearer picture of the temporal variations in uranium release from site NRZs as influenced by vadose zone processes. These studies examined the cycling of various nutrients in response to snowmelt-driven high flows in the Colorado River each May and June, which can temporarily increase groundwater levels in the alluvial aquifer by as much as 5 to 6 ft. Arora et al. (2016) used a variably saturated flow model combined with a biogeochemical reaction package to identify how the cycling of carbon at the site during spring and summer 2013 involved multiple chemical reactions in both unsaturated and saturated zones. The model accounted for observed changes in water chemistry at three different multi-well clusters oriented along a line extending south-southwest from the north border of the site to near the Colorado River. The data collected at the clusters showed that chemical changes above and within the NRZs were noticeably different from those associated with non-reduced sediments. The chemical reactions in the NRZs were both abiotic and microbially mediated, and were considered likely influences on the long-term fate of uranium in groundwater (Arora et al. 2016).

Danczak et al. (2016) tracked hydrologic and chemical changes at the same three multi-well clusters in 2014. Analysis of both chemical and microbial changes in the clusters indicated that snowmelt-induced water-table increases in May and June of the year led to the scavenging of two oxidants—dissolved oxygen and nitrate—from the vadose zone, which in turn were integral to redox and other reactions that liberated U(IV) from NRZs for mobilization of dissolved U(VI) in surrounding groundwater. In addition to the delivery of oxygen and nitrate from the unsaturated zone to the saturated zone, Danczak et al. (2016) showed that mill-related uranium mass normally residing in the vadose zone was also leached by the rising groundwater, contributing additional uranium contamination to the aquifer each year. This observation supported the hypothesis presented in the DOE groundwater remedy review (DOE 2011) that vadose-zone uranium represented a persistent contaminant source (Section 2.4.2.1). Using information presented in a geophysical survey of sediments on the west half of the site Wainwright et al. (2015) and Danczak et al. (2016) reported that about 3 percent of the total aquifer volume consists of NRZ sediments.

Yabusaki et al. (2017) incorporated the findings from the nutrient cycling and geochemical assessments described above in a three-dimensional model of variably saturated flow and reactive chemical transport in the entire alluvial aquifer. Future versions of the model should provide insight into uranium fate at the site; it has thus far been used to understand the complex biogeochemistry of site NRZs over the full year 2014. The hydrological and biogeochemical conceptual model that forms the basis for this simulation assumes that uranium mobilization from chemically reduced sediments is wholly dependent on the snowmelt-driven increase in groundwater levels each spring and early summer. Though the numerical model by Yabusaki et al. (2017) accounts for spatially and temporally variable surface-complexation desorption of uranium from alluvial sediment across the entire Old Rifle site, the apparent slow release of uranium to groundwater and the persistence of relatively stable uranium concentrations on the site's west side is mostly attributed to NRZ releases. The combined findings from models by Danczak et al. (2016) and Yabusaki et al. (2017) suggest that the annual snowmelt-induced oxidation of solid-phase U(IV) in chemically reduced sediments is sufficient to maintain dissolved U(VI) concentrations in the aquifer that perennially exceed the MCL for many years.

Aside from the biogeochemical assessments of site NRZs, work under SFA 2.0 identified two separate secondary sources of uranium in remnant tailings under U.S. Highway 6 on the north side of the site (Williams et al. 2015). The relative effects of the two sources, in separate supplemental standards zones within the larger supplemental standards area identified beneath the highway (Figure 5), were manifest in the temporal history of uranium concentrations in two SFA 2.0 wells at the base of the embankment on the highway's south shoulder. During the years 2013–2015, uranium concentrations in well SY08 (Figure 15) remained in a narrow range of about 0.2–0.3 mg/L, reflecting continuous leaching of remnant tailings in one of the supplemental standards zones. This consistent leaching of U(VI) each year was attributed to the fact that groundwater levels in this part of the site are always higher than the base elevation of the tailings zone. In contrast, uranium concentrations at well SY02 (Figure 15) fluctuated greatly over the same period, reflecting the fact that the local groundwater level only exceeded the base of the other tailings zone in response to very high snowmelt-driven flows on the Colorado River in spring and early summer. During and immediately following the high flows, U(VI) concentrations at this well increased to about 0.5–0.6 mg/L, and then gradually tapered off to about 0.02–0.007 mg/L in fall and winter months. These results showed that this second supplemental standards zone represented an episodic source of leached uranium, that fed into the groundwater system during May through July, but contributed much less U(VI) in other months (Williams et al. 2015). Regardless of the nature of the uranium source in the respective tailings zones, the temporal histories of U(VI) concentration at wells SY02 and SY08 indicated that remnant tailings beneath and adjacent to U.S. Highway 6 are likely to contribute uranium to the groundwater system for many decades. These sources would augment sources of uranium previously identified as inflows from sediments on the north side of the highway (Section 2.4.2.1).

Collectively, the SC-sponsored research under the IFRC and SFA 2.0 indicate that releases of uranium from secondary sources in the subsurface are slow yet persistent, and that NRZs play a particularly important role in maintaining uranium concentrations above the MCL for tens to hundreds of years. The combination of oxidation of solid-phase, reduced uranium [U(IV)] in the NRZs, limited diffusion rates for dissolved U(VI) in the low-permeability NRZs, and both steady and episodic uranium influxes from upgradient areas suggest that regulatory standards via natural flushing are unlikely to be achieved within the 100-year compliance period (Zachara et al. 2013).

2.4.4 Diffusion Contributions to Plume Persistence

Assessment of all likely transport processes in the Old Rifle alluvial aquifer suggests that molecular diffusion of uranium can, in several ways, contribute to its persistence in groundwater at relatively high concentrations. The preceding section described how diffusion slows the delivery of dissolved U(VI) from seasonally oxidized U(IV) in NRZs to surrounding, flowing groundwater. However, as suggested in numerous reviews of contaminant transport in groundwater (e.g., National Research Council 2013, Sale et al. 2013, Suthersan et al. 2016) and the DOE remedy review (DOE 2011), it is also likely that diffusion of U(VI) by itself, without any dependence on seasonal chemical reactions, is responsible for sustaining uranium concentrations in groundwater that perennially exceed the uranium MCL. This section highlights how diffusion and other rate-limited processes similar to diffusion potentially contribute to plume persistence at the site.

Two separate investigations attempted to quantify the degree to which diffusion in Old Rifle site alluvium would slow the delivery of U(VI) derived from oxidation of U(IV) to flowing groundwater. In a combined laboratory and field study, Campbell et al. (2011) used biogenic uraninite suspended in permeable sample cells within an IFRC well subject to groundwater through-flow to identify the rate of U(IV) depletion within the cells. They concluded that molecular diffusion causes the rate of uranium mobilization to be 50–100 times slower than occurs without diffusion limitations. Giammar et al. (2012) conducted multiple laboratory experiments aimed at singling out the effects of diffusion on mobilization of U(VI) derived from NRZs. Using water with a chemistry considered representative of the Old Rifle groundwater, their study suggested that diffusion-driven dissolution of uraninite was about 10 to 100 times slower in the field than normally observed in laboratory settings.

Given the history of the Old Rifle site, it is reasonable to conclude that slow diffusion of mill-related contaminants from lower permeability sediments to the mixed sands and gravels comprising preferential-flow paths in the alluvial aquifer is partially responsible for the relative stability of uranium concentrations observed over the past 18 years. Mass loading of contaminants to the aquifer occurred from tailings impoundments during two milling periods (1924–1932, 1942–1958) totaling about 25 years, and probably for multiple years thereafter. Though more than 50 years have since passed, the hydraulic and chemical conditions that existed in the aquifer during the mass loading were probably favorable for large amounts of uranium incursion into environments that, many years later, are inclined to release uranium primarily through diffusion or other processes that emulate diffusion (e.g., slow advection, kinetic desorption). During the years when large portions of the west half of the site were subject to ponding (e.g., Figure 4), large hydraulic heads above the ground surface and in underlying groundwater mounds likely drove contaminated tailings water deep into the subsurface, and potentially as deep as the Wasatch Formation bedrock underlying the alluvium. The stratified alluvium was thus subject to downward hydraulic gradients capable of advecting uranium deep into the finer-grained layers and lenses in the subsurface. In addition, the elevated concentrations of tailings leachate in the milling years created large concentration gradients across strata, enabling rapid molecular diffusion into low-permeability zones. The persistently high levels of dissolved uranium also facilitated long-term adsorption of U(VI) on both high- and low-permeability sediments. Laboratory experiments by Tokunaga et al. (2004) that specifically measured uranium movement into alluvial sediments using both highly acidic and very alkaline waters similar to those used for milling purposes indicated that the rate and distance of uranium diffusion into the sediments, and the total mass of adsorbed U(VI) in them, are increased in high-concentration groundwater in comparison to water with low uranium levels.

After milling ended, influx of fresher water from areas upgradient of the site eventually caused a reversal in uranium concentration gradient, such that diffusion was now mostly from lower-permeability materials to preferential flow paths. This reversal process, often referred to as back-diffusion (Chapman and Parker 2005, Parker et al. 2008, National Research Council 2013, Adamson and Newell 2014), takes place at a much slower rate than the diffusion into low-permeability sediments that occurs during the mass loading periods (e.g., Sale et al. 2008, Parker et al. 2008, Chapman et al. 2012, Suthersan et al. 2013). Accordingly, back-diffusion can be used to explain why the total mass of solid-phase uranium remains at a high level in the subsurface at Old Rifle and dissolved uranium in the alluvial aquifer persists at concentrations larger than the MCL.

Slow diffusion of uranium from aquifer sediments produces a gradually evolving stability of uranium concentrations in a groundwater system. The relative stability of observed uranium concentrations in Old Rifle site wells for the past 18 years (Sections 2.3.1 and 2.3.4) appears to be the result of such processes. When incorporated in a temporal plot of concentration at each well, the stability or very gradual decrease of uranium concentrations, observed long after surface remediation takes place, is frequently referred to as contaminant tailing (Chapman et al. 2012, Adamson and Newell 2014). This tailing might also be described as a slow decrease in measured uranium concentration values toward an asymptote, and, as a result, the uranium is said to exhibit asymptotic behavior (National Research Council 2013). This occurs because the collective rate of both uranium release from aquifer sediments and uranium contributions from offsite sources is equal to, or slightly less than, the rate at which flushing is occurring. Though molecular diffusion is certainly contributing to tailing in the alluvial aquifer at the Old Rifle site, it is likely that other processes capable of producing the same effects generated by diffusion also occur in the aquifer. These diffusion-like mechanisms include slow advection of contamination from low-permeability materials to preferential flow paths (e.g., Suthersan et al. 2013) and kinetic desorption (e.g., Liu et al. 2009) of a contaminant.

As mentioned in the 2011 groundwater remedy review (DOE 2011), dual-domain phenomena are thought to provide a plausible explanation for the slow mobilization of uranium from lower-permeability sediments to preferential flow paths in the Old Rifle aquifer. Though mass transport between the mobile and immobile domains in the dual system is attributed primarily to diffusion, the actual transfer is rarely simulated using molecular diffusion coefficients and concentration gradients. Rather, the mass exchange is approximated by multiplying the difference in concentration between the mobile domain and the immobile domain in each model cell by a mass transfer coefficient with units of $time^{-1}$. In more advanced simulators, each model cell is divided into one mobile domain and two or more immobile domains (e.g., Ma et al. 2010, Suthersan et al. 2016), and a different mass transfer coefficient is used for each of the immobile domains. This multiple-rate mass transfer approach (e.g., Haggerty and Gorelick 1995, Hay et al. 2011) can also be used to account for rate-limited processes other than diffusion. While attempting to model the combined transport of bicarbonate and dissolved U(VI) during an IFRC field investigation at Experimental Plot B (Figure 15), Fox et al. (2012) found that accurate simulation of the sorption of U(VI) on aquifer sediments required the use of both a surface complexation sorption model and a multiple-rate mass transfer model representative of kinetic sorption. It is possible that multiple-rate mass transfer would be integral to quantitatively evaluating the persistence of uranium contamination on a sitewide scale.

Rate-limited mass transfer from intragranular porosity in alluvial sediments (e.g., Ma et al. 2010, Hay et al. 2011) is also expected to slow the natural flushing of uranium from the Old Rifle site. This nonequilibrium release mechanism consists of diffusion of dissolved U(VI) from immobile water in pore space within and on individual sediment grains (fractures, dead-end pores, mineral surface coatings) into surrounding groundwater (National Research Council 2013). Though the pore space in sediment grains typically accounts for about 1 percent or less of total aquifer porosity, it can have a strong influence on uranium plume persistence because intragranular surface area can contain as much as 30 percent of the total reactive surface area in an aquifer (Hay et al. 2011). Zachara et al. (2013) identified diffusion across mineral coatings of grain surfaces in organic-rich sediments as a cause of uranium recalcitrance at the Old Rifle site.

The above-mentioned findings from SFA 2.0 research and the scientific literature on groundwater remedies indicate that diffusion and other "diffusion-like" processes are significant contributors to uranium plume persistence at the Old Rifle site. It is noteworthy that several published papers over the past 40 years on the modeling of contaminant attenuation at environmental sites (e.g., Gillham et al. 1984, Labolle and Fogg 2001, Hadley and Newell 2014) discuss why advection and molecular diffusion, rather than dispersion, are the most important physical processes to evaluate when assessing the long-term fate of contamination in groundwater at a site.

2.4.5 Updated Conceptual Model

The conceptual model of groundwater processes at the Old Rifle site can be updated using all the work that has been conducted to characterize flow, transport, and biogeochemical processes in the alluvial aquifer. The aquifer is heterogeneous, with hydraulic conductivities that span 3 to 5 orders of magnitude, suggesting that most groundwater flow occurs in preferential flow paths that are supplied with uranium from less permeable zones. The groundwater flow system is naturally transient, and increases in water levels each spring and early summer are instrumental in the oxidation of solid-phase U(IV) in NRZs and subsequent diffusion of dissolved U(VI) into surrounding groundwater. Several chemical reactions, in both the vadose and saturated zones, are involved in the seasonal oxidative release of uranium from site NRZs. Sorption of uranium on aquifer sediments is dependent on spatially and temporally variable chemistry of the groundwater. Desorption can also be rate-limited, or kinetic, which slows the natural flushing of uranium from the subsurface to the river. A combination of surface-complexation modeling and multiple-rate mass transfer between mobile and immobile zones can be used to better understand both diffusion and desorption contributions to uranium plume persistence at the site. Diffusion processes slow the transport of uranium from low-permeability sediments and NRZs to preferential flow paths, and from intragranular porosity to groundwater, leading to contaminant tailing and asymptotic behavior at individual site wells.

Table 2 summarizes the various hydrogeological conditions and flow and biogeochemical processes that contribute to uranium persistence at the site. The processes listed in this table and uranium concentration data for the Old Rifle site during the past 18 years indicate that natural flushing is unlikely to reduce uranium levels in many site monitoring wells to concentrations less than or equal to the MCL over the next 100 years.

2.5 Human Health and Environmental Risks

Baseline risks associated with the Old Rifle site were assessed in the SOWP (DOE 1999). The risk assessment concluded that use of groundwater as a drinking water source was unacceptable. It was also determined that site conditions presented no complete pathways by which site-related contamination could adversely affect ecological receptors.

Site conditions can be summarized as follows:

- The alluvial aquifer contamination is confined to the Old Rifle site and is isolated from any other aquifers—it is bounded both laterally and vertically.
- ICs prohibit any use of site groundwater.
- Water from the aquifer discharges to the Colorado River (the only potentially complete point of exposure to site-related constituents), where any site-related contamination rapidly mixes with river water. River water quality adjacent to the site is indistinguishable from background surface water quality. The estimated dilution factor for the river is on the order of 3×10^{-5} under average flow conditions (DOE 1999).
- Uranium concentrations in site groundwater since completion of surface remediation have consistently been less than 1 mg/L. Given these relatively low groundwater concentrations and the high degree of dilution with discharge to the river, it is virtually impossible for site-related contamination to have an adverse impact on river water quality. The surface water quality standard for the river is 0.03 mg/L based on its use as a source of drinking water (CDPHE Regulation No. 31).

Table 2. Hydrogeological Conditions and Transport Processes Contributing to Uranium Persistence in Old Rifle Site Groundwater

Factors and Processes		Description	Significance
		Aquifer/Site Characteristics	
Geology	Aquifer Media/Depth/Stratification	• Total aquifer depth 20–25 ft; saturated thickness under background conditions 7–10 ft. • Largely sands, gravels, and gravelly sand, but also fine-grained sands, silty sands, sandy silts, silt and clays.	• Organic matter in some fine-grained sediments has led to the development of chemically reduced sediments referred to as NRZs. • Heterogeneity of strata leads to slow flow in fine-grained, low permeability zones and high flow in coarse-grained (high- permeability zones. • Heterogeneity creates preferential flow paths, and dual-domain or multiple-domain flow systems). • Seasonal changes in flow direction cause contaminant spreading and increase subsurface volume of U contamination.
	Physical Heterogeneity	• Stratified. • Fine-grained sediments occur as continuous layers and discontinuous lenses.	
Hydraulics/Flow	Flow Dimensions and Directions	• Predominantly horizontal flow under background groundwater conditions. • Flow is mostly toward the south-southwest, but seasonal changes occur.	
	Hydraulic Conductivity	• Can vary 4 to 5 orders of magnitude (approximately 0.01 ft/day to 50–100 ft/day).	
	Transient flow	• Groundwater elevation increase of 4–6 ft during spring snowmelt flow in the Colorado River. • Change in flow direction up to 90 degrees or more during high river stage.	• Periodic wetting of higher elevation sediments causes leaching of U, change in groundwater chemistry (oxidizing). • Release of U due to elevated groundwater elevations happens only seasonally. • Change in flow direction works against natural flushing.
Site Use	Primary Sources	• Primary sources located across the site (high U).	• Primary sources contributed dissolved U directly to groundwater. • High rates of contaminant mass loading to the aquifer (groundwater and aquifer sediments) occurred during milling years.
	Release Duration	• Created strong vertical gradient under ponds, tailings. • Strong concentration gradients from surface sources to underlying sediments. • Primary sources in the form of tailings and raffinate ponds were present for more than two decades; leaching of remaining tailings by precipitation continued for decades after milling ended.	
	Surface Remediation	• Most primary contaminant sources (tailings, raffinate ponds, mill buildings, ore piles) were removed.	• Secondary sources of U remain primarily in low-permeability sediments.
		Residual Contamination Characteristics	
Contaminant Distribution (resulting from site use superimposed on starting groundwater conditions)	Contaminant phases	• U occurs in solid and dissolved phases. • Solid-phase U(IV) is immobile and occurs only in NRZs. • Mobile U(VI) is dissolved in groundwater; solid-phase U(VI) is adsorbed on aquifer sediments.	• Majority of U mass is retained in low permeability zones (both NRZs and non-NRZs) which serve as persistent reservoirs; U is transferred slowly back to high-permeability sediments through various processes. • Much of the U in in water migrated into NRZs and was chemically reduced to immobile U(IV).
	Dual Domain/Multiple Domains	• System conceptualizations and model constructs that attempt to account for the flushing of U due to non-equilibrium mass transfer between various subsurface media and preferential flow paths. • Dual domain assumes U transport in each model cell can be simulated by advection in a single mobile domain that exchanges U mass with less-permeable media in a single immobile domain. • The rate of transfer between the domains is governed by a single mass transfer coefficient that is assigned to the immobile domain. • Multiple-rate mass transfer simulates transport in a single mobile domain that exchanges U mass with multiple immobile domains, with a different mass transfer coefficient assigned to each immobile domain.	
	Spatial Extent of Contamination	• Elevated uranium concentrations occurred in groundwater across the entire site. • U was and continues to be distributed in both groundwater as dissolved U(VI) and the solid phase as adsorbed U(VI) and U(IV) in aquifer sediments throughout the aquifer.	• Virtually the entire aquifer is a secondary source of U contamination, in both high- and low-permeability zones.
Secondary Sources	Naturally Reduced Zones (NRZs)	• Microbially mediated redox reactions cause the oxidative conversion of solid-phase U(IV) back into dissolved U(VI) that slowly diffuses into flowing groundwater. • Solid-phase U occurs as both crystalline uraninite and non-crystalline, monomeric U(IV); most of the oxidative dissolution of U(IV) is attributed to the monomeric form.	• U(IV) in NRZs is released due to seasonal increases in groundwater elevation, which create oxidizing conditions and the conversion of U(IV) to U(VI). • Some NRZs occur in deeper portions of the aquifer; oxidative conversion of U(IV) to U(VI) in the deeper zones probably occurs less frequently than in shallow parts of the saturated zone. • Uraninite is more resistant to oxidation than non-crystalline U(IV) and, therefore, a more persistent source of dissolved uranium.
	Low-Permeability Sediments	• Adsorbed U(VI) and dissolved U(VI) in low-permeability sediments other than NRZs are additional secondary sources of uranium.	• U(VI) is released slowly through back-diffusion processes.
	Remnant Tailings and Offsite flows	• Tailings remain in supplemental standards areas on the north side of the site. • Water with elevated U concentrations from sources north of the site flows into and mixes with site groundwater.	• U(VI) is released through both steady, continuous leaching of some remnant tailings (0.3 mg/L U) and episodic leaching of higher-elevation tailings (0.6 mg/L U). • Background U concentration up to 0.055 mg/L in inflowing groundwater observed.

Table 2. Hydrogeological Conditions and Transport Processes Contributing to Uranium Persistence in Old Rifle Site Groundwater (continued)

Factors and Processes		Description	Significance
		Contaminant Release	
Chemical and Physical Properties and Processes	Chemical Reactions	• The types of chemical reactions involved in the oxidative conversion of solid-phase U(IV) to dissolved U(VI) range from abiotic to heterotrophic and autotrophic, and involve a wide spectrum of microbes. • The types of reactions include precipitation, dissolution, fermentation, denitrification, iron reduction and oxidation, sulfate reduction and sulfide oxidation. • Chemical reactions also occur in non-NRZ areas, but, because the concentration of dissolved organic carbon is low in these areas, these reactions are abiotic. • Chemical reactions occur in the subsurface throughout the entire Old Rifle Site.	• Uranium is present in sediments throughout the alluvial aquifer, in both lower permeability and higher permeability strata. Uranium is released from secondary sources by a variety of processes, which vary both spatially and temporally. • Back-diffusion of dissolved U(VI) from low-permeability sediments to flowing groundwater is slower than the mass loading processes that delivered U(VI) to low-permeability sediments during milling years. • Processes releasing U to preferential flow paths are much slower than previously thought. • Temporal plots of long-term U concentration at individual wells show that concentrations have either stabilized or are decreasing slowly; the concentrations and are said to exhibit contaminant-tailing, or asymptotic, behavior.
	Surface Complexation Sorption	• Sorption of U(VI) on aquifer solids is a chemistry-dependent process that varies with local pH and calcium, bicarbonate, and uranium concentrations. • Surface complexation models for uranium developed using sediment samples from the Old Rifle site show the linear, equilibrium soil-water distribution coefficient (Kd) for U(VI) can vary by more than an order of magnitude, from 0.5 mL/g to 20 mL/g. • Surface-complexation sorption occurs in the subsurface throughout the entire Old Rifle Site (not just in NRZs).	
	Rate-Limited Mass Transfer/Molecular Diffusion (collectively referred to as back-diffusion)	Back-diffusion processes include: • Diffusion of dissolved uranium derived from the oxidative dissolution of U(IV) in NRZs and subsequent release of U(VI) to flowing groundwater. • Diffusion of dissolved U(VI) from low-permeability zones, that is not dependent on chemical reactions, and is simulated as a nonequilibrium form of mass transfer. • Diffusion of dissolved U(VI) derived from desorption in intragranular porosity (e.g., grain fractures, dead-end pores, mineral grain coatings), representing another type of nonequilibrium mass transfer.	
	Rate-Limited Mass Transfer/Diffusion-like Processes	Diffusion-like processes include: • Slow advection of dissolved U(VI) from low-permeability sediments to high-permeability sediments. • Kinetic desorption of U(VI) from both fine-grained and coarse-grained sediments.	

U = uranium, U(IV) = solid-phase, tetravalent uranium, U(VI) = hexavalent uranium, NRZ = naturally reduced zone, ft = feet, foot

Because of restrictions prohibiting groundwater use (see Section 3.2), it can be concluded that current site conditions are protective of human health and the environment. At most wells, contaminant concentrations in groundwater have been stable for more than a decade, and those conditions are expected to continue. No adverse site-related effects have been observed in the Colorado River (the only point of exposure). Therefore, protectiveness will be maintained as long as ICs restrict groundwater use. The alluvial aquifer at the Old Rifle site has not been used for any beneficial purpose (other than monitoring conducted for research projects). With the Colorado River as a plentiful and high-quality source of water, the need for alluvial groundwater use in the future, particularly from an aquifer that is so limited in volume, is highly unlikely.

The Colorado River is designated critical habitat for two species of endangered fish—the Colorado pikeminnow (*Ptychochielus Lucius*) and razorback sucker (*Xyrauchen texanus*) (USFWS website; https://ecos.fws.gov/ecp0/reports/species-by-current-range-county?fips=08045). The segment of the Colorado River that runs through the Rifle area is the uppermost reach of designated critical habitat for these species. Because any site-related contamination that discharges to the Colorado River is quickly diluted, the site will not have any impact on these species or any other terrestrial or aquatic receptors.

No evidence has been observed to date that site-related contamination has resulted in degradation of river water quality. Based on this analysis, the only driver for groundwater remediation at the Old Rifle site is the achievement of regulatory standards. Current site conditions, which incorporate the use of ICs, are protective of human health and the environment for present and projected future site uses.

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3.0 Groundwater Compliance

DOE is required to follow the compliance strategy selection framework described in Section 2.1 of the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (DOE 1996). NRC has accepted the compliance strategy framework and has incorporated it into their guidance for review of compliance at UMTRCA Title I sites with contaminated groundwater (NUREG-1724, NRC 2000). Based on the Programmatic Environmental Impact Statement framework, compliance strategies will be reevaluated if conditions change or if monitoring indicates that EPA groundwater standards will not be met. Section 2.4 presented information indicating that the current compliance strategy of natural flushing is not likely to achieve the UMTRCA standard for uranium. A revised compliance strategy is presented in this section.

3.1 Compliance Strategy Selection

The uppermost aquifer at the site is defined as the alluvial aquifer and the upper, weathered Wasatch Formation that is hydraulically connected with the alluvium. The deeper Wasatch Formation is not contaminated at the Old Rifle site and is therefore not considered in the development of a compliance strategy.

As discussed in Section 2.2, the components of the existing compliance strategy are:

- Modeling indicated that natural flushing of the uppermost aquifer would meet the MCL for uranium of 0.044 (mg/L) or the background value within a 10-year period (starting in 1998).
- Modeling also indicated that the proposed selenium ACL (the primary drinking water standard of 0.05 mg/L) would be achieved within a 50-year period.
- A vanadium ACL of 1.0 mg/L was established based on historical maximum values; the vanadium ACL was met at the time it was established.
- Onsite wells were considered to be POC locations; the Colorado River was established as the point of exposure.
- ICs were selected as an additional component of the compliance strategy to restrict groundwater use at the site during the natural flushing period and ensure protectiveness of the vanadium ACL.

Based on the results of continuing studies and new characterization work (presented in DOE 2012 and discussed in Section 2.4 of this GCAP), the conceptual model for the Old Rifle site has changed significantly and shows that the natural flushing approach is unlikely to achieve compliance. DOE has therefore determined that no remediation is required and that application of ACLs for uranium, vanadium, and selenium is the most appropriate compliance strategy for this site (Figure 16, Box 7 of this document). As discussed in Section 3.2, the ACLs proposed in this GCAP have a different basis than those proposed in the 2001 GCAP and do not rely on natural flushing.

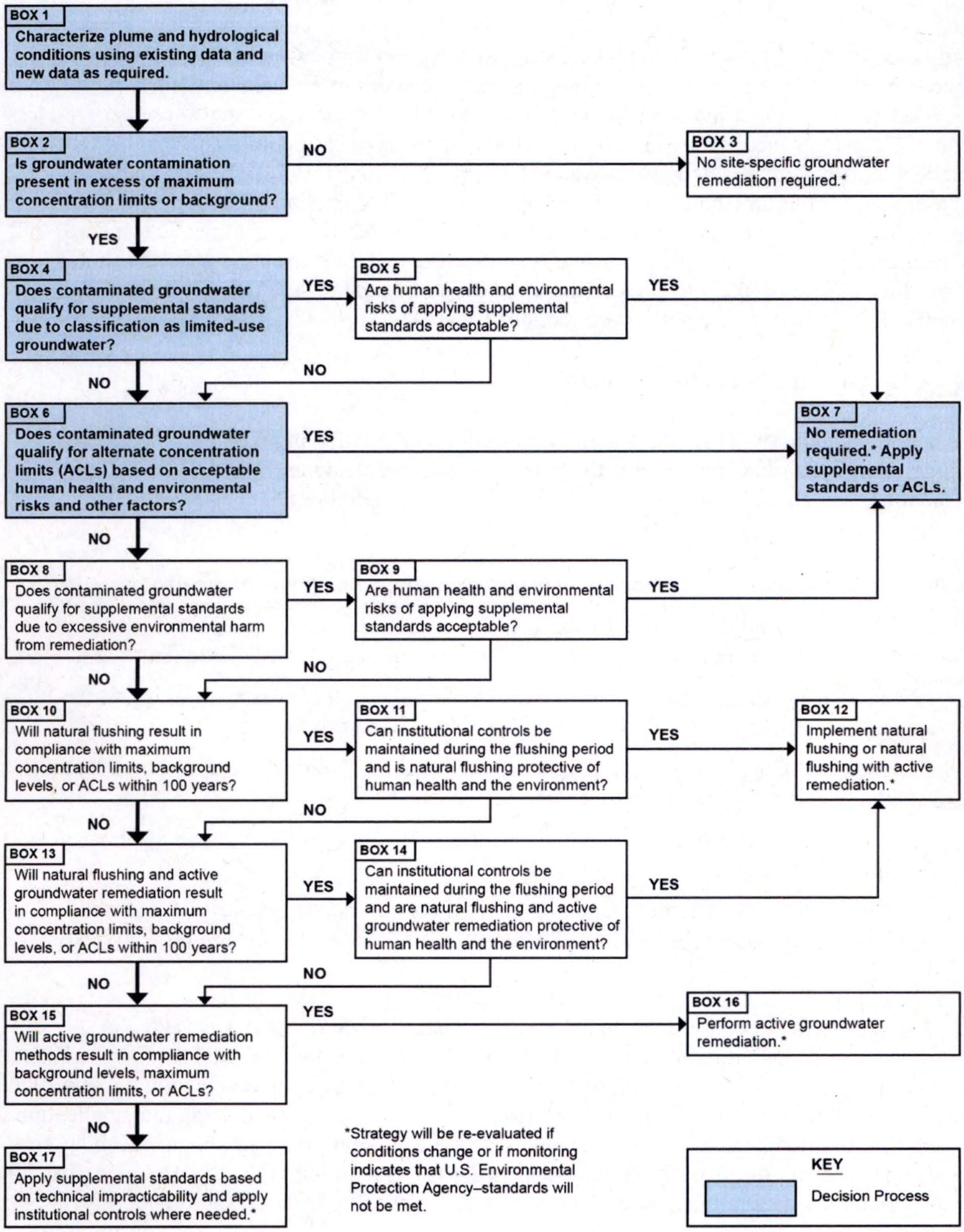


Figure 16. Compliance Selection Framework for the Old Rifle Site (The preferred path is shaded.)

DOE followed the groundwater compliance strategy selection framework summarized in Figure 16 for determining the appropriate compliance strategy for groundwater in the alluvial (uppermost) aquifer at the Old Rifle site. DOE has determined that current and projected future site conditions are protective of human health and the environment (Section 2.5). Therefore, the proposed compliance strategy for the alluvial aquifer at the Old Rifle site for all constituents is no remediation with the application of ACLs, the implementation of institutional controls (Section 4.2), and continued monitoring (Section 4.1). An explanation of the strategy is summarized in Table 3.

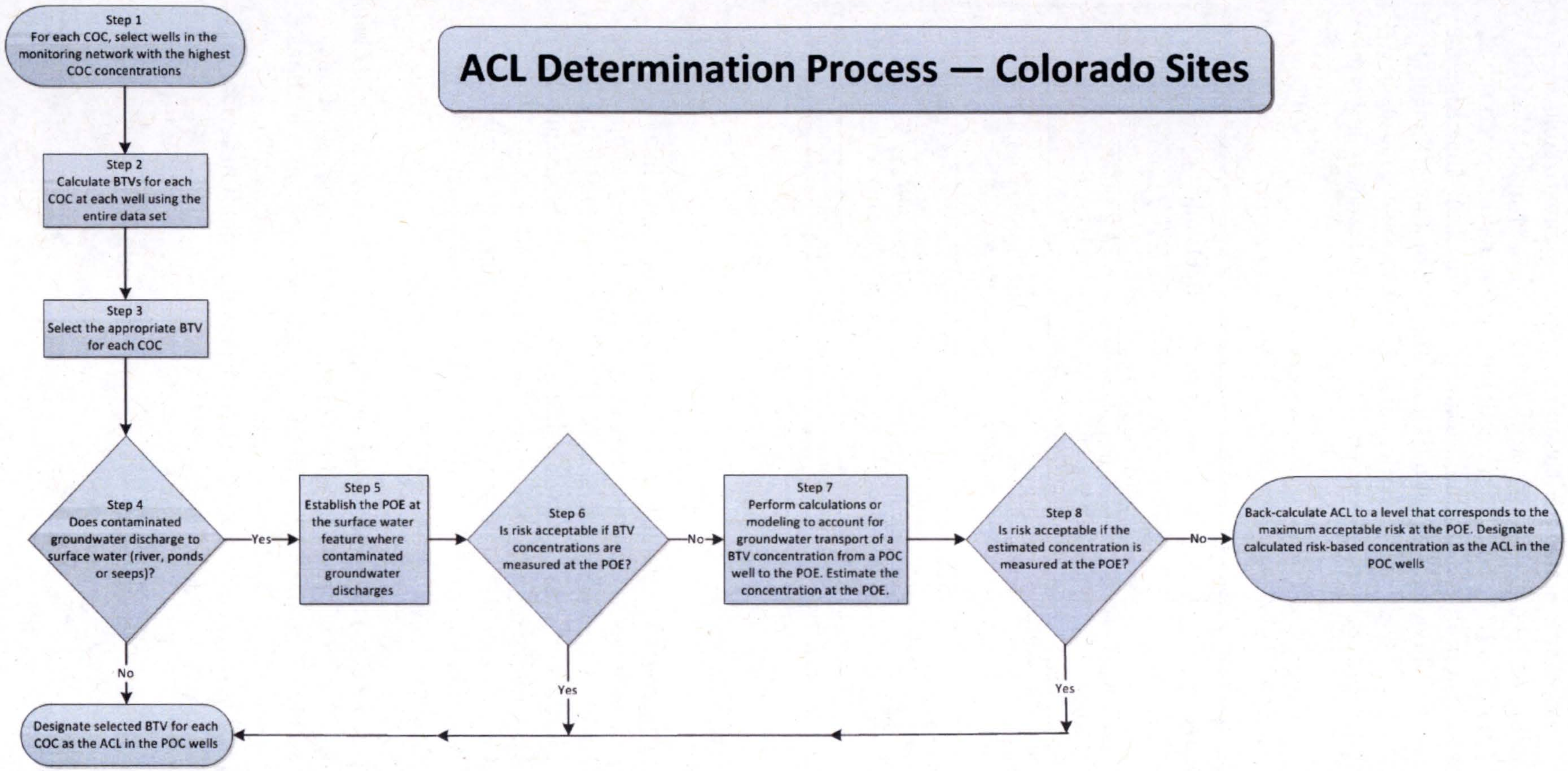
Table 3. Explanation of Compliance Strategy Selection Process

Box Figure 16	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions.	See discussion of hydrology and site-related contamination in Sections 2.3 and 2.4. Move to Box 2.
2	Is groundwater contamination present in excess of 40 CFR 192 MCLs or background?	Selenium and uranium exceed the 40 CFR 192 MCLs at one or more monitoring points. Vanadium has exceeded its risk-based concentration. Move to Box 4.
4	Does contaminated groundwater qualify for supplemental standards due to its classification as limited use groundwater?	Alluvial groundwater is not classified as limited use, so supplemental standards do not apply. Move to Box 6.
6	Does contaminated groundwater qualify for ACLs based on acceptable human health and environmental risk and other factors?	Institutional controls prevent improper use of contaminated groundwater. Discharge of groundwater to the Colorado River does not affect surface water quality. Groundwater poses no unacceptable risks to human health or the environment. Apply alternate concentration limits.
7		No remediation required. Apply supplemental standards or ACLs.

3.2 Establishment of ACL Values

DOE and CDPHE developed an approach to establish numerical values for ACLs in a manner that satisfies requirements of both agencies. A decision flow chart was developed to provide a consistent and defensible method for determining ACLs at UMTRCA sites located in the state of Colorado. A generic flow chart for this process is shown in Figure 17. Generally, the approach involves selecting a well or wells with the highest historical concentrations of the COCs. Statistical analysis of historical data is then used to compute numerical values that may be suitable for use as ACLs. POC locations are identified where ACLs apply. ACLs must be demonstrated to be protective at point-of-exposure locations.

Existing NRC and EPA ACL guidance does not specify or recommend any particular statistical tests for establishing ACL values. A review of NRC-approved ACLs for Title II sites indicates that ACL values are most commonly set on the basis of maximum groundwater concentrations associated with source areas at a site (e.g., WNI 1999; Umetco 2001; Pathfinder 2002). Oftentimes the numerical values for ACLs are based on a statistical evaluation of historical site data.



Notes:

- BTV = Background threshold value
- This proposed approach applies to Title I processing sites in Colorado.
- ICs are in place that encompass site-related groundwater plumes; therefore, there is no unacceptable exposure to contaminated groundwater, and the only potential exposure is where groundwater discharges to the surface.
- ACL is based on actual monitoring data using accepted statistical methods — the ACL will be based on the appropriate BTV calculated for each COC (one ACL for each COC) and applied to all POC wells.
- Entire data set (including pre-surface-remediation data) will be used to calculate the USL_{95} to account for residual source that could be mobilized by high water levels or construction activities.
- If the selected BTV is protective (based on available benchmarks), then modeling or risk assessment is not required.
- If risk needs to be assessed, receptors and risk scenarios need to be identified.
- Modeling or calculations may be required to estimate the concentration at the POE accounting for dilution, dispersion, and attenuation as groundwater migrates from the POC to the POE.

Figure 17. ACL Determination Process—Colorado Sites

EPA's *ProUCL Version 5.0.00 Technical Guide* (EPA 2013) discusses statistical measures that are commonly used as "background threshold values" (BTVs). These measures are typically used to estimate the upper limits of a background dataset for use in detection monitoring programs at potentially contaminated sites. An exceedance of a BTV is generally considered to be evidence of site-related contamination and is often used to trigger corrective action. EPA describes several commonly used BTVs, including upper percentiles, upper prediction limits (UPLs), upper tolerance limits (UTLs), and upper simultaneous limits (USLs). These measures are usually assigned confidence coefficients that reflect the degree of confidence that the true value of the parameter is contained within these estimated limits. The most commonly used confidence coefficient for these limits is 0.95 (e.g., a 95% USL, or USL95). Additionally, a coverage probability (i.e., a confidence coefficient associated with the UTL itself) is specified for a UTL. A 0.95 coverage probability is commonly used (e.g., a 95% UTL with 95% coverage, or a UTL95-95).

Both parametric and nonparametric BTVs are available and are calculated by ProUCL. Nonparametric tests do not require a specific data distribution but may not provide the specified coverage when sample sizes are small (<60; EPA 2013). Parametric statistical tests assume some underlying distribution of the observed data. While a normal distribution is often chosen as the default for statistical testing, other distributions may be more appropriate for application to environmental data. Gamma and lognormal distributions have both been used for this purpose (Gilbert 1987). EPA notes that in corrective action monitoring, where groundwater is known to have been impacted, a default presumption of lognormality can often be made. However, rather than deferring to an assumed default distribution, EPA recommends using a goodness-of-fit test when the dataset is of ample size (8 or more; EPA 2009). ProUCL performs these goodness-of-fit tests for normal, gamma, and lognormal distributions.

EPA (2013) discusses advantages and disadvantages of various BTVs. UPL95s are commonly used for detection and compliance monitoring purposes (e.g., Gibbons 1990, 1991; ASTM D7048-04). However, to correctly apply this measure, it is necessary to specify in advance the number of future measurements (k) to which the UPL95 will be compared; the computed UPL95 is valid only for that number of comparisons. For example, a facility may collect four upgradient (background) and four downgradient samples each year and do a yearly comparison of all background and downgradient wells ($k = 1$). The UPL95 would be computed using previous background data, if any, plus the four new analyses. The UPL would be valid for only the one end-of-year comparison. A new UPL would be computed for the next year's comparison after collecting four additional background samples.

For the Old Rifle site, it is desirable to have a single value for an ACL that can be used for an unspecified number of future comparisons. Generally, when a BTV is needed to compare with many future observations, EPA recommends the use of a USL95 or UTL95-95 over a UPL (EPA 2013). A parametric UTL is recommended over a nonparametric UTL, although it is noted that a lognormal UTL can produce "unrealistically high" values. A USL95 tends to result in fewer false positives than a UTL95-95, particularly with a larger dataset. There is no single "right" statistic for use in any particular situation. The selection should be based on whether a value seems "reasonable" for its intended purpose (EPA 2013).

Upper threshold statistics were computed using EPA's ProUCL software (EPA 2013, version 5.0.00). Well RFO-0305 had the highest historical concentrations for the three constituents requiring ACLs. Duplicate analyses were eliminated, but otherwise, all data available for well RFO-0305 were used. There were no nondetects in the dataset for the constituents of interest. ProUCL calculates multiple BTVs assuming different distributions of the data (e.g., normal, lognormal). Nonparametric statistics are also calculated. Table 4 summarizes the statistical results for well RFO-0305 for the COCs. ProUCL output is included in Appendix D.

The data for selenium did not conform to a normal distribution. Selenium data did appear to approximate both a gamma and lognormal distribution at the 5% significance level. Data for uranium and vanadium appeared to approximate all distributions at the 5% significance level.

Table 4. Upper Threshold Statistics for Source Area Well RFO-0305

Distribution	Statistic	Selenium	Uranium	Vanadium
Normal	UTL95-95	0.0905	0.313	0.874
	USL95	0.109	0.347	1.008
Gamma	WH UTL95-95	0.0968	0.317	0.974
	HW UTL95-95	0.0987	0.318	0.994
	WH USL95	0.129	0.361	1.21
	HW USL95	0.134	0.363	1.255
Lognormal	UTL95-95	0.107	0.321	1.08
	USL95	0.16	0.372	1.456
Nonparametric	UTL95-95	0.122	0.36	0.877
	USL95	0.122	0.36	0.877

The nonparametric USL is proposed as the ACL for selenium and uranium. This statistic does not require conformance to a particular distribution. Values of this statistic for selenium and uranium are 0.122 mg/L and 0.36 mg/L, respectively. The nonparametric USLs are neither the highest nor lowest candidate values. They appear to be sufficiently high to prevent excessive false positives in the future. The already approved ACL value of 1.0 mg/L for vanadium is within the range of applicable statistical measures. Therefore, no change to the vanadium ACL is proposed.

4.0 Compliance Strategy Implementation

4.1 Groundwater Monitoring

Monitoring is proposed to further demonstrate the stability of the groundwater system and compliance with the proposed ACLs. The proposed network consists of monitoring wells 0292A, 0304, 0305, 0309, 0310, 0655, 0656, and 0658; surface locations 0538, 0396, and 0741 on the Colorado River; and seep/surface locations 0395 and 0398 (Table 5 and Figure 6) to be augmented by other groundwater and surface locations as needed. Locations will be monitored annually for selenium, uranium, and vanadium the first 5 years. If little variation in concentrations is observed in the first 5 years, monitoring frequency will be reduced to every 5 years for the next 30 years. After that time, the monitoring strategy will be reevaluated. If concentrations vary considerably or show significant increasing trends after the first 5 years, the monitoring strategy will be reevaluated at that time. DOE will consider discontinuing monitoring when sufficient monitoring data have been accumulated to demonstrate that potential exceedances of an ACL are highly improbable.

Table 5. Summary of Monitoring Requirements

Location	Monitoring Purpose	Analytes	Frequency
RFO-0305, -0655	Center of plume, west side of ditch	Se, U, V	Annually for first 5 years; at least every 5 years for the next 30 years
RFO-0656	Center of plume, east side of ditch	Se, U, V	Annually for first 5 years; at least every 5 years for the next 30 years
RFO-0304, -0309, -0310	Downgradient edge of plume	Se, U, V	Annually for first 5 years; at least every 5 years for the next 30 years
RFO-0292A, -0658	Background groundwater quality; upgradient wells	Se, U, V	Annually for first 5 years; at least every 5 years for the next 30 years
RFO-0398, -0395	Background surface or seep water recharging onsite aquifer	Se, U, V	Annually for first 5 years; at least every 5 years for the next 30 years
RFO-0538,- 0396, -0741	Upgradient, adjacent to site, and downgradient locations along the Colorado River, respectively; monitor effect of site contaminants on river water	Se, U, V	Annually for first 5 years; at least every 5 years for the next 30 years

4.2 Institutional Controls

Residual contamination will remain in the groundwater for an extended period; therefore, it is critical that restrictions on groundwater use be maintained to ensure protectiveness of the remedy. ICs are enforceable mechanisms for implementing these restrictions. Groundwater contamination at the Old Rifle site has not migrated into any offsite aquifers; it discharges directly into the Colorado River where it rapidly mixes with river water. Therefore, ICs only need to be applied within the site boundary. Multiple layers of ICs restricting groundwater use have been established for the Old Rifle site. Copies of all ICs are provided in Appendix A, "Institutional Controls for the Old Rifle Site."

This section describes the three ICs—quitclaim deed restrictions, environmental covenant (EC), and the Uranium Mill Tailings Remedial Action (UMTRA) Overlay Zone District—and the general requirements for verifying their performance.

4.2.1 Quitclaim Deed (2003)

Along with transfer of the property from the State of Colorado (Grantor) to the Grantee (City of Rifle), eight requirements are listed in the last paragraph of the deed. As stated in the deed, the City agrees:

(i) to comply with applicable provisions of UMTRCA, 42 U.S.C.7901 et. seq., as amended;

(ii) not to use groundwater from the site for any purpose, and not to construct wells or any means of exposing groundwater to the surface unless prior written approval for such use is given by the Grantor and U.S. Department of Energy;

(iii) not to sell or transfer the land to anyone other than a governmental entity within the state;

(iv) that any sale or transfer of the property described in this deed shall have prior written approval from the Grantor and the U.S. Department of Energy; and that any deed or other document created for such sale or transfer and any subsequent sale or transfer will include information stating that the property was once used as a uranium milling site and all other information regarding the extent of residual radioactive materials removed from the property as required by Section 104(d) of the Uranium Mill Tailings, 42, U.S.C. § 7014(d), and as set forth in the Annotation attached hereto;

(v) not to perform construction and/or excavation or soil removal of any kind on the property without permission from the Grantor and the U.S. Department of Energy unless prior written approval of construction plans (e.g., facilities type and location) is given by the Grantor and the U.S. Department of Energy;

(vi) that any habitable structures constructed on the property shall employ a radon ventilation system or other radon mitigation measures;

(vii) that its use of the property shall not adversely impact groundwater quality, nor interfere in any way, with groundwater remediation under UMTRCA activities; and

(viii) to use the property and any profits or benefits derived therefrom only for public purposes as required by UMTRCA § 104 (e)(1)(C), 42 U.S.C. 7914 (e)(1)(C).

4.2.2 Environmental Covenant (2003)

CDPHE executed an EC pursuant to §C.R.S. 25-15-321 et seq. It specified four use restrictions (listed below) and provides the statutory process for modification or termination of the EC. The use restrictions stipulated in the EC are as follows:

A. No habitable structure may be constructed on the property without properly designed radon mitigation as approved by the Department.

B. Wells completed in the alluvial aquifer or the Entrada formation may not be used for domestic or potable water supplies.

C. No tilling, excavation, grading, construction, or any other activity that disturbs the ground surface is permitted on the Property, without the express written consent of the Department and the U.S. Department of Energy.

D. No activities that will in any way damage any monitoring or remedial wells installed by the Department of Energy, or interfere with the maintenance, operation, or monitoring of said wells is allowed, without the express written consent of the Department and the U.S. Department of Energy.

4.2.3 UMTRA Overlay Zone District, Ordinance No. 9 Series of 2008

The City of Rifle created the UMTRA Overlay Zone District and included in the district the Old (East) and New (West) Rifle sites. The purpose of the district was to establish procedures and restrictions governing development of the properties under the new municipal code (Section 16-3-540 of Ordinance No. 9, Series of 2008). The new ordinance lists six restrictions (provided below) and provided eight standard operating procedures (SOPs) for conducting activities within the UMTRA Overlay Zone District (i.e., the Old and New Rifle sites). The restrictions placed on the site include:

1. Ground water from the site shall not be used for any purpose, nor shall anyone construct wells or any means of exposing ground water to the surface unless prior written approval for such use is given by the Colorado Department of Public Health and Environment ("CDPHE) and the U.S. Department of Energy ("DOE).
2. The land shall not be sold or transferred to anyone other than a governmental entity within the state.
3. Any sale or transfer of the property described in this deed shall have prior written approval from the CDPHE and the DOE; and that any deed or other document created for such sale or transfer and *any* subsequent sale or transfer will include information stating that the property was once used as a uranium milling site and all other information regarding the extent of residual radioactive materials removed from the property as required by Section 104(d) of the Uranium Mill Tailings Radiation Control Act, 42 U.S.C. Sec. 7014(d), and as set forth in the Annotation attached hereto.
4. Construction and/or excavation or soil removal of any kind shall not occur on the property without permission from the CDPHE and DOE unless prior written approval of construction plans (e.g., facilities type and location), is given by the CDPHE and DOE.
5. Any habitable structures constructed on the property shall employ a radon ventilation system or other radon mitigation measures.
6. Use of the UMTRA sites shall not adversely impact groundwater quality, nor interfere in any way, with groundwater remediation under UMTRCA Sec. 104(e)(1)(c), 42 U.S.C. Sec. 7914(e)(1)(C).

The SOPs included in the ordinance require the City to secure written permission from CDPHE and DOE when intrusive work is planned for the site, to formalize training for subcontractors working on the site, to include a Materials Handling Plan as needed, and to submit a Completion Report to CDPHE for all projects. While neither CDPHE nor DOE are signatories to a zone overlay, the restrictions in the overlay contain the same restrictions as in the quitclaim deed, and mandates both CDPHE and DOE approval for proposed actions at the site.

4.3 Institutional Controls Monitoring

Most of the formal obligations for verifying and enforcing the ICs rest with the City and CDPHE. According to Section 10 of the EC, the owner of the EC (City of Rifle) is required to submit to CDPHE an annual report of site activities. The report is due on the date that the EC was executed by the City. The annual report details the owner's compliance, and any lack of compliance, with the terms of the covenant. Verification of the restrictions in the Zone Overlay is required Under No. 8 of Subsection (d), the SOPs. The City Manager shall annually inform all City department heads of the SOPs, deed restrictions, and environmental covenants affecting the UMTRA sites.

DOE verification that the City has upheld the quitclaim deed conditions will be an ongoing process, accomplished throughout each year by (1) discussions with City officials about construction projects and possible incursions of groundwater that could result from these activities, (2) physical inspection of the site by State and/or DOE contractor staff, usually at the time of the annual disposal site inspection, and (3) observations by groundwater sampling staff at other times of the year. Observations made during inspection or groundwater sampling events will be included in the trip reports for those events.

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Appendix A

Institutional Controls for the Old Rifle Site

Quitclaim Deed
Environmental Covenant
UMTRA Overlay Zone District

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 12, 2000

JAN 18 2000

Ms. Donna Bergman-Tabbert, Manager
U.S. Department of Energy
Grand Junction Office
2597 B 3/4 Road
Grand Junction, CO 81503

SUBJECT: TRANSFER OF FORMER URANIUM PROCESSING SITE AT OLD RIFLE, COLORADO

Dear Ms. Bergman-Tabbert:

By letter dated December 20, 1999, the U.S. Department of Energy (DOE) provided information related to the request from the Colorado Department of Public Health and Environment (CDPHE) for DOE and U.S. Nuclear Regulatory Commission (NRC) concurrence to transfer the Old Rifle former uranium processing site to the City of Rifle for perpetual public use. In this regard, Section 104(e)(1) of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) requires DOE and NRC concurrence in the final disposition of processing sites acquired by the cooperating state, and DOE has indicated it concurs with the CDPHE request to transfer the Old Rifle site to the City of Rifle, Colorado.

The NRC staff has reviewed the Old Rifle land transfer information provided by DOE, including the "Quit Claim Deed" and attached "Land Annotation" which will be used to effect the transfer of the property. The staff finds that the "Quit Claim Deed" and attached "Land Annotation" appropriately reflect the requirements of UMTRCA Section 104. Accordingly, NRC concurs with the CDPHE request to transfer the Old Rifle site to the City of Rifle, Colorado.

If you have any questions regarding this letter, please contact the NRC Project Manager, Rick Weller, at (301) 415-7287.

Sincerely,

Thomas H. Essig, Chief for
Uranium Recovery and
Low-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

cc: R. Edge, DOE-GJO
J. Deckler, CO

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(Please direct all correspondence to our Glenwood Springs Office)

RECEIVED DOE
OCT 23 2002
GRAND JUNCTION OFFICE

October 22, 2002

Jeffrey Deckler
Remedial Programs Manager
Colorado Department of Public Health and the Environment
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530

Re: City of Rifle East UMTRA Site Deed and Environmental Covenant

Dear Jeff:

Enclosed are the Quitclaim Deed and Environmental Covenant for the East UMTRA Site, both of which have been executed by the City of Rifle. Please have the appropriate State officials execute these documents and let me know as soon as possible if there are any other documents required for this transaction. Please also let me know how you wish to handle the recording of the documents. We would be happy to assist with recording them with the Garfield County Clerk and Recorder's Office. If your office records them, please ensure that this office ends up with the original Deed.

Thank you for your assistance throughout this matter.

Very truly yours,

LEAVENWORTH & KARP, P.C.

Jim Neu

James S. Neu

JSN:
Enclosures
cc: Selby Myers (w/o enc.)
Don Metzler (w/o enc.)

Recorder 982

QUIT CLAIM DEED

The Colorado Department of Public Health and the Environment ("Grantor"), whose address is 4300 Cherry Creek Drive South, Denver, Colorado, 80222-1530, City and County of Denver, State of Colorado, pursuant to 42 U.S.C.§ 7914 (e) (1) (B) and C.R.S. § 25-11-303, hereby donates and quit claim(s) to the City of Rifle ("Grantee"), whose address is 202 Railroad Avenue, Rifle, Colorado, 81650, City of Rifle, County of Garfield, State of Colorado, the following real property in the County of Garfield, State of Colorado, to wit: A parcel of land described as follows:

Beginning at a point on the South right-of-way line of the U.S. Highway 6 & 24, said point more particularly described as being South 0°18' West 1415 feet more or less, from the northeast corner of the NW-1/4 of the NW-1/4 of Section 15, Township 6 South, Range 93 West, 6th P.M. and running then South 0°18' West 36.5 feet to the North right-of-way line of the D&RGW Railroad, thence South 76°36' West 1891.8 feet along said right-of-way, thence continuing along said right-of-way line the following courses and distances. South 79°2' West, 194.9 feet; South 85°35' West 194.1 feet; North 87°20' West 193.9 feet; North 80°23' West 194.0 feet; North 79°32' West 26.7 feet; thence North 74.5 feet to the said South right-of-way line of the U.S. Highway 6 & 24, and a point on a 673 foot radius curve to the left, thence Northeasterly along said curve an arc distance of 453.5 feet (chord bears north 69°26'30" East 445 feet); thence North 50°07' East 655.7 feet to a point on a 472.98 foot radius curve to the right, thence Northeasterly along said curve an arc distance of 223.16 feet (chord bears North 63°38' East 221.1 feet); thence North 80°51'30" East 293.9 feet; thence South 79°33' East 157.7 feet to a point on a 2825 foot radius curve to the right, thence Southeasterly along said curve an arc distance of 460.21 feet (chord bears South 74°53' East 459.7 feet); thence South 70°13' East 306.5 feet to a point on a 1081.8 foot radius curve to the left, thence Easterly along said curve an arc distance of 348.81 feet (chord bears South 79°24' East 347.2 feet) to the point of beginning.

EXCEPTING therefrom those portions of the above described property conveyed to the Denver and Rio Grande Western Railroad Company in deed recorded May 8, 1978 in Book 509 at Page 551 and that part conveyed to the City of Rifle in deed recorded January 18, 1971 in Book 416 at Page 257.

Subject to: (i) any coal, oil, gas, or other mineral rights in any person; (ii) existing rights-of-way for roads, railroads, telephone lines, transmission lines, utilities, ditches, conduits, or pipelines on, over, or across said lands; (iii) court liens, judgments, or financial encumbrances such as deeds of trust for which a formal consent or order has been obtained from a court for the lien holder; (iv) other rights, interests, easements, reservation or exceptions of record; and the following terms, conditions, rights, reservations and covenants:

Grantor reserves to (i) itself, the U. S. Department of Energy, their employees, agents and contractors the right of access to the property as may be necessary to complete activities under the Uranium Mill Tailings Radiation Control Act of 1978, 42 U.S.C. § 7901 et seq. ("UMTRCA") and for other lawful purposes, until such time as Grantor and the U.S. Department of Energy determine that all remedial activities are complete; and (ii) to itself any non-tributary groundwater underlying this parcel, the right to develop tributary groundwater, and the right to surface access for groundwater development.

Grantee covenants to hold harmless the Grantor and the Department of Energy for any liability associated with disruption of any public purpose ventures on the property conveyed by this deed, the disruption of any improvement on said property made by the Grantee, its successors and assigns, and any temporary or permanent limitations to the use of the property, should the Grantor and the Department of Energy be required to perform additional surface remedial activities on the property conveyed by this deed.

Grantee covenants (i) to comply with the applicable provisions of UMTRCA, 42 U.S.C. #7901 et. seq., as amended; (ii) not to use ground water from the site for any purpose, and not to construct wells or any means of exposing ground water to the surface unless prior written approval for such use is given by the Grantor and the U.S. Department of Energy; (iii) not to sell or transfer the land to anyone other than a governmental entity within the state; (iv) that any sale or transfer of the property described in this deed shall have prior written approval from the Grantor and the U.S. Department of Energy; and that any deed or other document created for such sale or transfer and any subsequent sale or transfer will include information stating that the property was once used as a uranium milling site and all other information regarding the extent of residual radioactive materials removed from the property as required by Section 104(d) of the Uranium Mill Tailings, 42 U.S.C. sec. 7014(d), and as set forth in the Annotation attached hereto; (v) not to perform construction and/or excavation or soil removal of any kind on the property without permission from the Grantor and the U.S. Department of Energy unless prior written approval of construction plans (e.g., facilities type and location), is given by the Grantor and the U.S. Department of Energy; (vi) that any habitable structures constructed on the property shall employ a radon ventilation system or other radon mitigation measures; and (vii) that its use of the property shall not

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After recording, please return to:
Leavenworth & Karp, P.C.
P. O. Drawer 2030
Glenwood Springs, CO 81602

adversely impact groundwater quality, nor interfere in any way, with groundwater remediation under UMTRCA activities; and (viii) to use the property and any profits or benefits derived therefrom only for public purposes as required by UMTRCA sec. 104(e)(1)(C), 42 U.S.C. 7914 (e)(1)(C).

These covenants are made in favor and to the benefit of Grantor, shall run with the land and be binding upon Grantee and its successors and assigns, and shall be enforceable by Grantor;

Grantee acknowledges that the property was once used as a uranium milling site, and that the Grantor makes no representations or warranties that the property is suitable for Grantee's purposes;

619021 01/21/2003 04:29P B1428 P983 M ALSDORF
2 of 6 R 31.00 D 0.00 GARFIELD COUNTY CO

IN WITNESS WHEREOF:

APPROVED AS TO FORM:

David Kreutzer, Assistant Attorney General

GRANTOR:

STATE OF COLORADO
Bill Owens, Governor
Acting by and through
The Department of Public Health and Environment

By: ______________________
Executive Director
Acting

By: ______________________
Program Approval

ACCEPTANCE OF DEED
AND COVENANTS

GRANTEE:

CITY OF RIFLE
(Full Legal Name of Agency)

By: ______________________
Name. Keith Lambert

Title: Mayor

Signed this 9th day of January ~~XX~~ 2003.

STATE OF COLORADO,
County of Garfield } SS.

The foregoing instrument was acknowledged before me this 9th day of January, 2003 , ~~19~~ , by Keith Lambert, Mayor, City of Rifle, Colorado.

My commission expires. 12/18/06

Witness my hand and official seal ______________________

Notary Public.

NOTARY PUBLIC BRENDA S. LADD STATE OF COLORADO

No. ______

619021 01/21/2003 04:29P B1428 P984 M ALSDORF
3 of 6 R 31.00 D 0.00 GARFIELD COUNTY CO

QUIT CLAIM DEED

TO

STATE OF COLORADO, } ss.
County of

I hereby certify that this instrument was filed

for record in my office, at ______

o'clock _M., ______, 19_

and is duly recorded in book ______

page ______.

Film No. ______ Reception No. ______

______ Recorder.

By ______ Deputy.

Fees, $ ______

AG ALPHA: HL-UM-IDAPW
AG FILE: P:\NR\NRKREUDE\UMTRCA\RFLDEED.AH1.DOC

ATTACHMENT A

LAND ANNOTATION

OLD RIFLE, COLORADO PROCESSING SITE

The Uranium Mill Tailings Radiation Control Act (Public Law 95-604), Section 104, requires that the State notify any person who acquires a designated processing site of the nature and extent of residual radioactive materials removed from the site, including notice of the date when such action took place, and the condition of the site after such action. The following information is provided to fulfill this requirement.

The Old Rifle Colorado processing site consists of one land parcel which contained a large tailings pile. The site was operated by Standard Chemical company and later the U.S. Vanadium Corporation, over the period from 1924 to 1946 as a uranium processing facility. Approximately 597,000 cubic yards of contaminated materials which included 1) tailings; 2) subpile soils; 3) surficial materials in the mill yard; and 4) windblown materials; were removed from the mill site from 1992-1996. The remediation was conducted in accordance with regulations promulgated by the U.S. Environmental Protection Agency, in 40 CFR 192. These regulations require that the concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than: 5 pCi/g (picocuries per gram), averaged over the first 15 cm (centimeters) of soil below the surface, and 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below the surface. Verification measurements were conducted at the site by dividing the site into approximately 30-foot by 30-foot grids. A soil sample was collected and analyzed for contaminants from each grid to verify that the standards had been met. All verification grids on the site met the EPA standards for radium and thorium.

After remediation was complete the site was backfilled with clean fill material, graded for drainage and revegetated. Backfill materials were routinely analyzed for radium-226 and were determined to have concentrations near background (1.5 pCi/g).

Excavation of residual radioactive material was also conducted for thorium-230 beneath the tailings pile in the subpile soils. For thorium-230, the cleanup standard was determined as a projected 1,000 year radium-226 concentration based on the eventual decay of the thorium to radium. The average thorium in-growth at depth was calculated to be 3.8 pCi/g.

The EPA standards also allow for contamination to be left in place where removal would present a risk of injury to workers, would result in environmental harm, or where the cost of removal clearly outweighs the benefit in terms of risk reduction. At the Old Rifle site, these areas where contamination was left (called "supplemental standards") are the following:

1) an area 1,600 feet long, along the steep slopes at the northern edge of the property. This deposit extends under U.S. Highway 6 & 24;

2) under the railroad right of way extending the length of the site off the southern boundary; and

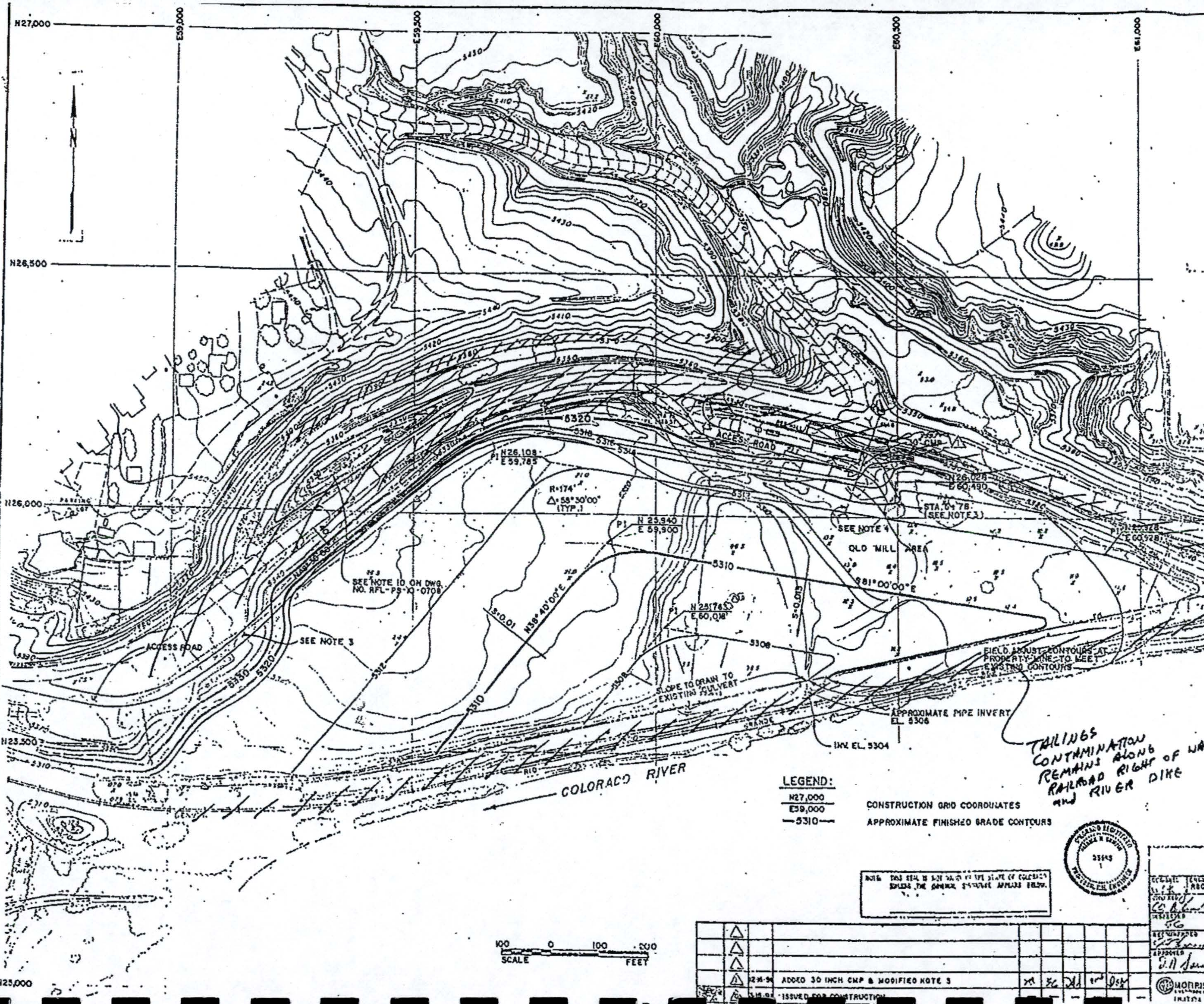
3) along the riverbank to the south of the site.

The supplemental standards areas are shown on the attached map. These deposits have been covered with clean fill and pose no risk unless disturbed. The average gamma exposure is 11 microroentgen per hour at waist height, which is equivalent to background.

The groundwater beneath the Old Rifle mill site remains contaminated and will be addressed during Phase II of the Uranium Mill Tailings Remedial Action Project. Several groundwater monitor wells are present on and downgradient of the site and will remain in place until the U.S. Department of Energy determines that they can be removed.

Any person who acquires a designated processing site shall apply for any permits, including U.S. Army Corps of Engineers Section 404 permits regarding construction in or near wetlands, as required by law.

Additional information concerning the remedial action, and groundwater conditions is available from the Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division.



NOTES:

1. FINAL GRADING CONTOURS BETWEEN ELEV. 5314 TO 5320 SHALL BE ADJUSTED TO BLEND WITH ACCESS ROAD CONTOURS.
2. ALL OTHER FINAL GRADING CONTOURS WITHIN THE PROPERTY LINE SHALL BE ADJUSTED TO BLEND WITH EXIST CONTOURS AT THE SITE BOUNDARIES.
3. THE EXISTING EAST SIDE ACCESS ROAD SHALL BE TERMINAT AT STA. 6+78 WHERE THE ROADWAY SHALL BE REGRADED T PROVIDE A SMOOTH TRANSITION TO THE FINAL GRADING CONTOURS. THE WEST SIDE ACCESS ROAD TO BE CONSTRUCTE UNDER THIS CONTRACT SHALL BE REMOVED AS NECESSARY TO CONFORM TO SITE EXCAVATION AND FINAL GRADING REQUIREM
4. GRADES IN VICINITY OF CMP PIPE SHALL BE ADJUSTED TO PROVIDE A MINIMUM COVER OF 2 FEET OVER THE PIPE.
5. COORDINATE POINTS ARE APPROXIMATE ONLY AND MAY BE ADJUSTED IN THE FIELD.

REFERENCE DRAWINGS:

RFL-PS-10-0708	EXCAVATION SEQUENCE AND TAILINGS EXCAVATION PLAN
RFL-PS-10-0727	ACCESS FROM WEST SIDE (SHEET 1 OF 3)
RFL-PS-10-0728	ACCESS FROM WEST SIDE (SHEET 2 OF 3)
RFL-PS-10-0729	ACCESS FROM WEST SIDE (SHEET 3 OF 3)

LEGEND:

N27,000 / E59,000	CONSTRUCTION GRID COORDINATES
—5310—	APPROXIMATE FINISHED GRADE CONTOURS

1	2-16-9_	ADDED 30 INCH CMP & MODIFIED NOTE 3
0	3-15-9_	ISSUED FOR CONSTRUCTION

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

OLD RIFLE PROCESSING SITE
RIFLE, COLORADO
PHASE II CONSTRUCTION

FINAL GRADING PLAN

MORRISON-KNUDSEN ENGINEERS, INC.

DE-AC04-83AL1879

619022 01/21/2003 04:30P B1428 P988 M ALSDORF
1 of 5 R 25.00 D 0.00 GARFIELD COUNTY CO

This property is subject to an Environmental Covenant held by the Colorado Department of Public Health and Environment pursuant to section 25-15-321, C.R.S.

988

ENVIRONMENTAL COVENANT

By this deed, the City of Rifle grants an Environmental Covenant ("Covenant") this 16th day of October, 2002 to the Colorado Department of Public Health and the Environment ("the Department") pursuant to § 25-15-321 of the Colorado Hazardous Waste Act, § 25-15-101, *et seq*. The Department's address is 4300 Cherry Creek Drive South, Denver, Colorado 80246-1530.

WHEREAS, The City of Rifle is the owner of certain property commonly referred to as the Old Rifle Uranium Mill site in Rifle, Colorado in Garfield County, more particularly described in Attachment A, attached hereto and incorporated herein by reference as though fully set forth (hereinafter referred to as "the Property"); and

WHEREAS, Union Carbide, disposed of uranium mill tailings at the Old Rifle Mill site, and as a result of this disposal, groundwater under the property is contaminated; and

WHEREAS, pursuant to the Site Observational Work Plan for the Old Rifle Mill Site, the Property is the subject of remedial action pursuant to the Uranium Mill Tailings Radiation Control Act, 42 U.S.C. § 7901 *et seq.*; and

WHEREAS, the purpose of this Covenant is to ensure protection of human health and the environment by restricting surface disturbance and groundwater use as further described below; and

WHEREAS, The City of Rifle desires to subject the Property to certain covenants and restrictions as provided in Article 15 of Title 25, Colorado Revised Statutes, which covenants and restrictions shall burden the Property and bind The City of Rifle, its heirs, successors, assigns, and any grantees of the Property, their heirs, successors, assigns and grantees, and any users of the Property, for the benefit of the Department.

NOW, THEREFORE, The City of Rifle hereby grants this Environmental Covenant to the Department, with the U.S. Department of Energy as a third party beneficiary, and declares that the Property as described in Attachment A shall hereinafter be bound by, held, sold, and conveyed subject to the following requirements set forth in paragraph 1 below, which shall run with the Property in perpetuity and be binding on the City of Rifle and all parties having any right, title or interest in the Property, or any part thereof, their heirs, successors and assigns, and any persons using the land. The City of Rifle and all parties having any right, title or interest in the Property, or any part thereof, their heirs, successors and assigns shall hereinafter be referred to in this covenant as OWNER.

After recording, please return to:
Leavenworth & Karp, P.C.
P. O. Drawer 2030
Glenwood Springs, CO 81602

1. Use restrictions

A. No habitable structure may be constructed on the property without properly designed radon mitigation as approved by the Department.

B. Wells completed in the alluvuial aquifer or the Entrada formation may not be used for domestic or potable water supplies.

C. No tilling, excavation, grading, construction, or any other activity that disturbs the ground surface is permitted on the Property, without the express written consent of the Department and the U.S. Department of Energy.

D. No activities that will in any way damage any monitoring or remedial wells installed by the Department of Energy, or interfere with the maintenance, operation, or monitoring of said wells is allowed, without the express written consent of the Department and the U.S. Department of Energy.

2. Purpose of this covenant The purpose of this Covenant is to ensure protection of human health and the environment by minimizing the potential for exposure to any residual radioactive material or contaminated groundwater that remains on the Property. The Covenant will accomplish this by restricting groundwater use, minimizing those activities that result in disturbing the ground surface, and by creating a review and approval process to ensure that any such intrusive activities are conducted with appropriate precautions to avoid or eliminate any hazards.

3. Modifications This Covenant runs with the land and is perpetual, unless modified or terminated pursuant to this paragraph. OWNER or its successors and assigns may request that the Department approve a modification or termination of the Covenant. The request shall contain information showing that the proposed modification or termination shall, if implemented, ensure protection of human health and the environment. The Department shall review any submitted information, and may request additional information. If the Department determines that the proposal to modify or terminate the Covenant will ensure protection of human health and the environment, it shall approve the proposal. No modification or termination of this Covenant shall be effective unless the Department has approved such modification or termination in writing. Information to support a request for modification or termination may include one or more of the following:

a) a proposal to perform additional remedial work;
b) new information regarding the risks posed by the residual contamination;
c) information demonstrating that residual contamination has diminished;
d) information demonstrating that the proposed modification would not adversely impact the remedy and is protective of human health and the environment; and
other appropriate supporting information.

4. Conveyances OWNER shall notify the Department at least fifteen (15) days in advance of any proposed grant, transfer or conveyance of any interest in any or all of the Property.

5. Notice to Lessees OWNER agrees to incorporate either in full or by reference the restrictions of this Covenant in any leases, licenses, or other instruments granting a right to use the Property.

6. Notification for proposed construction and land use OWNER shall notify the Department simultaneously when submitting any application to a local government for a building permit or change in land use.

7. Inspections The Department shall have the right of entry to the Property at reasonable times with prior notice for the purpose of determining compliance with the terms of this Covenant. Nothing in this Covenant shall impair any other authority the Department may otherwise have to enter and inspect the Property.

8. No Liability The Department does not acquire any liability under State law by virtue of accepting this Covenant, nor does any other named beneficiary of this Covenant acquire any liability under State law by virtue of being such a beneficiary

9. Enforcement The Department may enforce the terms of this Covenant pursuant to §25-15-321. C.R.S. The City of Rifle and any named beneficiaries of this Covenant may file suit in district court to enjoin actual or threatened violations of this Covenant.

10. Owner's Compliance Certification OWNER shall submit an annual Report to the Department, on the anniversary of the date this Covenant was signed by The City of Rifle, detailing OWNER's compliance, and any lack of compliance, with the terms of this Covenant.

11. Notices Any document or communication required under this Covenant shall be sent or directed to:

Jeffrey Deckler
Remedial Programs Manager
Colorado Department of Public Health and the Environment
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530

Donald Metzler
U.S. Department of Energy
Grand Junction Project office
Grand Junction, Colorado

The City of Rifle, has caused this instrument to be executed this 16th day of October, 2002.

The City of Rifle

By: Keith Lambert
Title: Keith Lambert, Mayor, City of Rifle, Colorado

STATE OF Colorado)
) ss:
COUNTY OF Garfield)

The foregoing instrument was acknowledged before me this 16 day of October, 2002 by Mayor Keith Lambert on behalf of The City of Rifle

Ellen J. Gaugler
Notary Public
4841 154 Road
Address
Glenwood Springs, CO 81601

My commission expires: 11/8/2004

Accepted by the Colorado Department of Public Health and Environment this 29th day of October, 2002.

By: Douglas Benevento

Title: Acting Executive Director

STATE OF Colorado)
) ss:
COUNTY OF Denver)

The foregoing instrument was acknowledged before me this 29th day of October, 2002 by Douglas H Benevento on behalf of the Colorado Department of Public Health and Environment.

Maria S. Zepeda-Sanchez
Notary Public
5863 Magnolia St
Address
Commerce City, CO 80022

My commission expires: 4/14/03

SCHEDULE A
Legal Description

The land referred to in this Commitment is situated in the County of Garfield, state of Colorado and described as follows:

Beginning at a point on the south right of way line of U.S. Highway 6 & 24, said point more particularly described as being South 0°18' West 1415 feet, more or less, from the northeast corner of the NW1/4 of the NW1/4 of Section 15, Township 6 South, Range 93 West, 6th P.M. and running then South 0°18' West 36.5 feet to the North right of way line of the D&RGW Railroad, thence South 76°36' West 1891.8 feet along said right of way, thence continuing along said right of way line the following courses and distances: South 79°2' West, 194.9 feet; South 85°35' West 194.1 feet; North 87°20' West 193.9 feet; North 80°23' West 194.0 feet; North 79°32' West 26.7 feet; thence North 74.5 feet to the South right of way line of the U.S. Highway 6 & 24, and a point on a 673 foot radius curve to the left, thence North-easterly along said curve an arc distance of 453.5 feet (chord bears North 69°26'30" East 445 feet); thence North 50°07' East 655.7 feet to a point on a 472.98 foot radius curve to the right, thence Northeasterly along said curve an arc distance of 223.16 feet (chord bears North 63°38' east 221.1 feet); thence North 80°51'30" East 293.9 feet; thence South79°33' East 157.7 feet to a point on a 2825 foot radius curve to the right, thence Southeasterly along said curve an arc distance of 460.21 feet (chord bears South 74°53' East 459.7 feet); thence South 70°13' East 306.5 feet to a point on a 1081.8 foot radius curve to the left, thence Easterly along said curve an arc distance of 348.81 feet (chord bears South 79°24' East 347.2 feet) to the POINT OF BEGINNING.

EXCEPTING therefrom those portions of the above described property conveyed to the Denver and Rio Grande Western Railroad Company in deed recorded May 8, 1978 in book 509 at age 551 and that part conveyed to the City of Rifle in deed recorded January 18, 1971 in Book 416 at Page 257.

CITY OF RIFLE, COLORADO
ORDINANCE NO. 9
SERIES OF 2008

AN ORDINANCE OF THE CITY OF RIFLE, COLORADO, CREATING THE UMTRA OVERLAY ZONE DISTRICT AND INCLUDING WITHIN THE DISTRICT THE CITY'S EAST AND WEST UMTRA SITES.

WHEREAS, the City of Rifle is the owner of an approximately 21.76 acre parcel of land known as the East UMTRA Site and an approximately 142 acre parcel of land known as the West UMTRA Site, both of which parcels were acquired from the Colorado Department of Public Health and Environment ("CDPHE) following successful remediation of the sites in partnership with the U.S. Department of Energy under the Uranium Mill Tailings Radiation Control Act ("UMTRA"); and

WHEREAS, pursuant to Rifle Municipal Code ("RMC") Section 16-6-140, the Planning Commission initiated an application to create an UMTRA Overlay Zone District for the purpose of establishing procedures and restrictions governing development of East and West UMTRA Sites, which are both zoned Public Zone District; and

WHEREAS, on April 29,2008, the City of Rifle Planning Commission considered the zoning overlay application and found that creation of the UMTRA Overlay Zone District was appropriate given development constraints on the UMTRA parcels created by the presence of residual contaminants from former uranium mining operations and deed restrictions placed on the parcels by CDPHE's conveyance of the sites to the City; and

WHEREAS, the Planning Commission recommended adoption of regulations governing the UMTRA Overlay Zone District by the creation of a new Section 16-3-540 of the Rifle Municipal Code ("RMC") and further recommended the City's East and West UMTRA Sites be included within the new overlay zone district ; and

WHEREAS, the City Council reviewed the zoning application at its May 21,2008 and June 4,2008 meetings and concurred with the Planning Commission's findings; and

WHEREAS, the City of Rifle Planning Commission and the Rifle City Council have held duly-noticed public hearings as required by the Rifle Municipal Code, and now wish to create the UMTRA Overlay Zone District as a new overlay zone district within the City and to include the East and West UMTRA Sites within said UMTRA Overlay Zone District.

NOW, THEREFORE, THE COUNCIL OF THE CITY OF RIFLE, COLORADO, ORDAINS THAT:

Section 1. The aforementioned recitals are hereby fully incorporated herein.

Section 2. A new Section 16-3-540 of the Rifle Municipal Code, entitled "UMTRA Overlay Zone District," is hereby adopted to read as follows.

Section 16-3-540. UMTRA Overlay Zone District.

(a) Description. The intent of the UMTRA overlay zoning district is to set forth the procedures and restrictions governing development on the City-owned East and West UMTRA sites. Due to the presence of residual contaminants on the two UMTRA sites, the City must obtain prior written consent before conducting any operations on either site that will disturb the soil, wetlands or groundwater. Special handling of both soil and groundwater will be required, and the City shall adopt a Materials Handling Plan that details how human health and the environment will be protected during any activities on the sites.

(b) Uses. The uses permitted on sites within the UMTRA Overlay Zone District will be that of the underlying zone district.

(c) Restrictions on use of UMTRA sites. The City must comply with the following applicable provisions of UMTRCA, 42 U.S.C. Sec. 7901, et. seq., as amended:

(1) Ground water from the site shall not be used for any purpose, nor shall anyone construct wells or any means of exposing ground water to the surface unless prior written approval for such use is given by the Colorado Department of Public Health and Environment ("CDPHE) and the U.S. Department of Energy ("DOE).

(2) The land shall not be sold or transferred to anyone other than a governmental entity within the state.

(3) Any sale or transfer of the property described in this deed shall have prior written approval from the CDPHE and the DOE; and that any deed or other document created for such sale or transfer and *any* subsequent sale or transfer will include information stating that the property was once used as a uranium milling site and all other information regarding the extent of residual radioactive materials removed from the property as required by Section 104(d) of the Uranium Mill Tailings Radiation Control Act, 42 U.S.C. Sec. 7014(d), and as set forth in the Annotation attached hereto.

(4) Construction and/or excavation or soil removal of any kind shall not occur on the property without permission from the CDPHE and DOE unless prior written approval of construction plans (e.g., facilities type and location), is given by the CDPHE and DOE.

(5) Any habitable structures constructed on the property shall employ a radon ventilation system or other radon mitigation measures.

(6) Use of the UMTRA sites shall not adversely impact groundwater quality, nor interfere in any way, with groundwater remediation under UMTRCA Sec. 104(e)(1)(c), 42 U.S.C. Sec. 7914 (e)(1)(C).

(d) Procedure. The following are the City's Standard Operating Procedures for conducting activities within the UMTRA Overlay Zone District:

(1) The City of Rifle shall install and maintain a sign at the entrance of both UMTRA sites stating "Any excavation of material or exposure of groundwater on this Property must be approved by the City of Rifle, Colorado Department of Public Health and Environment and U.S. Department of Energy."

(2) When a use is proposed for an UMTRA site, City staff will review the project with the Planning Director. The Planning Director will review the GIS maps and identify the special procedures that must be followed. Staff shall also hold preliminary discussions with DOE and CDPHE to identify any preliminary issues about the use of the property for the proposed project and further define the project for City Council approval of contracts for design and plan preparation.

(3) Staff shall hire consulting engineers or work with the developer's engineers to refine design development project and to identify and obtain other permits or approvals necessary for the project (e.g. USACE permitting, storm water permits, site plan application, etc.).

(4) Staff shall develop a letter of request including a project description (detailing building footprints, location, depth of bury, radon mitigation system design), applicable maps and drawings, and for approval of defined project by CDPHE and DOE. The City Attorney shall review the letter to ensure compliance with deed restrictions and environmental covenants prior to submission to DOE and CDPHE.

(5) Upon written approval by both DOE and CDPHE and approval of the Site Plan by the Planning Department, the City Council shall authorize issuance of a Notice to Proceed with construction and the execution of construction contract. The project will then be eligible for issuance of a building permit.

(6) Appropriate training shall be provided to ensure that all project personnel are aware of the contaminants on site, restrictive covenants, and the requirements of the

Materials Handling Plan. The City shall periodically inspect the site to confirm compliance with all Code requirements.

(7) Upon completion of the project, the developer shall submit a Completion Report to CDPHE containing a construction summary and identifying any deviations from the original proposal. The Completion Report shall also document compliance with the Materials Handling Plan and detail the final disposal and disposition of any uranium mill tailings encountered on the site.

(8) The City Manager shall annually inform all City department heads of these Standard Operating Procedures, deed restrictions, and environmental covenants affecting the UMTRA sites.

Section 3. The City's East and West UMTRA Sites are hereby included within the UMTRA Overlay Zone District established at Section 16-3-540 of the Rifle Municipal Code. The underlying Public Zone District ("PZ") designation for the parcels shall remain in full force and effect.

Section 4. Within thirty (30) days after the effective date of this Ordinance, the City Clerk shall incorporate the terms of this Ordinance into the Geographical Information System described in RMC $16-3-20 shall cause a printed copy of the amendment to the City Zone District Map to be made, which shall be dated and signed by the Mayor and attested to by the City Clerk, and which shall bear the seal of the City. The amended map shall include the number of this Ordinance. The signed original printed copy of the Zoning Map shall be filed with the City Clerk. The Clerk shall also record a certified copy of this Ordinance with the Garfield County Clerk and Recorder. The City staff is further directed to comply with all provisions of the Rifle Land Use Regulations, RMC §16-1-10 *et seq.*, to implement the provisions of this Ordinance.

INTRODUCED on May 21, 2008, read by title, passed on first reading, and ordered published as required by the Charter.

INTRODUCED a second time at a regular meeting of the Council of the City of Rifle, Colorado, held on June 4,2008, passed without amendment, approved, and ordered published in full as required by the Charter.

DATED this 9 day of June ,2008.

CITY OF RIFLE, COLORADO

By Keith J. Lambert
Mayor

ATTEST:

Wanda Nelson
City Clerk

CITY OF RIFLE
SEAL
GARFIELD COUNTY, COLORADO

U:\ORDNCS\Ord 08\Second Reading\09 (4).wpd

Appendix B

Alternative Concentration Limit Application

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B1.0 General Information

B1.1 Introduction

The purpose of this document is to fulfill the U.S. Nuclear Regulatory Commission (NRC) requirements for an application for alternate concentration limits (ACLs) under Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) for two of the constituents of concern at the former Old Rifle, Colorado, Processing Site. Much of the information required by the NRC for an ACL application (NRC 1996, NRC 2000) has been compiled in the Site Observational Work Plan (SOWP) (DOE 1999) for the Old Rifle site as well as the revised Draft Groundwater Compliance Action Plan (GCAP) to which this appendix is attached. Of particular relevance in this application is the reevaluation of the natural flushing groundwater remedy for the site (DOE 2011), which resulted in a substantial revision to the conceptual site model that was presented in the SOWP.

The intent of this attachment is not to duplicate information found in other site documents, but to provide a link between NRC ACL evaluation criteria and relevant detailed discussion pertaining to those criteria in previously prepared documents. NRC guidance for preparing ACL applications for Title II sites (NRC 1996) was used as a model for this application. This document summarizes pertinent information from the SOWP regarding "Factors Considered in Making Present and Potential Hazard Findings" (Table 1 in NRC 1996; also specified in 40 CFR Part 192 with slight modifications). It also identifies sections of the SOWP and GCAP that contain information corresponding to sections listed in the "Standard ACL Application Format" (Table 2 in NRC 1996). This ensures that all factors and information related to the proposed ACLs have been considered, while minimizing duplication of effort.

Though NRC's ACL guidance was prepared for Title II UMTRCA sites, the guidance can be applied to Title I sites, with modifications made to accommodate the differences between Title II and Title I sites. One of the major differences between these sites is that the groundwater remedies at Title I sites were generally postponed until after surface remediation was complete. At Title II sites, groundwater corrective action was often initiated during site operations and continued throughout the surface reclamation and closure process. Additionally, the groundwater remedy selection process for Title I sites allows for the application of alternative standards before any active remediation measures must be considered. Therefore, active remediation alternatives may not be evaluated for sites meeting this criterion, as indicated in the flow chart in Figure 16 of the GCAP. Therefore, data corresponding to the corrective action assessment portion of the standard ACL application may be quite limited, as is the case for the Old Rifle site.

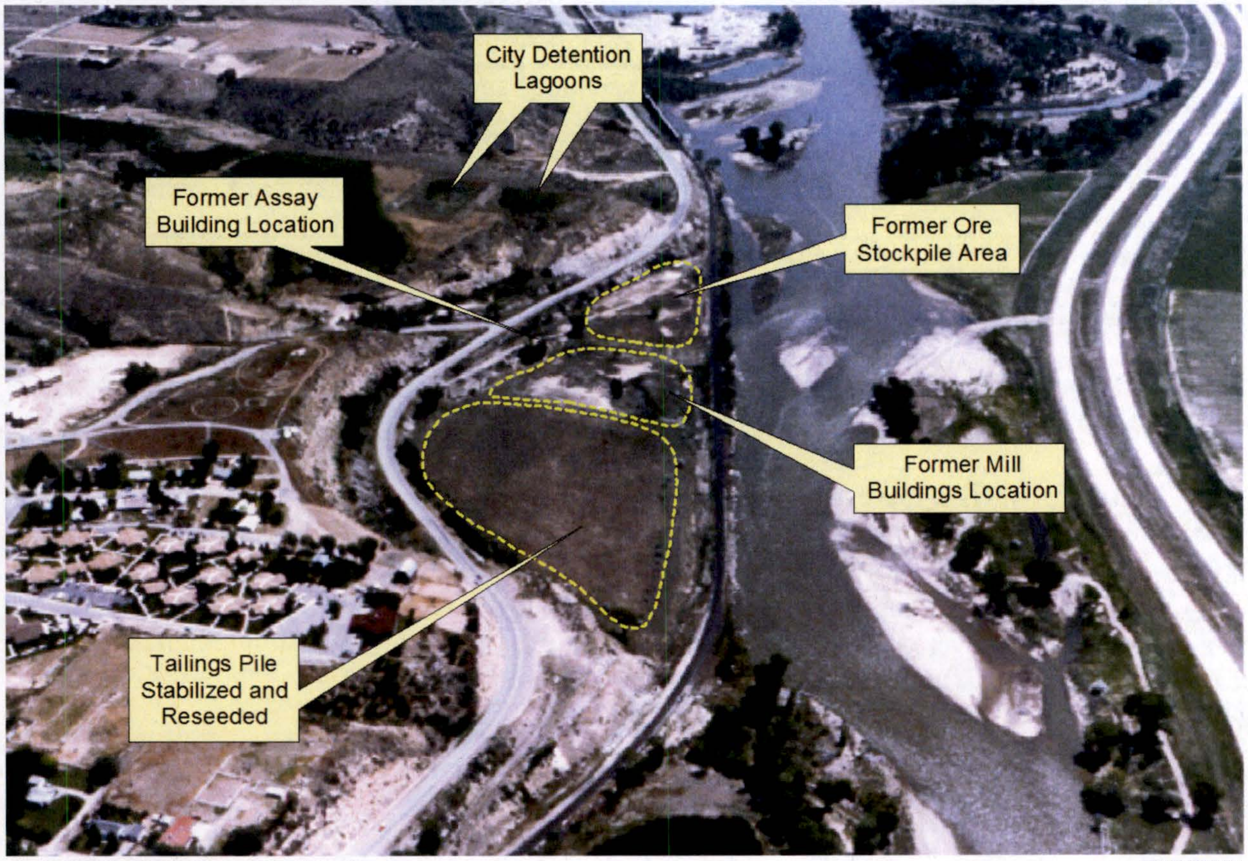
Section B2.0 of this document briefly discusses the constituents for which ACLs are proposed and the rationale for the numerical values. Section B3.0 summarizes the factors considered in making hazard findings. Section B4.0 presents a brief corrective action assessment and the proposed ACLs.

B1.2 Facility Description

The U.S. Vanadium Company constructed the original Old Rifle processing plant in 1924 for the production of vanadium (Merritt 1971) (Figure B-1). In 1926 the assets of U.S. Vanadium Company were purchased by Union Carbide and Carbon Corporation (Union Carbide), and the U.S. Vanadium Corporation was established as a subsidiary (Chenoweth 1982). The plant closed in 1932 as a result of a shortage of vanadium ore. In 1942 Union Carbide reactivated the plant for vanadium production as a result of an increase in demand due to World War II. The plant continued to operate until 1946 when it was modified to include the recovery of uranium as well as vanadium. Uranium and vanadium production continued until 1958 when the plant was replaced with a new mill located approximately 3 miles west of the Old Rifle site. Mill feed consisted of raw ore mined from deposits located primarily in Garfield (Garfield and Rifle Mines), Mesa, Montrose, Moffat (Meeker Mine), and San Miguel Counties in Colorado (Chenoweth 1982). Atomic Energy Commission (AEC) records from 1947 to 1958 indicate that 761,000 tons of ore were processed at the site. Over 2000 tons of uranium concentrate (U_3O_8) were sold to the AEC (Chenoweth 1982). The site was covered at various times with tailings piles, ore stockpiles, and several ponds, such that the entire property was disturbed by milling-related activities at some time or another (Figure B-1). For orientation, note that the site is bounded by the Colorado River on the south.

Upon site closure in 1958, most of tailings were removed for reprocessing at the New Rifle site. Approximately 13 acres of tailings remained at the Old Rifle site before the surface remedial action. No structures remained at the mill site. Union Carbide stabilized the relatively flat tailings pile in 1967 in accordance with State of Colorado regulations (DOE 1992). The edge of the pile was moved away from the railroad tracks, and the entire pile was covered with 6 inches of soil, fertilized, and seeded with native grasses. Water from the Colorado River was used for irrigation. Surface water draining from an upgradient seep across U.S. Highway 6&24 flowed through the site. The seep water collected in a lined pond after it passed the tailings pile. Overflow from the pond was released into the Colorado River. The pond and tailings were removed during surface remedial action, which commenced in 1992 and was completed in 1996.

Contaminant releases at the site involved large volumes of tailings and ore, both of which were located onsite for long durations (decades). Leaching of these sources and subsequent downward migration to the water table provided continual mass loading of contaminants to the alluvial aquifer materials for many years. Surface cleanup required remediation to meet only the Ra-226 standard, but even that standard could not be met for materials in an adjacent vicinity property located along the northern site boundary adjacent to the highway embankment (and possibly below the water table). Similarly, soil sampling at the site as part of the characterization effort for the SOWP (DOE 1999) identified residual uranium contamination in solid-phase materials remaining at the site.



m:\ugw\511\0017\20\u00867\u0086700.apr smithw 2/23/2000, 8:59 U0086700-01

Figure B-1. Former Tailings Pile, Ore Storage Area, and Associated Buildings at the Old Rifle Site June 1987

B1.3 Extent of Groundwater Contamination

See Section 2.3 of the GCAP. Uranium is elevated above the standard across the entire Old Rifle site. Selenium and vanadium are elevated in only two wells in the former footprint of the tailings pile. In the 20 years since completion of surface remediation, average concentrations of uranium across the site have not shown a decline (GCAP Figure 8).

B1.4 Current Groundwater Protection Standards

Table B-1 lists the current groundwater standards that apply to the Old Rifle site. Also provided are the maximum concentrations and associated wells based on the most recent (2016) sampling data.

Table B-1. Comparison of Groundwater Standards with Recent Sampling Results

Contaminant	Groundwater Standard from Current GCAP (mg/L)[a]	Maximum Observed in Groundwater in 2016 (mg/L)	Well with Maximum 2016
Selenium	0.05[b]	0.059	0655
Uranium	0.044[c]	0.22	0656
Vanadium	1.0[b]	0.3	0305, 0655

[a] mg/L = milligrams per liter
[b] Alternate concentration limit from 2001 GCAP (DOE 2001)
[c] 40 CFR 192 standard

B1.5 Proposed Alternate Concentration Limits

Table B-2 provides the proposed ACLs for the Old Rifle site. All wells are considered to be point-of-compliance wells where the ACLs must be met. Section 3.2 of the GCAP describes how these proposed values were determined. Section 4.0 of the GCAP describes implementation measures, including institutional controls (ICs) and monitoring.

Table B-2. Proposed ACLs for Old Rifle Site

Contaminant	Proposed ACL (mg/L)
Selenium	0.122
Uranium	0.36
Vanadium	1.0

B2.0 Hazard Assessment

B2.1 Source and Contamination Characterization

The discussion here focuses primarily on uranium, as it is the most widely distributed constituent at the Old Rifle site. The primary source of contamination at the site—the uranium mill tailings—was removed from the site in the mid-1990s. Concentrations of uranium in groundwater declined by about an order of magnitude as a result of source removal. However, since that time, groundwater concentrations have not changed appreciably. Secondary sources of uranium contamination likely remain in subsurface materials as discussed in Section 2.4 of the GCAP.

B2.2 Transport Assessment

See Section 2.4 of the GCAP. The discussion in that section indicates that natural flushing of uranium will not reduce concentrations to the applicable standard.

B2.3 Exposure Assessment

Baseline risks associated with the Old Rifle site were assessed in the SOWP (DOE 1999). The risk assessment concluded that use of groundwater as a drinking water source was unacceptable. It was also determined that site conditions presented no complete pathways by which site-related contamination could adversely affect ecological receptors.

Site conditions can be summarized as follows:

- The alluvial aquifer is hydraulically isolated from any other aquifers—it is bounded both laterally and vertically. Water in the aquifer is either lost to evapotranspiration or discharges to the Colorado River.
- For groundwater compliance purposes, the entire site would be considered the "facility." There is no hydraulically connected aquifer downgradient of the facility; the aquifer ends at the facility boundary.
- ICs prohibit any use of site groundwater.
- Water that discharges to the Colorado River (the only potentially complete point of exposure to site-related constituents) rapidly mixes with river water; river water quality adjacent to the site is indistinguishable from background surface water quality. Based on calculations in the SOWP, the estimated dilution factor for contaminated groundwater discharging to the river is 3×10^{-5} under average river flow conditions (DOE 1999).
- Uranium concentrations in the site groundwater since completion of surface remediation have consistently been less than 1 milligram per liter (mg/L). Given these relatively low groundwater concentrations and the high degree of dilution with discharge to the river, it is virtually impossible for site-related contamination to have an adverse impact on river water quality. The surface water quality standard for the river is 0.03 mg/L based on its use as a source of drinking water (Colorado Department of Public Health and Environment Regulation No. 37).

Based on restrictions prohibiting groundwater use, it can be concluded that current site conditions are protective of human health and the environment. In most wells, contaminant concentrations in groundwater have been relatively stable for more than a decade, and those conditions are expected to continue. No adverse site-related effects have been observed in the Colorado River (the only point of exposure). Therefore, protectiveness will be maintained as long as ICs restrict groundwater use. The alluvial aquifer at the Old Rifle site has not been used for beneficial purposes. With the Colorado River as a plentiful and high-quality source of water, the need for alluvial groundwater use in the future, particularly from an aquifer that is so limited in areal extent, is highly unlikely.

B3.0 Factors Considered In Making Present And Potential Hazard Findings

The list of factors below is from the Title I regulations [40 CFR 192.02(c)(3)(ii)(B)(1) and (2)], and differs slightly from the list in the NRC Title II guidance. An additional groundwater quality factor is added.

B3.1 Potential Adverse Effects on Groundwater Quality

B3.1.1 **The physical and chemical characteristics of constituents in the residual radioactive material at the site, including their potential for migration.** No disposal cell is present at the site. Surface remediation was completed in 1996. Source removal was completed to the extent practicable. Some tailings were left in areas that were difficult to remediate as permitted by application of supplemental standards. Studies at the site have shown that residual contamination in solid-phase materials at the site is slowly released to the groundwater over time. These releases are likely to continue for a prolonged period of time. See Section 2.4 of the GCAP for further discussion.

B3.1.2 **The hydrogeological characteristics of the site and surrounding land.** The hydrogeology of the site was characterized for input to the flow and transport model (see SOWP, Sections 5.1 "Geology," and 5.2 "Hydrologic System" and Section 2.4 of the GCAP). The uppermost aquifer at the site and in the Rifle area is made up of alluvial deposits and the uppermost weathered Wasatch Formation on which the alluvial sediments were deposited. Impermeable rock outcrops at the downgradient site boundary prevent downgradient migration of groundwater. Shallow groundwater within the site boundary discharges to the Colorado River or is lost through evapotranspiration. There are no surface expressions of contaminated groundwater onsite.

B3.1.3 **The quantity of groundwater and the direction of groundwater flow.** Groundwater flow is generally west-southwest. The volume of contaminated groundwater is estimated at approximately 70 million gallons (DOE 1996).

B3.1.4 **The proximity and withdrawal rates of groundwater users.** There are no groundwater users in the vicinity of the site. Contamination is prevented from migrating to potential downgradient users by the impermeable rock outcrops at the downgradient site boundary.

B3.1.5 **The current and future uses of groundwater in the region surrounding the site.** Historically, the uppermost aquifer in the Rifle area has been used as a source of water for residential and industrial use (DOE 1995). However, the quality of shallow groundwater in the area is generally poor and has mainly been used for purposes other than drinking water. Uses for well water at residences include bathing, showering, and watering plants and livestock. The zoning for the land encompassing the site is agricultural/industrial. Potential future uses could be open space/agricultural, wildlife habitat enhancement, environmental education, passive recreation, and mine reclamation. ICs prevent the use of site groundwater for any purpose without the prior consent of DOE.

B3.1.6 **The existing quality of groundwater, including other sources of contamination and their cumulative impact on groundwater quality.** Groundwater quality at the site is generally poor, as is most of the groundwater in the Rifle vicinity. Historically, background concentrations of molybdenum, selenium, and uranium have exceeded EPA standards. Fluoride, iron, manganese, and sulfate in background groundwater all exceed EPA's secondary drinking water standards. Water at the site also has elevated concentrations of arsenic, selenium, uranium, and vanadium as a result of milling activities. There are no other known sources of groundwater contamination.

B3.1.7 **The potential for health risks caused by human exposure to constituents.** The only potentially unacceptable risks to humans would occur through regular use of groundwater as drinking water in a residential scenario, which currently does not exist. Incidental use would not result in any unacceptable risks. ICs and the designation of the site as agricultural/industrial will ensure that groundwater will not be used in any manner resulting in human health risks. Prior approval by DOE is required for any future use of groundwater.

B3.1.8 **The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents.** There are currently no exposures of wildlife or crops to contaminated groundwater. Some vegetation may be rooted into the contaminated groundwater; however, no adverse effects are expected. There is no current exposure of existing physical structures to groundwater. However, if such exposure did occur, no damage due to contamination would be expected. Water from the site discharges into the Colorado River and is rapidly diluted to undetectable levels, leaving aquatic life unaffected. Institutional controls will prevent exposure of wildlife, crops, and vegetation to contamination.

B3.1.9 **The persistence and permanence of the potential adverse effects.** It is possible that groundwater contamination could remain at levels determined to be unacceptable for hundreds of years or longer. Significant amounts of contamination may be present in solid-phase materials; this contamination is released very slowly to the groundwater and could result in groundwater remaining contaminated for a very long time. However, institutional controls will be in place to prevent groundwater use.

B3.1.10 **The presence of underground sources of drinking water and exempted aquifers identified under §144.7 of this chapter.** There are no sources of drinking water or exempted aquifers that can be affected by contamination at the site, as all groundwater at the site discharges into the Colorado River.

B3.2 Potential Adverse Effects on Hydraulically Connected Surface Water Quality

B3.2.1 **The volume and physical and chemical characteristics of the residual radioactive material at the site.** No disposal cell is present at the site. Surface remediation was completed in 1996. Some mill tailings were left in place, and some secondary contamination in subsurface materials remains that has the potential to contribute to groundwater contamination for a prolonged period of time (see Section 2.4 of the GCAP).

B3.2.2 **The hydrogeological characteristics of the site and surrounding land.** Only the uppermost aquifer at the site is contaminated. It is composed mostly of unconsolidated alluvial material deposited by the Colorado River; the material ranges in size from clay to cobbles. The alluvial material is approximately 20 to 25 feet thick over most of the site. The saturated thickness of the aquifer ranges from 5 to 20 feet. Groundwater movement is generally west-southwest. Groundwater from the site discharges into the Colorado River. Movement downgradient of the site is prevented by outcrops of impermeable bedrock at the western site boundary. Seeps are located north of the site, and an irrigation ditch runs from north to south across the site and discharges to the Colorado River. The seeps and ditch provide recharge to the surficial aquifer and are unaffected by site contamination. (Sections 5.1 and 5.2 of the SOWP describe the geology and hydrology of the site, respectively.)

B3.2.3 **The quantity and quality of groundwater and the direction of groundwater flow.** Groundwater flow is generally west-southwest at a rate of 1.4 to 2.0 ft/day. Water quality is poor, with several constituents exceeding groundwater standards. Water quality is summarized in Section 2.3 of the GCAP. The quantity of contaminated groundwater is estimated at approximately 70 million gallons.

B3.2.4 **The patterns of rainfall in the region.** The Rifle area receives on average approximately 13.46 inches of total precipitation per year (http://www.wrcc.dri.edu). Rainfall occurs during the summer in high-intensity, short-duration, late afternoon thunderstorms that are conducive to runoff. Precipitation occurs in the winter as snowfall. Precipitation events have no measurable effect on quality of water in the Colorado River as a result of site contamination.

B3.2.5 **The proximity of the site to surface waters.** The Colorado River forms the southern boundary of the site. An open ditch flows across the eastern part of the site. The ditch is fed primarily by water coming from topographically higher areas. It has perennial flow and likely loses water to the aquifer.

B3.2.6 **The current and future uses of surface waters in the region surrounding the site and any water-quality standards established for those surface waters.** The Colorado River in the site vicinity is classified for use as recreation, water supply (i.e., source of drinking water for a community), and agriculture. Water quality standards for the river are established in Regulation No. 37 of the Colorado Department of Public Health and Environment's Water Quality Control Commission. The river water in the site vicinity does not exceed any of these standards or any of the Colorado state standards established for agricultural water use. No drinking water standards for human health or water quality criteria for aquatic life are exceeded.

B3.2.7 **The existing quality of surface water, including other sources of contamination and the cumulative impact on surface water quality.** Water in the Colorado River in the vicinity of the site is designated high quality by the State of Colorado. The site has no measurable impact on the river water quality. Water in the vicinity of the site is indistinguishable from background Colorado River water samples.

B3.2.8 **The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents.** There is no potential damage, as site contamination has no impact on the Colorado River water quality.

B3.2.9 **The persistence and permanence of potential adverse effects.** No adverse effects are currently present in the Colorado River and none are expected in the future.

B4.0 Corrective Action Assessment

B4.1 Results of Corrective Action Program

Corrective action to date has consisted predominantly of source removal. A comparison of pre-surface-remediation groundwater data for uranium with recent concentrations indicates that remediation resulted in about an order-of-magnitude reduction in groundwater concentrations. Maximum uranium concentrations reported in the Remedial Action Plan (DOE 1992) for the 1987–1990 time period are on the order of 1 to 2 mg/L compared with current maximum concentrations of around 0.1 to 0.2 mg/L (see Section 2.3 of this document). Wells formerly in the vicinity of existing well 0309 had concentrations of 0.11 to 0.13 mg/L (DOE 1992), compared with recent concentrations around 0.02 mg/L (GCAP Figure 7). It therefore appears that source control (i.e., removal of the tailings and other residual radioactive materials) resulted in rapid and significant improvements in water quality of the alluvial aquifer. However, the uranium plume at the site has remained largely unchanged since those initial reductions, as data from 1998 through 2016 show (GCAP Figures 11 through 14). GCAP Figures 13 and 14 show plume maps with fewer data points than Figures 11 and 12.

B4.2 Feasibility of Alternative Corrective Action

Section 2.4 of the GCAP details why corrective action at the site is not feasible. Uranium concentrations are expected to remain above the cleanup standard for hundreds of years.

The original flow and transport modeling that formed the basis for selection of a natural flushing compliance strategy assumed that site characteristics could be simplified in a manner that favored full restoration of the alluvial aquifer. DOE's reassessment of the site conceptual model based on more than a decade of research indicates that flow and transport processes are much more complex than earlier thought and that potential restoration of the aquifer will be more difficult than originally conceived. Though the possibility that some form of remediation could eventually succeed cannot be ruled out, the methods used to accomplish aquifer cleanup would have to be robust enough to overwhelm the large variety of hydraulic, chemical, and biological processes that currently control uranium behavior on a sitewide scale.

Experience at other DOE sites has also shown that remediation of uranium is more problematic than anticipated. The "tailing" effect, in which concentrations of uranium tend to remain above applicable standards over many tens of years, has been observed at a number of UMTRCA Title I and Title II sites. Examples of such sites include those at Tuba City, Arizona (DOE 2014), and Split Rock, Wyoming (WNI 1999), both of which have undergone active remediation. Though uranium concentrations at those locations showed significant decreases during the first few years of remediation, they then leveled off to relatively constant values that remained above applicable standards. However, unlike at the Old Rifle site, the primary sources of uranium (i.e., tailings piles) at these and other former mill sites have been stabilized in place in disposal cells, and gradually decreasing remnant seepage from the cells might still be impacting underlying groundwater systems.

At another uranium mill tailings site—the Monticello, Utah, Operable Unit III Superfund site—concentrations of uranium have not declined according to model predictions after a number of years of active remediation coupled with monitored natural attenuation (DOE 2007). As at the Old Rifle site, mill tailings at the Monticello site were removed. In addition, secondary source materials (alluvial sediments) located beneath the tailings were completely removed down to bedrock, leaving only uranium in downgradient portions of the affected aquifer as a potential contaminant source. While removal of the tailings and contaminated alluvial materials produced significant decreases in uranium contamination, continued remediation of groundwater through use of a permeable reactive barrier coupled with extraction and treatment of groundwater has been ineffective in further reducing uranium concentrations. As with the Old Rifle site, concentrations have leveled off in the 0.1 to 0.2 mg/L range. The proposed reason for the recalcitrant contamination is slow release of uranium bound up in aquifer materials through adsorption or other, unknown mechanisms (DOE 2007).

Assessments of subsurface remediation at the Monticello site and UMTRCA sites suggest that remediation of uranium in groundwater in alluvial aquifer settings is much more difficult than previously expected. Short of completely removing all affected aquifer materials at a site, both active and passive remediation efforts face significant limitations.

Despite a better understanding of the site conceptual model, it does not appear that alternatives to the natural flushing remedy (e.g., pump-and-treat, in situ chemical manipulation) would improve the potential for restoring the aquifer at the Old Rifle site. As with natural flushing, active remediation approaches would face serious limitations in removing uranium from a heterogeneous aquifer containing persistent long-term contaminant sources. The same factors that would limit active remediation would also limit more-passive, in situ methods for either immobilizing or mobilizing uranium.

Because it is not feasible to restore the aquifer to meet either background levels or numerical UMTRCA standards, alternative standards are required. UMTRCA regulations allow the use of ACLs if it can be demonstrated that they are protective of human health and the environment.

B4.3 Corrective Action Costs

Detailed cost estimates were not conducted for Old Rifle site remedial alternatives, as a comparative analysis of alternatives was not completed for the Old Rifle SOWP. Costs reported here can be considered as order-of-magnitude estimates and are provided for a relative comparison only. Costs are based on estimates developed for the New Rifle site (DOE 1999), which is similar in geology and chemistry to the Old Rifle site.

B4.3.1 Pump and Treat

A pump-and-treat system would require installation of extraction wells, construction and installation of a treatment system, and injection or disposal of system effluent. Costs would also be incurred for operation and maintenance of the system. Capital costs for a pumping system capable of extracting 30 gallons per minute are estimated at $210,000 (DOE 1999). Annual operation and maintenance costs are estimated at $6,000 for the pumping system. Capital costs for the zero-valent iron (ZVI) system is estimated at $76,000 with annual operating costs of about $57,000, including costs for disposal of spent ZVI. Costs for effluent discharge are not included, as these would depend on the quality of the effluent and could only be determined after completion of a site-specific pilot study. The 18-month present worth cost of this treatment alternative, excluding effluent disposal, is estimated at $0.23 million (in 1999 dollars).

B4.3.2 In-Situ Stabilization

The process for stabilizing uranium in situ has not been developed or demonstrated, so no meaningful cost estimate can be prepared at this time. Costs will be required for chemicals used and development of a process for injecting chemicals into the ground in such a way that subterranean mixing is optimized. Monitoring of the subsurface in some fashion would also be required. However, in-situ stabilization will not require extraction, treatment, or effluent disposal systems and is therefore expected to cost less than a pump-and-treat system.

B4.4 Corrective Action Benefits

Based on the assessment of restoration potential of the aquifer, it is unlikely that active remediation will achieve meaningful reductions in contaminant concentrations in the groundwater. Groundwater at the site was never used for any beneficial purpose. The City of Rifle currently owns the site and uses it for a storage and maintenance facility. Implementation of corrective action could interfere with these operations. Dilution of contaminants by the river is very high (5 orders of magnitude); therefore, plume remediation or immobilization provides no improvements in surface water quality.

B4.5 As Low As Reasonably Achievable Demonstration

Based on current site conditions with institutional controls in place, corrective action would result in virtually no risk reduction at the site. Corrective action cost estimates (based on the New Rifle SOWP) could range from approximately $200,000 to more than $4 million (1999 dollars) and provide no tangible benefit. The proposed remedy of no remediation and the establishment of ACLs would therefore be considered as low as reasonably achievable.

B5.0 Proposed Alternate Concentration Limits

B5.1 Proposed Alternate Concentration Limits

Section 3.2 of the GCAP describes the methodology for developing the ACL values. Table B-3 presents the proposed ACLs.

Table B-3. Summary of Proposed ACLs

Constituent	Proposed ACL (mg/L)	Basis
Selenium	0.122	Nonparametric USL95
Uranium	0.36	Nonparametric USL95
Vanadium	1.0	Current approved GCAP

B5.2 Proposed Implementation Measures

See Section 4.0 of the GCAP.

B5.3 References

Section 5.0 of the GCAP.

B5.4 Appendixes and Supporting Information

Appendixes A through E of SOWP and DOE 2011.

Appendix C

Establishment and Calculation of Alternative Concentration Limits for the Old Rifle Site

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References

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DOE (U.S. Department of Energy), 2012. *2012 Verification Monitoring Report for the Old and New Rifle, Colorado, Processing Sites*, LMS/FRO/FRN/S09046, June.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring data at RCRA Facilities, Unified Guidance*, EPA530-R-09-007, March.

EPA (U.S. Environmental Protection Agency), 2011. ProUCL Version 4.1.00 available at https://www.epa.gov/osp/hstl/tsc/software.htm.

Attachment 1. ProUCL Output for Old Rifle Monitoring Data

	Background Statistics for Uncensored Full Data Sets		
User Selected Options			
Date/Time of Computation	10/31/2016 10:52		
From File	WorkSheet.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Coverage	95%		
New or Future K Observations	1		
Number of Bootstrap Operation:	2000		
305-Se			
General Statistics			
Total Number of Observations	40	Number of Distinct Observations	37
Minimum	0.0093	First Quartile	0.0248
Second Largest	0.0929	Median	0.0325
Maximum	0.122	Third Quartile	0.0429
Mean	0.0398	SD	0.024
Coefficient of Variation	0.603	Skewness	1.681
Mean of logged Data	-3.372	SD of logged Data	0.538
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.117	d2max (for USL)	2.868
Normal GOF Test			
Shapiro Wilk Test Statistic	0.837	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.94	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.213	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Background Statistics Assuming Normal Distribution			
95% UTL with 95% Coverage	0.0905	90% Percentile (z)	0.0705
95% UPL (t)	0.0807	95% Percentile (z)	0.0792
95% USL	0.109	99% Percentile (z)	0.0956
Gamma GOF Test			
A-D Test Statistic	0.748	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.753	Detected data appear Gamma Distributed at 5% Significance Leve	
K-S Test Statistic	0.139	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0.14	Detected data appear Gamma Distributed at 5% Significance Leve	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	3.565	k star (bias corrected MLE)	3.314
Theta hat (MLE)	0.0112	Theta star (bias corrected MLE)	0.012
nu hat (MLE)	285.2	nu star (bias corrected)	265.1
MLE Mean (bias corrected)	0.0398	MLE Sd (bias corrected)	0.0218
Background Statistics Assuming Gamma Distribution			
95% Wilson Hilferty (WH) Approx. Gamma UPL	0.0818	90% Percentile	0.069
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.0825	95% Percentile	0.0811
95% WH Approx. Gamma UTL with 95% Coverage	0.0968	99% Percentile	0.107
95% HW Approx. Gamma UTL with 95% Coverage	0.0987		
95% WH USL	0.129	95% HW USL	0.134
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.983	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.94	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.104	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			

Background Statistics assuming Lognormal Distribution			
95% UTL with 95% Coverage	0.107	90% Percentile (z)	0.0684
95% UPL (t)	0.0859	95% Percentile (z)	0.0831
95% USL	0.16	99% Percentile (z)	0.12
Nonparametric Distribution Free Background Statistics			
Data appear Gamma Distributed at 5% Significance Level			
Nonparametric Upper Limits for Background Threshold Values			
Order of Statistic, r	40	95% UTL with 95% Coverage	0.122
Approximate f	2.105	Confidence Coefficient (CC) achieved by UTL	0.871
95% Percentile Bootstrap UTL with 95% Coverage	0.122	95% BCA Bootstrap UTL with 95% Coverage	0.122
95% UPL	0.0927	90% Percentile	0.0719
90% Chebyshev UPL	0.113	95% Percentile	0.0892
95% Chebyshev UPL	0.146	99% Percentile	0.111
95% USL	0.122		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background
data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data
represents a background data set and when many onsite observations need to be compared with the BTV.

310-U

General Statistics			
Total Number of Observations	40	Number of Distinct Observations	24
Minimum	0.16	First Quartile	0.182
Second Largest	0.33	Median	0.204
Maximum	0.36	Third Quartile	0.232
Mean	0.216	SD	0.0458
Coefficient of Variation	0.212	Skewness	1.303
Mean of logged Data	-1.553	SD of logged Data	0.196
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.117	d2max (for USL)	2.868
Normal GOF Test			
Shapiro Wilk Test Statistic	0.888	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.94	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.134	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.14	Data appear Normal at 5% Significance Level	
Data appear Approximate Normal at 5% Significance Level			
Background Statistics Assuming Normal Distribution			
95% UTL with 95% Coverage	0.313	90% Percentile (z)	0.274
95% UPL (t)	0.294	95% Percentile (z)	0.291
95% USL	0.347	99% Percentile (z)	0.322
Gamma GOF Test			
A-D Test Statistic	0.786	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.747	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.122	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0.139	Detected data appear Gamma Distributed at 5% Significance Leve	
Detected data follow Appr. Gamma Distribution at 5% Significance Level			

Gamma Statistics			
k hat (MLE)	25.52	k star (bias corrected MLE)	23.62
Theta hat (MLE)	0.00845	Theta star (bias corrected MLE)	0.00913
nu hat (MLE)	2042	nu star (bias corrected)	1890
MLE Mean (bias corrected)	0.216	MLE Sd (bias corrected)	0.0444
Background Statistics Assuming Gamma Distribution			
95% Wilson Hilferty (WH) Approx. Gamma UPL	0.295	90% Percentile	0.274
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.295	95% Percentile	0.294
95% WH Approx. Gamma UTL with 95% Coverage	0.317	99% Percentile	0.332
95% HW Approx. Gamma UTL with 95% Coverage	0.318		
95% WH USL	0.361	95% HW USL	0.363
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.937	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.94	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.112	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Background Statistics assuming Lognormal Distribution			
95% UTL with 95% Coverage	0.321	90% Percentile (z)	0.272
95% UPL (t)	0.296	95% Percentile (z)	0.292
95% USL	0.372	99% Percentile (z)	0.334
Nonparametric Distribution Free Background Statistics			
Data appear Approximate Normal at 5% Significance Level			
Nonparametric Upper Limits for Background Threshold Values			
Order of Statistic, r	40	95% UTL with 95% Coverage	0.36
Approximate f	2.105	Confidence Coefficient (CC) achieved by UTL	0.871
95% Percentile Bootstrap UTL with 95% Coverage	0.36	95% BCA Bootstrap UTL with 95% Coverage	0.36
95% UPL	0.329	90% Percentile	0.272
90% Chebyshev UPL	0.355	95% Percentile	0.302
95% Chebyshev UPL	0.418	99% Percentile	0.348
95% USL	0.36		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

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General Statistics			
Total Number of Observations	40	Number of Distinct Observations	34
Minimum	0.14	First Quartile	0.363
Second Largest	0.799	Median	0.471
Maximum	0.877	Third Quartile	0.61
Mean	0.499	SD	0.177
Coefficient of Variation	0.356	Skewness	0.165
Mean of logged Data	-0.766	SD of logged Data	0.398
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.117	d2max (for USL)	2.868
Normal GOF Test			
Shapiro Wilk Test Statistic	0.977	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.94	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.108	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.14	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			

Background Statistics Assuming Normal Distribution			
95% UTL with 95% Coverage	0.874	90% Percentile (z)	0.726
95% UPL (t)	0.801	95% Percentile (z)	0.791
95% USL	1.008	99% Percentile (z)	0.912
Gamma GOF Test			
A-D Test Statistic	0.254	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.75	Detected data appear Gamma Distributed at 5% Significance Leve	
K-S Test Statistic	0.0772	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0.14	Detected data appear Gamma Distributed at 5% Significance Leve	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	7.279	k star (bias corrected MLE)	6.75
Theta hat (MLE)	0.0685	Theta star (bias corrected MLE)	0.0739
nu hat (MLE)	582.3	nu star (bias corrected)	540
MLE Mean (bias corrected)	0.499	MLE Sd (bias corrected)	0.192
Background Statistics Assuming Gamma Distribution			
95% Wilson Hilferty (WH) Approx. Gamma UPL	0.858	90% Percentile	0.755
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.87	95% Percentile	0.851
95% WH Approx. Gamma UTL with 95% Coverage	0.974	99% Percentile	1.05
95% HW Approx. Gamma UTL with 95% Coverage	0.994		
95% WH USL	1.21	95% HW USL	1.255
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.956	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.94	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.101	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Background Statistics assuming Lognormal Distribution			
95% UTL with 95% Coverage	1.08	90% Percentile (z)	0.774
95% UPL (t)	0.917	95% Percentile (z)	0.895
95% USL	1.456	99% Percentile (z)	1.174
Nonparametric Distribution Free Background Statistics			
Data appear Normal at 5% Significance Level			
Nonparametric Upper Limits for Background Threshold Values			
Order of Statistic, r	40	95% UTL with 95% Coverage	0.877
Approximate f	2.105	Confidence Coefficient (CC) achieved by UTL	0.871
95% Percentile Bootstrap UTL with 95% Coverage	0.877	95% BCA Bootstrap UTL with 95% Coverage	0.877
95% UPL	0.798	90% Percentile	0.722
90% Chebyshev UPL	1.038	95% Percentile	0.771
95% Chebyshev UPL	1.282	99% Percentile	0.847
95% USL	0.877		
Note: The use of USL to estimate a BTV is recommended only when the data set represents a background			
data set free of outliers and consists of observations collected from clean unimpacted locations.			
The use of USL tends to provide a balance between false positives and false negatives provided the data			
represents a background data set and when many onsite observations need to be compared with the BTV.			

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