LMS/MON/S06584

Radiological Assessment of Stained Soils at the Monument Valley Processing Site

June 2010

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Abbreviations

ANL	Argonne National Laboratory
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	foot
LM	(DOE) Office of Legacy Management
m	meter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mrem	millirem
pCi/g	picocuries per gram
NRC	U.S. Nuclear Regulatory Commission
pCi/L	picocuries per liter
RAP	Remedial Action Plan
^{226}Ra	Radium-226
^{228}Ra	Radium-228
RDC	radon daughter concentration
SOWP	Site Observational Work Plan
^{234}U	Uranium-234
^{238}U	Uranium-238
UA	University of Arizona
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
WL	working level

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1.0 Introduction

This report summarizes the data and information that the U.S. Department of Energy (DOE) Office of Legacy Management (LM) has obtained in the evaluation of the recently discovered colored soil precipitate and elevated uranium in soils at the Monument Valley, Arizona, Processing Site. The site, a former uranium mill, is located on the Navajo Nation in northeastern Arizona (Figure 1–1) in an area that is characteristically rich in uranium ore; this ore body crops out near the surface (on Yazzie Mesa) just west of the site (Figure 1–2). Groundwater beneath the site was contaminated by milling operations that were ongoing from 1955 through 1968. Contaminated surface materials from tailing piles, leach areas, and an evaporation pond were completely removed from the site by January 1994 in accordance with Title 40 Code of Federal Regulations Part 192 (40 CFR 192) Subpart A, as part of the DOE Uranium Mill Tailings Remedial Action (UMTRA) Project. The former evaporation pond, shown in Figure 1–3, is the primary area of focus herein, as this is where recent field measurements and soil sampling indicated areas of elevated radioactivity.

The primary purpose of this report is to present all the available analytical data and information regarding the nature and extent of reported soil contamination (and all related media). This evaluation begins by revisiting historical characterization data to assess the potential source of the elevated levels. Site remediation activities (1992–1994) and post-cleanup verification data are then summarized to verify that previous DOE commitments (in the context of U.S. Nuclear Regulatory Commission [NRC] cleanup requirements) were fulfilled. Because the core of DOE's mission is the protection of human health and the environment, this evaluation culminates in a conservative evaluation of potential doses to workers resulting from exposure to radiological constituents in soils of the former evaporation pond.

1.1 Overview and Rationale for this Evaluation

In 1994, DOE removed mill tailings and other contaminated surface materials from the Monument Valley site. Nitrate and ammonium used during the milling process remain in a shallow groundwater plume spreading from the former mill site area. These two constituents, along with sulfate, are the primary groundwater contaminants of concern at the site. Uranium is also a contaminant of concern, but elevated levels in groundwater appear to be localized and are not as widespread as the primary contaminants. In 1999, in collaboration with the University of Arizona (UA), LM initiated pilot studies of remediation alternatives for contaminated groundwater at the site, focusing on nitrate. These pilot studies investigate remedies that rely on natural and enhanced attenuation processes. Plots were planted in the area of the former new tailings pile and later, in 2006, expanded to include some surrounding areas, including the former evaporation pond.

In August 2009, colored deposits were noticed on the surface of the soil in the phytoremediation plots. Samples were collected and analyzed, and the yellow- and green-colored samples from the former evaporation pond area were high in vanadium and uranium. In March 2010, additional samples were taken of the yellow- and green-colored soils for further evaluation. Radiological scanning was also conducted to evaluate if the colored soils posed any risk to site workers. Analytical results of the soil samples confirmed the elevated levels of vanadium and uranium, and the scanning indicated elevated gamma and beta activity in the former evaporation pond area. DOE documented these initial findings in a letter to NRC on April 1, 2010 (Appendix A). Table 1–1 summarizes the chronology pertinent to this evaluation. Since then, DOE has obtained

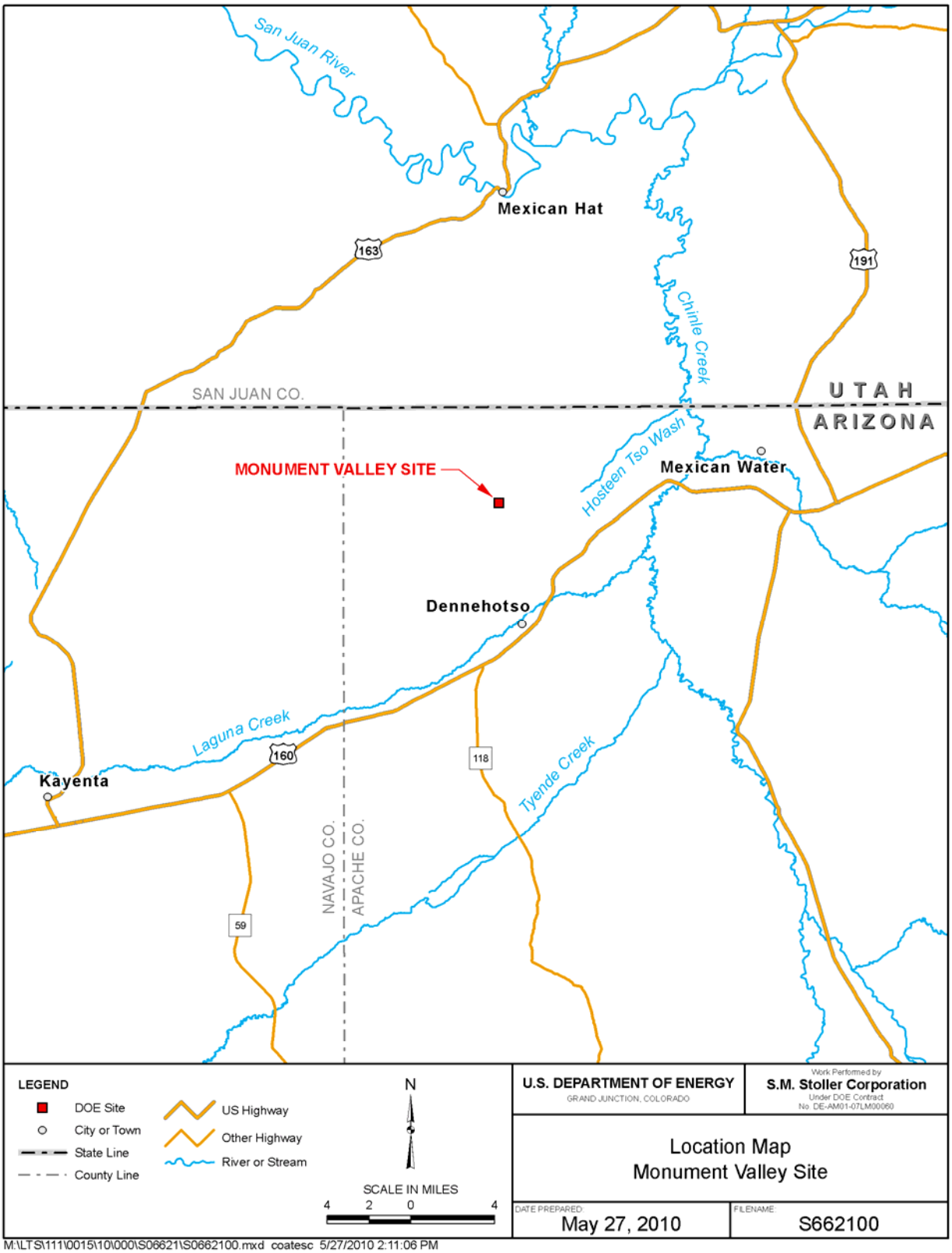

Figure 1–1. Monument Valley, Arizona, Processing Site Location Map

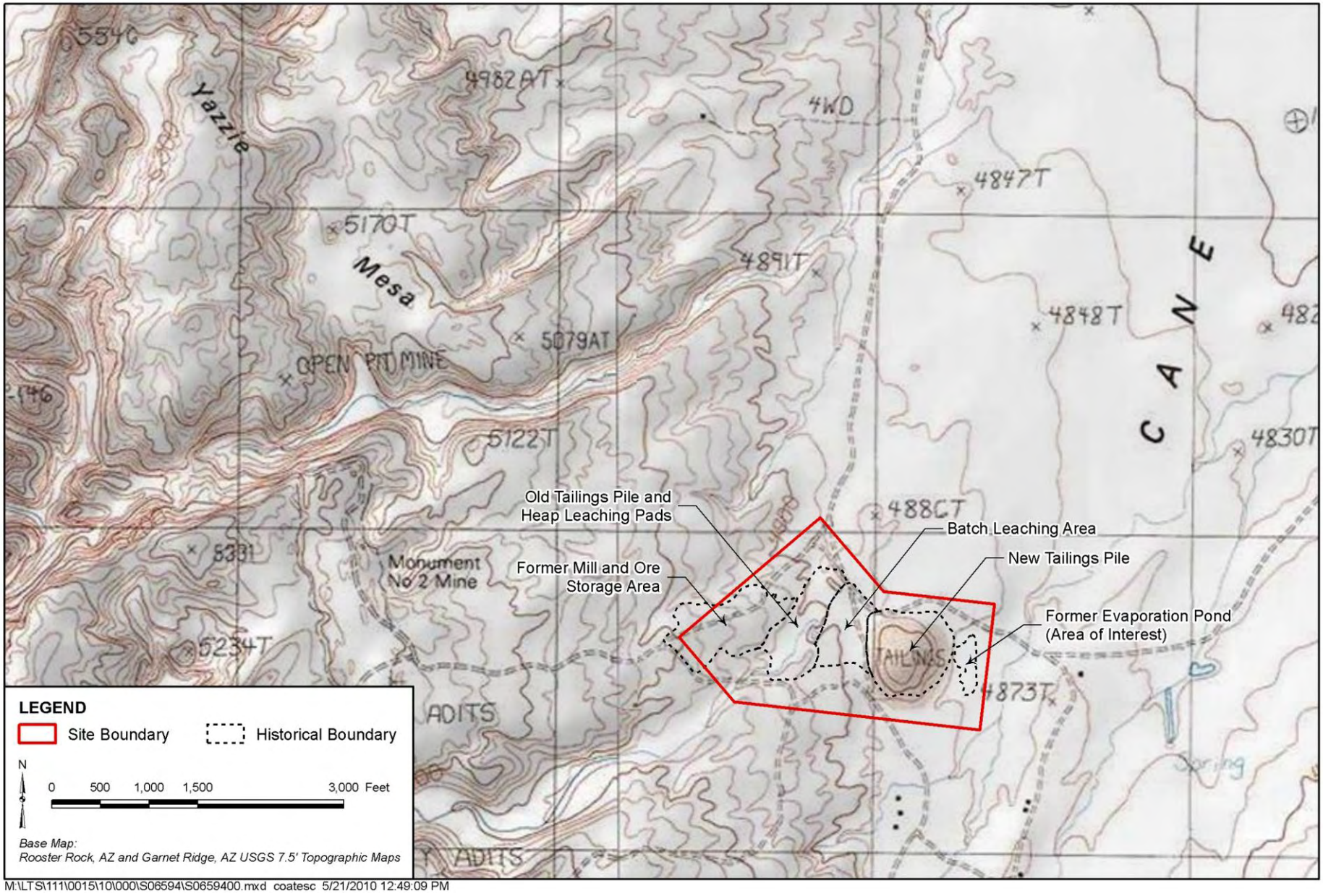

Figure 1–2. Monument Valley Site Regional Setting and Topography

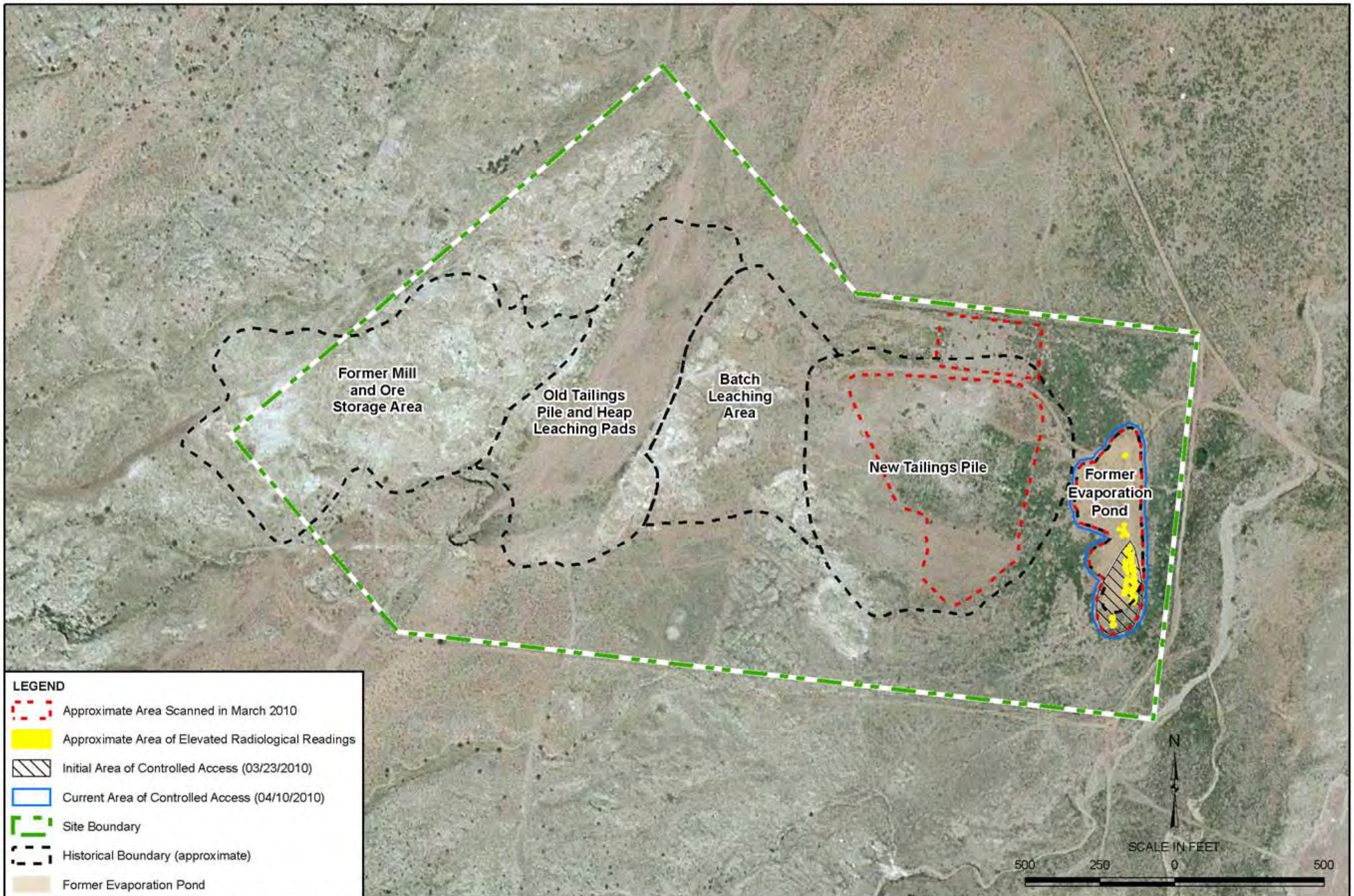

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Figure 1–3. Site Layout Showing Areas of Recent Radiological Scans and Investigations

Table 1–1. Site Chronology Relevant to this Evaluation

Date/Period	Monument Valley Site Observations and Activities
1955–1968	The mechanical milling operations at the Monument Valley site continued from 1955 to 1964. A batch-leach process was used from 1964 until 1968, when the mill closed and the lease expired.
1992–1994	Surface remediation began in 1992 and was completed in January 1994. During this period, the tailings piles, windblown tailings, contaminated radioactive materials, concrete foundations, and debris were removed and placed in the Mexican Hat UMTRA Project disposal cell, approximately 10 miles north of the former mill site.
1995–1997	Verification and approval—Final Completion Report issued. NRC Concurrence on September 16, 1997 (Appendix A).
1999–present	Groundwater monitoring (nitrate, ammonium, and sulfate are primary contaminants) and phytoremediation pilot studies. Phytoremediation pilot studies conducted in collaboration with the University of Arizona (UA) and Diné College.
2007–2008	UA personnel had earlier identified areas with poor plant growth in locations with red- and blue-hued surface soils. The soils were analyzed, and they contained elevated levels of manganese; however, the manganese was within background levels found in other soils, and the soils did not present a risk.
August–December 2009	UA personnel noticed surface soils in the former evaporation pond with yellow and green stains. These stains were dispersed mostly in the southern area of the former evaporation pond and did not appear to correlate to the irrigation water emitters. Samples of the stained surface soils were sent to a laboratory for analysis. The purpose of this investigation was to determine why poor plant growth occurred in this area. UA issued a memorandum documenting the results of the analyses and demonstrating that stained soil areas contain elevated levels of uranium and vanadium (this memorandum was issued on December 17, 2009, and is provided in Appendix C).
March 22–23, 2010	To further evaluate UA's findings, DOE collected additional samples from the same area where UA had collected the yellow- and green-stained soils.
March 23, 2010	Stoller conducted a radiological screening survey as a best management practice. The focus of this initial survey was the yellow- and green-stained soils in the former evaporation pond.
April 1, 2010	DOE issued a letter notifying NRC of the elevated radiological measurements in surface soils.
April 7, 2010	Fences in the area were upgraded to prevent livestock access to the area.
April 13, 2010	Because of concerns that elevated radiological levels may exist in other areas of the site, a second radiological screening survey was conducted using a crutch scintillometer. No elevated gamma activity outside of the former evaporation pond was detected. A more spatially comprehensive scan of the former evaporation pond was also performed at this time, and the survey area was expanded to include outlying areas (Figure 1–3).
April 14, 2010	Soil samples collected on March 22 were sent to an analytical laboratory for isotopic analysis; analytical results were obtained on this date. They indicated the highest activity for total uranium (^{238}U plus ^{234}U) was 985 picocuries per gram (pCi/g). These results also indicated that the highest Ra-226 activity was 1.67 pCi/g, which is below the 40 CFR 192 surface soil cleanup standard of 5 pCi/g above background averaged over 100 square meters.
April 20, 2010	Radiological technicians revisited the site to rope off and post the entire area of the former evaporation pond and to collect a surface soil sample (this sample was intended to be a worst-case sample based on field readings) for gamma spectroscopy analysis. The results of this analysis showed a total uranium concentration from all isotopes of 790 pCi/g.

additional data to determine the nature and extent of this material. Although the area is currently controlled (access restricted), the evaluation presented in this document will demonstrate that there is no imminent or potential health risk.

1.2 Regulatory Framework

The Monument Valley Processing Site is regulated under Title I of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) (Public Law 95-605). Under this law, DOE remediated Monument Valley and 21 other inactive uranium-ore processing sites in accordance with standards promulgated by the U. S. Environmental Protection Agency (EPA) in 40 CFR 192. According to cleanup criteria in Subpart B of 40 CFR 192, the concentration of radium-226 (Ra-226) in land averaged over any area of 100 square meters shall not exceed the background level by more than

- 5 picocuries per gram (pCi/g) averaged over the first 15 centimeters (cm) of soil below the surface, and
- 15 pCi/g averaged over 15-cm-thick layers of soil more than 15 cm below the surface.

These single-contaminant cleanup criteria were mostly risk-based, although the ability to use field instrumentation rather than laboratory analysis to determine the location of buried tailings at depth was also a consideration in the development of the cleanup standards.

EPA evaluated the risk associated with the dispersal of tailings off the former processing sites and concluded that the principal risk was exposure to radon daughter products (primarily from inside buildings that might be constructed on contaminated land).

In addition to the Ra-226 cleanup criteria, many UMTRCA Title I remediations also used thorium-230 as a cleanup standard to ensure that after 1,000 years of decay and radium ingrowth, site materials will not exceed the Ra-226 standards.

1.3 Scope, Content, and Organization

Section 2 presents pertinent background information, including a site description and an overview of pre-remediation and post-remediation radiological conditions. NRC approved the cleanup, but given the presence of elevated levels of uranium, DOE revisited historical information to verify that cleanup was performed in accordance with guidelines and that the radium-based cleanup standards were met.

Many investigations associated with phytoremediation and the active remediation of groundwater at the Monument Valley site have taken place since the Site Observational Work Plan (SOWP) was prepared in 1999 (DOE 1999). This evaluation focuses on only those data that are germane to the recent identification of elevated radioactivity. Therefore, Section 3 presents all available historical data since the remediation that are potentially related to this evaluation. For soils, these findings are presented in chronological order; Section 3 concludes with an evaluation of relevant groundwater and phytoremediation test plot data, as these studies are ongoing.

Section 4 documents results of analyses and investigations directly related to the stained soils. Although NRC approved the remediation of the Monument Valley site, the recently discovered elevated concentrations of uranium have raised concerns about the protection of site workers. To address this issue, Section 5 documents the results of a recent risk evaluation conducted to ensure that—in accordance with LM's primary mission—elevated levels of residual radioactive material do not pose a risk to human health and the environment. Section 6 summarizes the findings of this report. References are provided in Section 7, and detailed supporting information is provided in the Appendix A through Appendix C.

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2.0 Background

This section documents relevant aspects of site history, site conditions prior to remediation, information on the site cleanup and verification, and details on the NRC concurrence that the Monument Valley site was remediated to applicable standards.

2.1 Site History

A uranium-ore processing mill operated at the site from 1955 to 1968 on property leased from the Navajo Nation. During operation, approximately 2.2 million tons of ore were processed to produce 5700 tons of uranium oxide (U_30_8) concentrate (DOE 1993). The mill closed in 1968, and control of the site reverted to the Navajo Nation. Most of the mill buildings were removed shortly thereafter. The milling process produced radioactive mill tailings, a predominantly sandy material. From 1955 until 1964, ore at the site was processed by mechanical milling using an upgrader, which crushed the ore and separated it by grain size. The finer-grained material, which was higher in uranium content, was shipped to other mills for chemical processing; coarser-grained material was stored on site. These source materials and other site-related contamination were removed during surface remediation at the site from 1992 through 1994.

The total volume of contaminated material at the site was 1,083,000 cubic yards (yd^3) on 83 acres. All the contaminated material was moved to the Mexican Hat, Utah, disposal cell 17 road miles to the north, and surface remedial action was completed in May 1994.

The site areas on which previous investigations have largely focused are the old tailings pile and heap-leach area, the new tailings pile, and the evaporation pond (the focus of this report). The old tailings pile was composed of the sandy tailings that were a product of the mechanical upgrading of ore. The upgrading process used water containing minor amounts of flocculent but no other processing chemicals. Thus, tailings solutions in the old pile were water-equilibrated to minerals in the ore. Heap-leaching of these old tailings occurred in the area where they were stored. Old tailings were placed on the heap-leach pad, and sulfuric acid was added to the tailings. Heap-leach pads were lined to collect the acidic leachate. By contrast, the new tailings pile contained sandy tailings and processing solutions, which contained sulfate, nitrate, and ammonium from the processing chemicals. According to both the SOWP and the Environmental Assessment (DOE 1999, DOE 2005), the evaporation pond was probably used to retain seepage from the new tailings pile. Whether or not the pond was lined is not clear in the site documentation.

2.2 Site Conditions Prior to Remediation and Initial Characterization

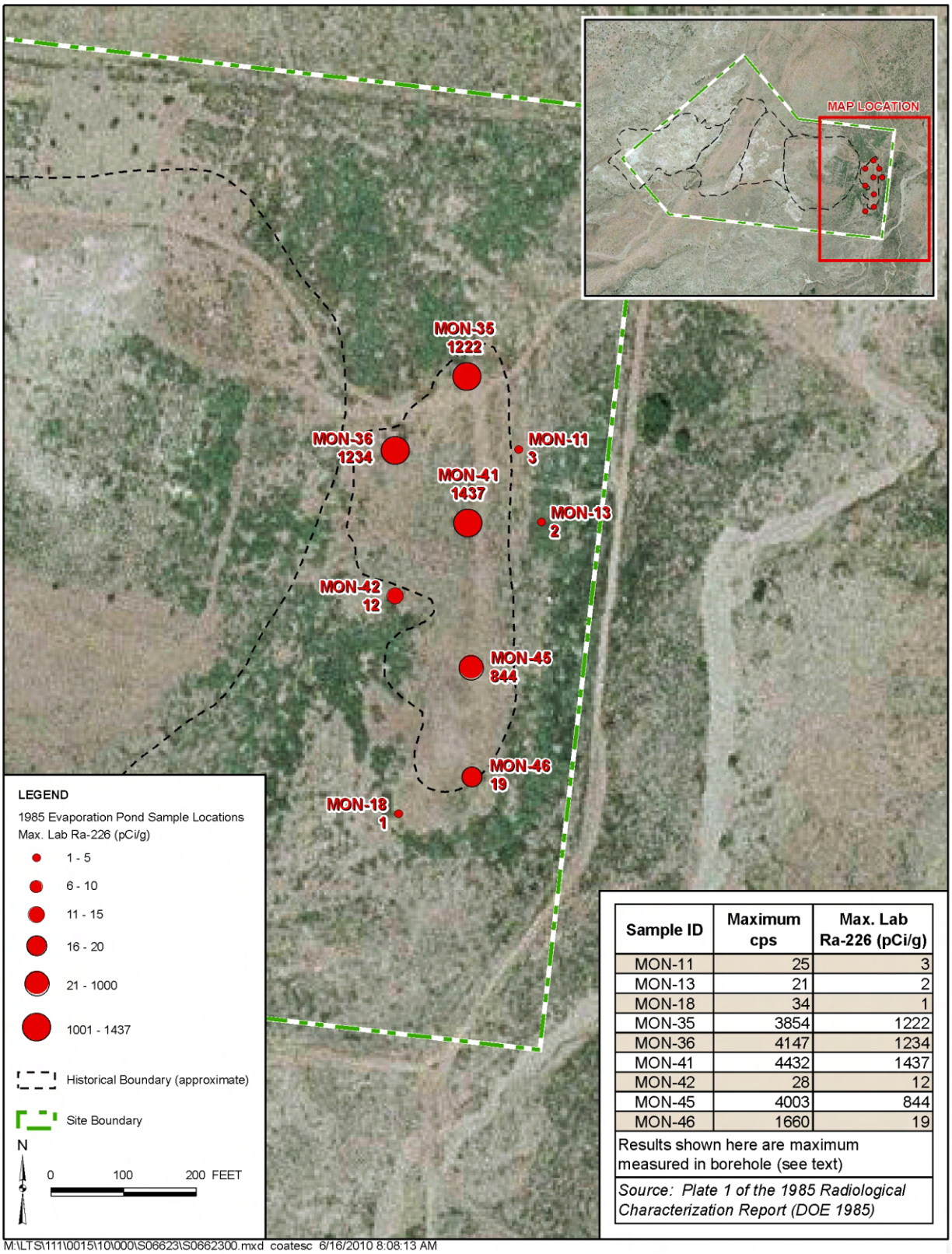
Although radiological data from the Monument Valley processing site have been collected in numerous investigations dating back to 1961 (Ford, Bacon, and Davis 1981; DOE 1993), the 1985 Radiologic Characterization report (DOE 1985) served as the primary source for initial (pre-remediation) characterization data summarized in this section. The field investigation preceding the report's development yielded an extensive and detailed evaluation of radiological conditions at the site—sample collection was comprehensive both laterally and with depth (sample depths ranged from the surface to 58 feet [ft]). That report demonstrated that the evaporation pond contained some of the highest concentrations of radium at the site. This was also shown in an earlier engineering assessment conducted by Ford, Bacon and Davis (1981).

Figure 2–1 plots the maximum soil Ra-226 concentrations measured at nine locations in the evaporation pond area during the 1985 characterization effort. This figure was adapted from the sitewide sample location map provided in the corresponding report (DOE 1985, Plate 1). For reference, maximum field gamma measurements taken during the initial radiological scans are also provided (expressed in counts per second [cps]). Five samples were collected within the pond area and four were peripheral.[1] Given the risk and regulatory drivers described in Section 1, Ra-226 was the primary analytical endpoint. Figure 2–1 shows that highly elevated concentrations of Ra-226, ranging up to 1437 pCi/g (also the sitewide maximum), were previously measured within the central portion of the evaporation pond. Comparison of this figure with Figure 1–2 and soil analytical data discussed later in this report indicates that evaporation pond areas with the highest soil Ra-226 concentrations prior to remediation correspond closely to those areas where elevated radioactivity was recently identified. (Note, however, that only uranium has been detected in elevated concentrations; the following sections will document that remediation efforts were effective in satisfying both the surface [5 pCi/g] and subsurface [15 pCi/g] radium-226 based regulatory standards.)

In light of the recently discovered areas of elevated radioactivity, an obvious question might be: how deep was the contamination in this area relative to the depth of the excavation? To address this question, Figure 2–2 provides a three-variable "bubble plot" perspective of the data shown in Figure 2–1. In this figure, the vertical (*y*) axis corresponds to the sample depth, and the point size reflects the relative magnitude of Ra-226 measured in the soil (*x* axis sample locations do not correspond to any spatial scale). Because of the wide range in the data set (1–1437 pCi/g) and the relative size of the "bubble" or point corresponds to the magnitude of these data, some points are barely discernible. Therefore, all points are labeled with the corresponding Ra-226 concentration to facilitate review. This figure demonstrates that, at the time of the initial characterization, Ra-226 concentrations exceeding 5−15 pCi/g were largely limited to the uppermost 3 ft soil depth. Based on information provided in the Remedial Action Plan (RAP) (DOE 1993), the average excavation depth during remediation was approximately 2.5 ft.

Given the risk and regulatory drivers described in Section 1, Ra-226 was the primary analytical endpoint; Th-230 and uranium were analyzed for only a subset of site samples, and for only one sample (MON-41) in the evaporation pond. Figure 2–3 plots Ra-226 in this sample versus the corresponding uranium and Th-230 concentrations. To provide a more comprehensive (sitewide) data set, Figure 2–4 plots data for the same variables (Ra-226, uranium, Th-230), but for all 1985 characterization data (DOE 1985). Because the majority of the data points are difficult to discern in the upper portion of this figure, the bottom plot excludes the outlier (high Ra-226) data points. These figures demonstrate that uranium concentrations were quite low relative to Ra-226 concentrations—the maximum was 268 pCi/g (2 ft depth)—and there is no apparent relationship (i.e., no equilibrium). This finding is not unexpected, given that milling processes should (in theory) have removed most of the uranium. However, these results are interesting in light of more recent findings, which revealed uranium levels as high as 1000 pCi/g.

[1] As noted in all figures, the historical boundaries shown in the figures are approximate. These boundaries were established over two decades ago, before the now-universal and well-established Global Positioning System surveying techniques were developed. Although the boundaries are approximately correct, the aerial photographs in the figures provided herein suggest that they may be offset somewhat in some areas.



Sample ID	Maximum cps	Max. Lab Ra-226 (pCi/g)
MON-11	25	3
MON-13	21	2
MON-18	34	1
MON-35	3854	1222
MON-36	4147	1234
MON-41	4432	1437
MON-42	28	12
MON-45	4003	844
MON-46	1660	19

Results shown here are maximum measured in borehole (see text)

Source: Plate 1 of the 1985 Radiological Characterization Report (DOE 1985)

Figure 2–1. 1985 Field Gamma Measurements and Soil Ra-226 Concentrations in Evaporation Pond Area

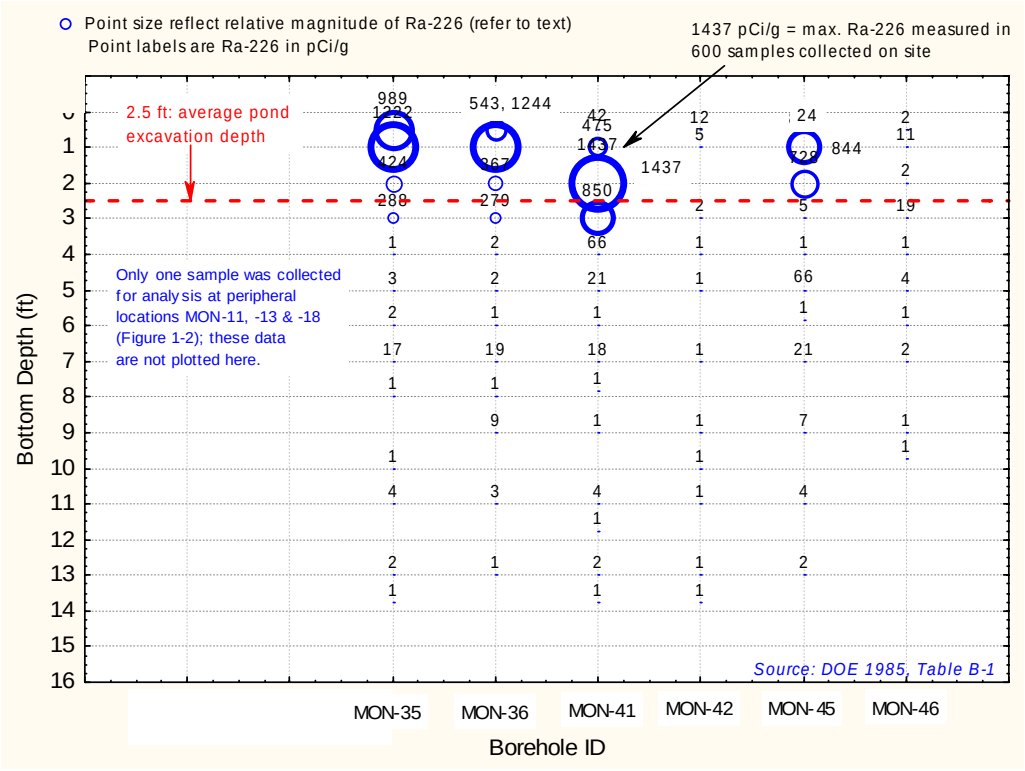


Figure 2–2. Bubble Plot of Ra-226 Concentrations in Evaporation Pond Area Borings (DOE 1985)

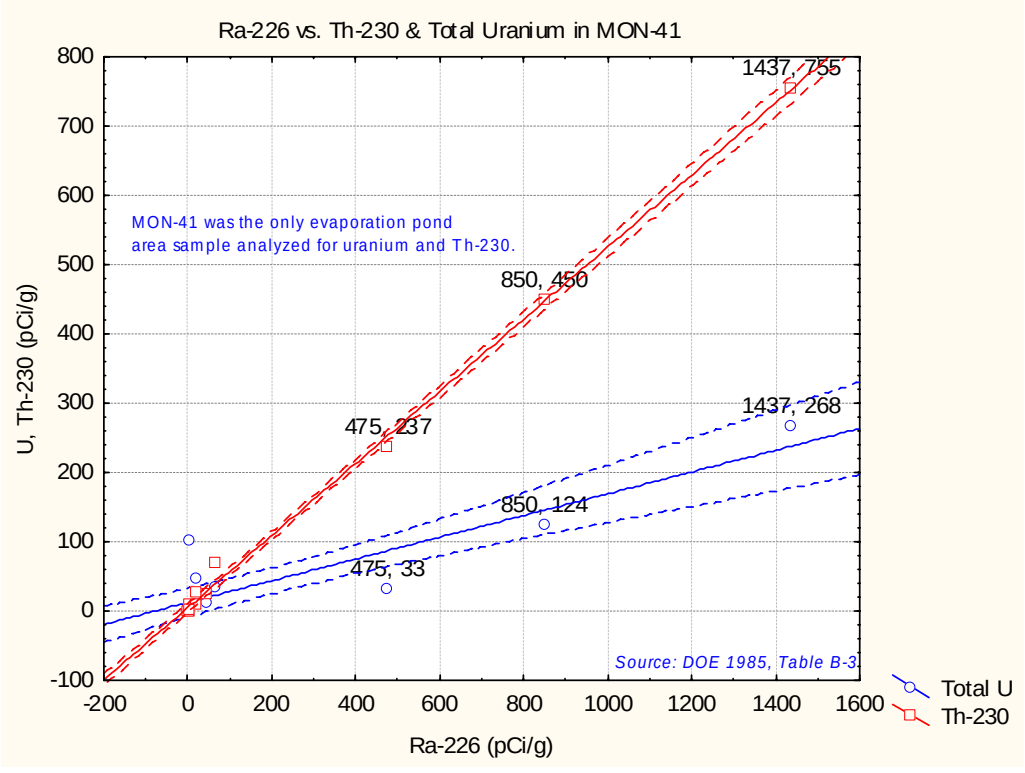


Figure 2–3. Corresponding Th-230 and Uranium Concentrations in One Sample

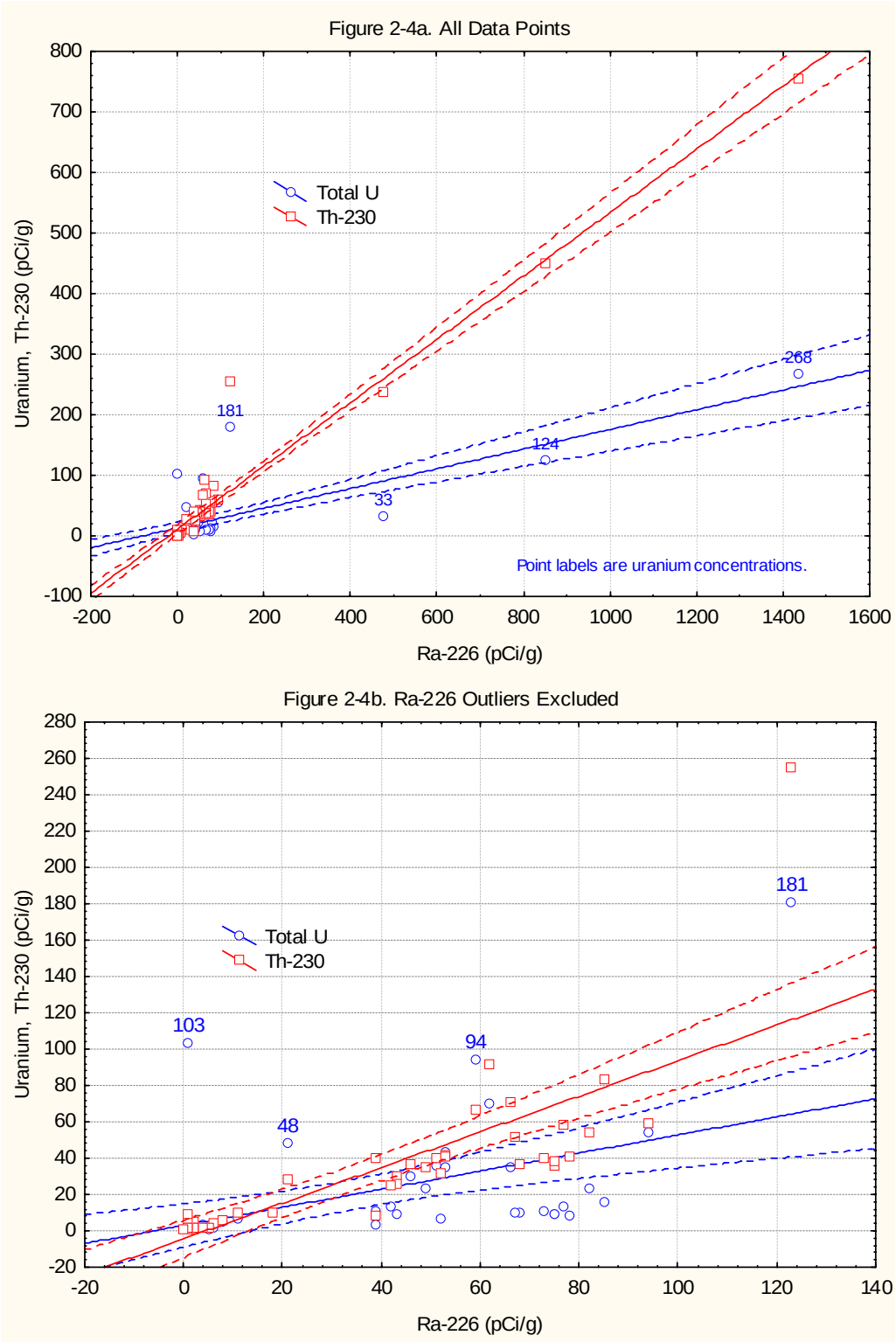


Figure 2–4. Plot of Ra-226 vs. Uranium and Th-230: All 1985 Characterization Data

2.3 Summary of Cleanup Efforts, Verification, and NRC Concurrence

The findings discussed in this section are based largely upon information in the following documents:

- *Remedial Action Plan for the Codisposal and Stabilization of the Monument Valley and Mexican Hat Uranium Mill Tailings at Mexican Hat, Utah* (DOE 1993)
- *Mexican Hat, UT, Monument Valley, AZ Final Completion Report* (DOE 1997)

2.3.1 Remedial Action Plan

The remedial action consisted of two phases: Phase I remedial action consisted primarily of demolishing the remaining mill buildings (except the sheet metal shop), constructing a vehicle decontamination pad and retention basins, and fencing the site. Phase II included the placement of demolition debris in the Mexican Hat disposal cell (the lower tailings pile), removal and disposal of upper tailings and windblown and waterborne materials in the disposal cell, and incorporation of permanent drainage features (DOE 1993).

Table 2–1 summarizes the volumes of contaminated material and Ra-226 concentrations of all major areas on the site. The total volume of contaminated material is about 1,083,000 yd^3.

Table 2–1. Excavation Volumes and Volume-Weighted Ra-226 Concentrations of Contaminated Material at the Monument Valley Site

Area Description	Contaminated Volume (yd^3)	Average Ra-226 (pCi/g)
Lower pile	759,964	46.7
Evaporation pond	9,000	219.6
Heap leach pads (upper pile)	258,936	51.2
Ore storage (RAP Area "E", miscellaneous area	32,922	66.0
Batch leach yard (RAP "Area C")	14,036	38.3
Old pile remnant (RAP "Area D"	1,406	40.0
Rubble piles	4,129	67.8
Roads	3,000	37.3
Total	**1,083,393**	**49.7**

Adapted from Table 3.1 of the RAP (DOE 1993); average Ra-226 concentrations are volume-weighted averages.

The RAP does not explicitly document the depths of the excavation; this information would be particularly useful for the former evaporation pond. However, the average depth of the excavation for this area can be estimated by dividing the contaminated volume by the area of the evaporation pond (9,000 yd^3 divided by 10,648 square yards (2.2 acres), yielding an estimated 0.85 yard, or an approximately 30-inch (2.5-ft) excavation depth.

2.3.2 Final Completion Report

The Final Completion Report documents the site conditions after cleanup and the verification procedures used to ensure that the site was remediated according to 40 CFR 192. Information from the Final Completion Report (mostly extracted from Appendix J, "Verification Measurements") that is applicable to this evaluation is summarized below:

- Approved procedures for soil verification measurements on the UMTRA Project were used at the Monument Valley site; verification measurements using both sampling and in situ techniques were employed during the site cleanup. Two types of in situ measurements were performed, RTRAK gamma survey measurements using a gamma scanning tractor and Hand-held Gamma Verification System (HGVS) measurements.
- Since Th-230 is the radioactive parent of Ra-226, elevated levels of Ra-226 can develop over long periods of time when Th-230 is present in elevated concentrations. Excavation control was conducted at the Monument Valley site such that the EPA limits would not be exceeded due the ingrowth of Ra-226 from levels of Th-230 in 1,000 years. Verification measurements for Th-230 were conducted on nearly 5 percent of the grids at the Monument Valley site. Additional measurements were conducted for areas suspected of having elevated concentrations of Th-230 in underlying soil such as heap-leach areas, raffinate ponds, and the upper tailings pile. If sampling indicated Th-230 in excess of the guideline, the surrounding grids were also sampled and analyzed for Th-230.
- Due to the natural error associated with radiological measurements, occasionally an independent laboratory result exceeded the limits while the site verification measurement met the limits. Review of Appendix J data indicates that "false negatives" (i.e., field measurements below criteria when laboratory results indicated otherwise) were infrequent. Also, these anomalous measurements are to be expected and are typical for a cleanup effort of this magnitude.
- The average Ra-226 concentration, including background, for 4,502 site verification samples was 1.4 pCi/g, and the maximum concentration was 6.3 pCi/g. Of the 221 verification samples analyzed by an independent laboratory for Th-230, the average concentration was 1.9 pCi/g, and the maximum was 29 pCi/g.
- Samples of backfill material were collected and analyzed to determine the levels of Ra-226. The average Ra-226 concentration for 236 backfill samples taken at the Mexican Hat and Monument Valley site was 0.6 pCi/g, and the maximum concentration was 4.6 pCi/g.

2.3.3 NRC Concurrence

On February 27, 1996, NRC notified the DOE UMTRA Project Office that NRC staff had completed its review of the final RAP and all associated documents pertinent to the proposed remedial action for the co-disposal and stabilization of the Monument Valley (and Mexican Hat) site. The staff's review was documented in the Final Technical Evaluation Report for the Monument Valley/Mexican Hat sites and transmitted with the February 1996 letter.

NRC's concurrence letter (September 18, 1996) stated that DOE's proposed remedial action complies with the EPA standards in 40 CFR 192, Subparts A–C, with the exception of the groundwater cleanup program at the Monument Valley site. As indicated in the Technical Evaluation Report, DOE must demonstrate compliance with EPA's final groundwater standards,

Subparts B and C, at the Monument Valley site. As with most Title I UMTRCA sites, DOE proposed deferral of the Monument Valley groundwater cleanup aspect of the remedial action and planned to handle this action in the separate groundwater program.

2.4 Discussion

Early (pre-remediation) characterization studies provide some insight as to the potential source of the elevated levels in the evaporation pond.

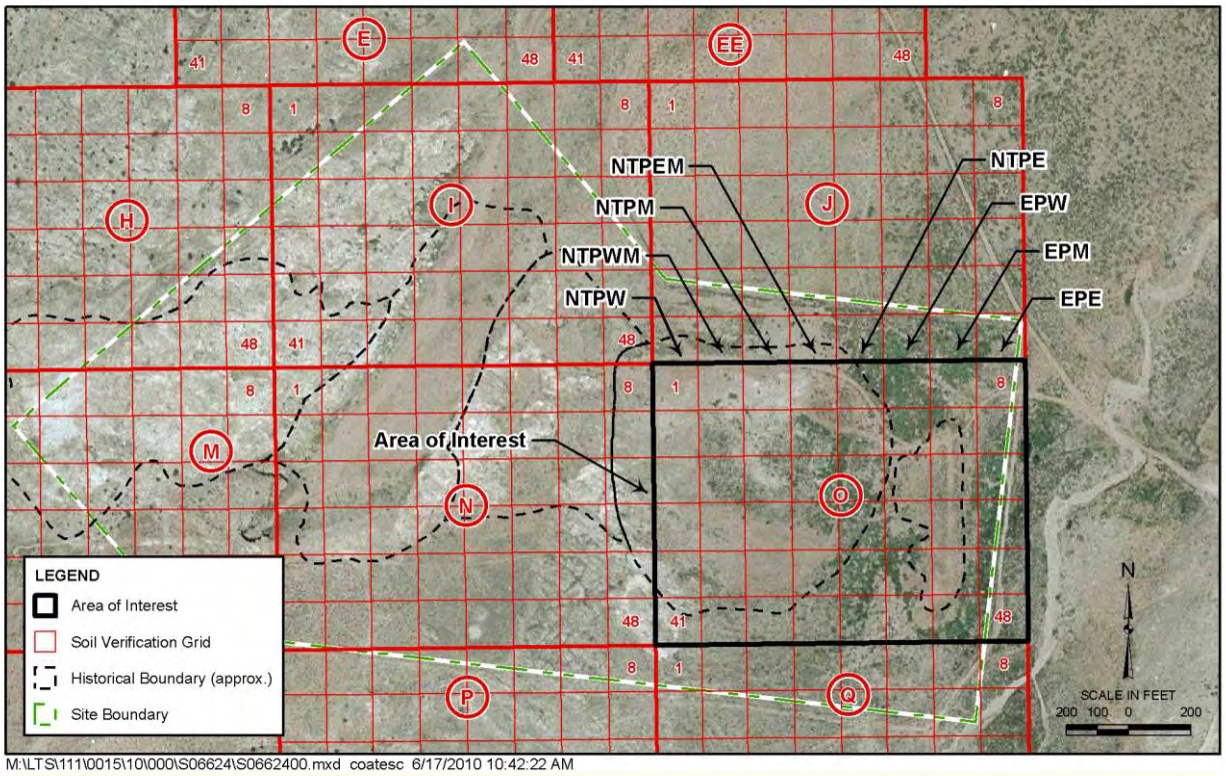
The information presented in the RAP and Final Completion Report indicates that the Monument Valley site was remediated in accordance with 40 CFR 192, and appropriate verification procedures were followed that included a quality control program and independent laboratory confirmation of field instrumentation. Moreover, NRC concurred that the remediation complies with requirements of 40 CFR 192. Figure 2–5 shows the site prior to remediation, and Figure 2–6 shows the Monument Valley site after cleanup was complete.

Because the recent elevated uranium in soils has been limited to the area of the former evaporation pond, a more robust evaluation of the data in the Final Completion report was performed for the evaporation pond and the surrounding areas; the results are shown in Figure 2–7. This figure shows that radium levels left after cleanup in the evaporation pond generally have a more widespread distribution and are more elevated than levels in surrounding areas; however, the surface standard for radium (5 pCi/g above background averaged over 100 square meters) was met. Although the cleanup standard was met, no indication was provided (or required) on the uranium that was left on site.

Figure 2–5. Contaminated Excavation and Haul from the Heap-Leach Area Prior to New Tailings Pile and Evaporation Pond Excavation (March 1993)

Figure 2–6. Monument Valley Site Post-Remediation and Cleanup Verification (February 1994)

† Source: Figure 4 and Figure 9 from the April 1997 Final Completion Report (DOE 1997).



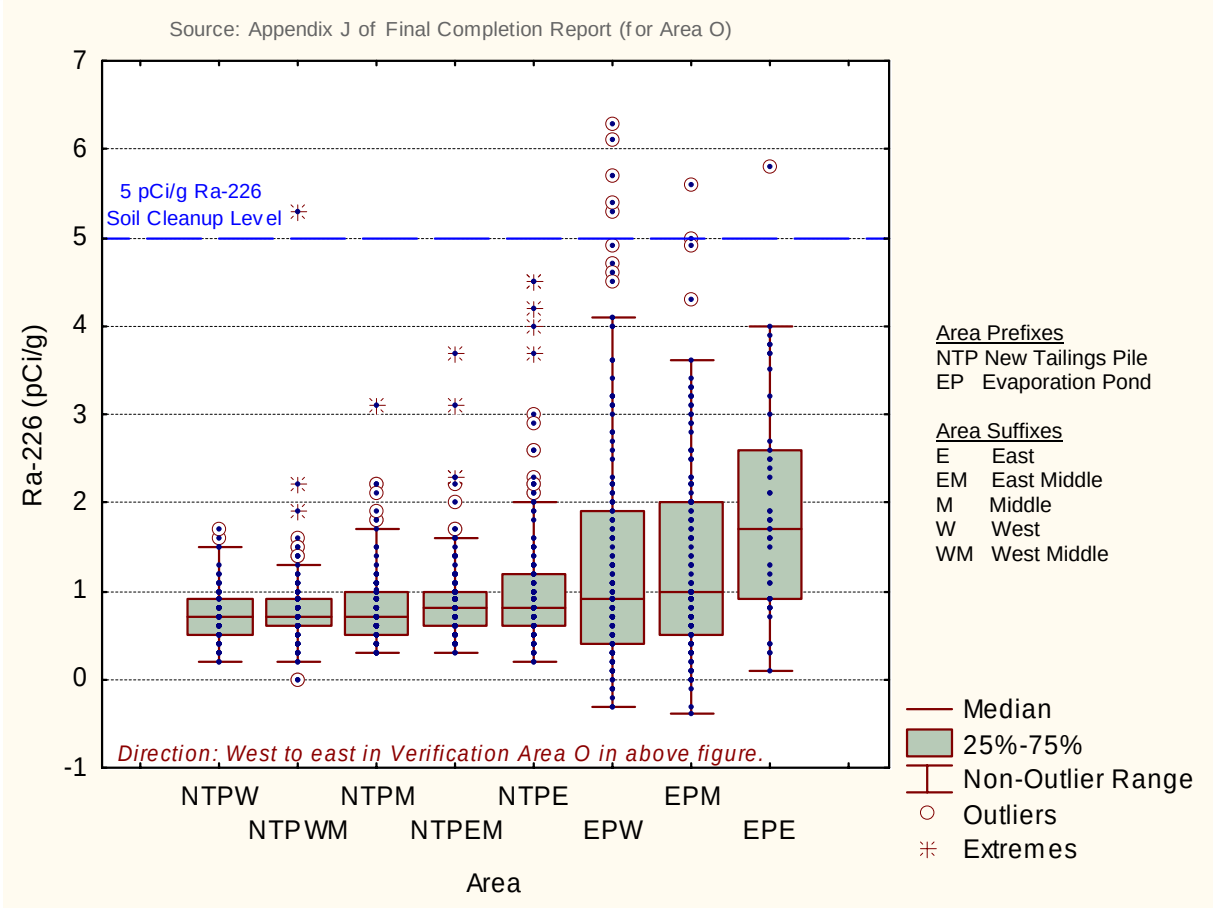


Figure 2–7. Final Completion Report Verification Results for Evaporation Pond and Surrounding Areas

3.0 Summary of Historical Data and Investigations

As with other UMTRCA Title I processing sites, the Monument Valley site was transferred to DOE for long-term care after remediation of the surface materials was complete. The post-remediation focus has been on contamination in groundwater, and additional characterization of on-site soils was therefore limited. However, some additional data have been gathered to support other purposes, such as ongoing phytoremediation pilot studies and the development of required regulatory documents. This section summarizes all data collected since the surface remediation was complete that is potentially relevant to this evaluation (the focus is on uranium results). Figure 3–1 plots all uranium soil data for the Monument Valley site, including results of recent investigations documented in Section 4 of this report. The results plotted in Figure 3–1 are the maximum uranium concentrations over all depths sampled.

Section 3.1 summarizes data from subpile soil samples collected in 1998 and 2004, Section 3.2 summarizes a salt crust evaluation, Section 3.3 summarizes pertinent information from phytoremediation pilot studies, and Section 3.4 summarizes information that can be gleaned from groundwater data that are relevant to this evaluation.

3.1 Subpile Soil Sampling (1998 and 2004)

To better understand site conditions and to thoroughly investigate the most appropriate way to address residual groundwater contamination at UMTRCA Title I processing sites, DOE generates a Site Observational Work Plan (SOWP). The SOWP documents the site-specific strategy that DOE will use to comply with EPA groundwater standards and provides a mechanism for stakeholder participation, review, and acceptance of the recommended remedial alternative. In 1999, DOE completed the *Final Site Observational Work Plan for the UMTRA Project Site at Monument Valley, Arizona* (DOE 1999),

During early characterization efforts conducted for the SOWP, DOE determined that soils beneath the surface of the historical tailings pile locations (subpile soils) likely represented a continuing source of ammonium and nitrate contamination to the alluvial aquifer. On the basis of pilot studies conducted before 2002, DOE concluded that phytoremediation would be a viable option for remediating nitrate and sulfate in the shallow areas of the alluvial aquifer and the subpile soils area. This option is also consistent with revegetation and land management goals at the site. However, DOE also determined that additional pilot studies should be conducted prior to final selection of the compliance strategy for nitrate and sulfate in the alluvial aquifer.

Data collected as part of initial groundwater characterization efforts (conducted while developing the SOWP) indicated that trace elements including manganese, uranium, and vanadium were present above background concentrations. Therefore, DOE conducted investigations to better assess areas of the site that could be a continuing source of groundwater contamination. Efforts were focused on the former tailings area: subpile soil samples were collected beneath the "footprint" of the former tailings piles. Two investigations were undertaken, one as part of the SOWP (in 1998), and a second in late 2004. Relevant findings are discussed below.

3.1.1 1998 Subpile Soil Sampling

Although soils at the site were remediated according to the radium standards in 40 CFR 192, the potential exists for nonradionuclide contaminants to have seeped into the soils. Contaminated soils could contaminate infiltrating water as it passes through them and prolong the groundwater cleanup effort. Soil samples were collected and analyzed to evaluate the distribution of selected site-related constituents in the soils underlying the former tailings piles, heap-leach pads, and evaporation ponds. Background soil samples were also collected and analyzed.

Subpile Soil Sampling Procedures

Twenty-six samples from nine soil borings were analyzed. Three soil borings were located in the former new tailings pile, two in the former heap-leach pads, two in the former evaporation pond, and two upgradient of the site (background soil borings). Figure 3–1 shows the location of the samples (see triangular symbols in this figure). Each soil boring was hand augered to a depth of 3.5 to 8.5 ft. The upper 1–2 ft was loose fill material that had been placed on the surface and graded after removal of the tailings and was not representative of the subpile soils. Samples were collected at approximately 1-ft intervals below the fill. Chemical extractions were used to determine the potential mobility of contaminants. Each sample was extracted by using three separate lixiviants, and the residue was completely digested and analyzed. The lixiviants were deionized water, alluvial groundwater, and 5 percent hydrochloric acid.

Table 3–1 summarizes the results, and Figure 3–2 shows the distribution of uranium concentrations from the 1998 subpile samples. The highest and most widely distributed concentrations of uranium were found in the subpile soils beneath the former evaporation pond.

3.1.2 December 2004 Subpile Soil Sampling

From 1998 to 2004, uranium concentrations in the groundwater at well 662 at the Monument Valley site rose approximately seven-fold. The purpose of the 2004 subpile sampling was to assess whether the former Old Tailings Pile and Heap Leach area is a potential source of leachable uranium.

Sampling was performed on a radial sampling grid; 25 samples were collected at the locations shown in Figure 3–1 (see circular symbols in this figure). Samples were collected at 1-meter intervals to a depth of 4 meters below the surface (i.e., at 3.3 ft, 6.3 ft, 6.6 ft, 10 ft, 13 ft). Figure 3–1 presents the sampling results, which are shown as the maximum uranium concentration measured in the depth profile.

This sampling was a limited, reconnaissance-level sampling event designed to answer the question of whether the former Old Tailings Pile and Heap Leach Pad area is a potential continuing source of leachable uranium. Most of the samples had uranium levels under 1 milligram per kilogram (mg/kg), three locations had uranium results greater than 3 mg/kg, and the highest was approximately 4.5 mg/kg. Uranium concentrations in several samples from this study were greater than those found in the 1998 soil sampling, including samples collected from the former evaporation pond.

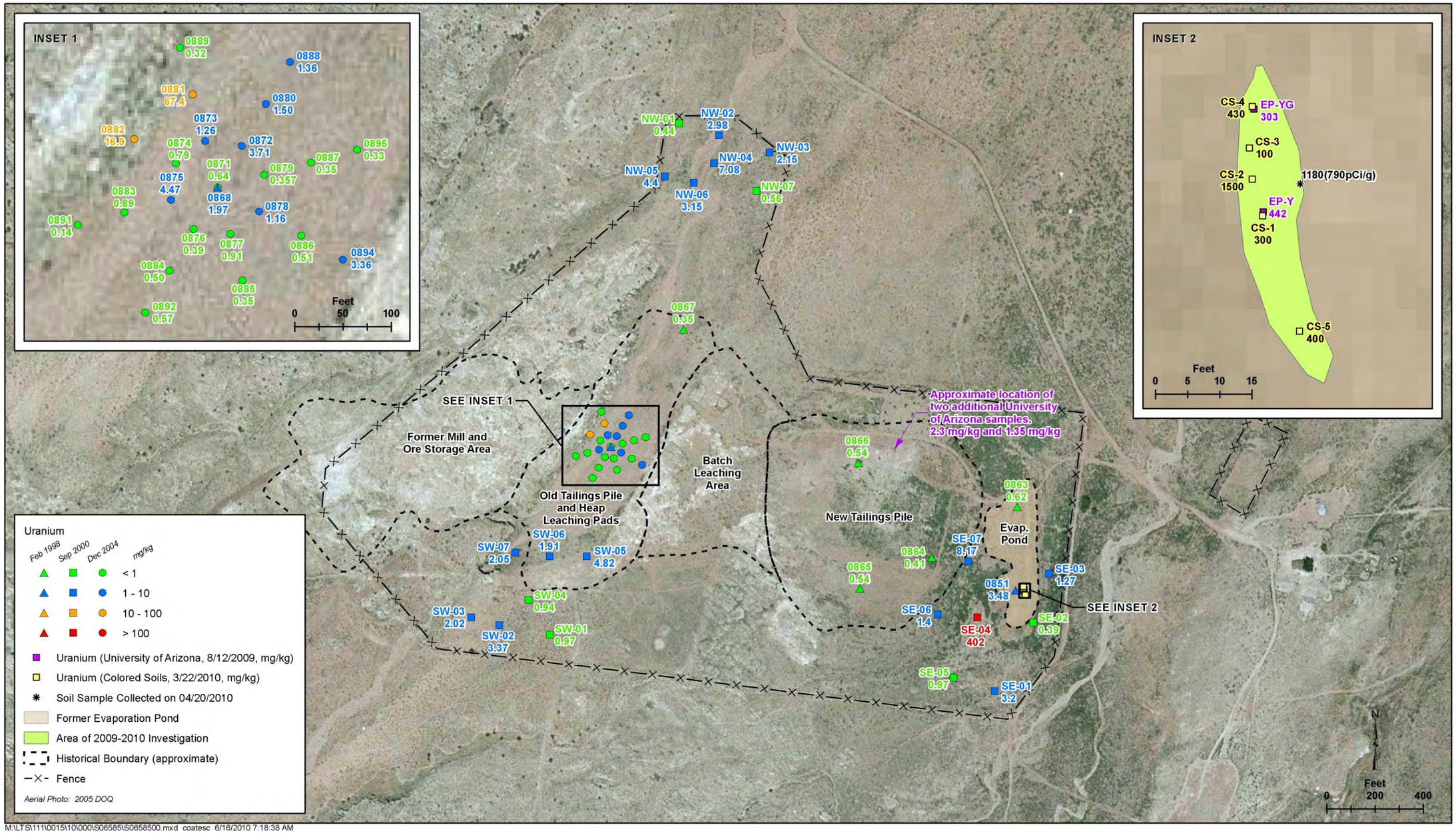


Figure 3–1. Uranium Soil Sample Analytical Results

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Table 3–1. Summary of 1998 Subpile Soil Sampling Results

Sample ID	Depth (ft)[a]	Area	Manganese mg/kg	Uranium mg/kg	Vanadium mg/kg	Ammonium mg/kg	Nitrate mg/kg	Sulfate mg/kg
851–2	2.5–3.5	EP	134.93	3.48	202.4	27.24	1775.8	7270
851–3	4.5–5.5	EP	122.89	1.11	142.1	10.81	942.7	2866
851–4	7–8	EP	188.28	1.57	89.11	30.6	252.9	375
863–2	3.5–4.5	EP	96.19	0.55	20.09	9.58	637.2	1690.3
863–3	6–7	EP	70	0.55	14.93	8.86	456.5	1389.9
863–4	8–8.5	EP	151.4	0.62	21.29	13.74	632.9	1768.1
864–2	2.5–3.5	NT	103.69	0.41	23.09	13.73	273.7	9337
864–3	4.5–5.5	NT	110	0.39	22.01	10.21	1407.4	1571
864–4	6.5–7.5	NT	125.87	0.38	22.58	9.71	351	431.5
865–2	2.5–3.5	NT	85.5	0.54	47.82	9.93	881.9	3307.4
866–2	2.5–3.5	NT	134.53	0.54	56.21	137.17	1157.1	2028
866–3	4–5	NT	48.46	0.33	21.44	154.17	1095.5	1913.4
866–4	5–6	NT	40.36	0.42	33.57	214.37	882.6	471
866–5	6 -7	NT	34.85	0.32	11.29	270.31	914.2	396.9
866–6	7–8	NT	32.69	0.36	6.85	310.47	956	308.8
867–2	2.5–3.5	HL	75.2	0.35	5.3	7.91	275.1	168.5
867–3	5–6	HL	66.68	0.32	5.4	8.15	207.4	165.7
868–2	4–5	HL	102	0.7	11.13	10.95	1612	243.1
868–3	5.5–6.5	HL	189.8	0.92	18.22	6.09	153.7	267.2
868–4	7–8	HL	328.1	1.97	34.47	7.77	161.2	530
869–2	2–3	BG	224.6	0.78	16.51	7.33	231.2	562
869–3	3–4	BG	139.8	0.58	9	7.79	114.2	611
869–4	4–5	BG	98.2	0.44	7.7	8.15	941.3	499
870–2	1–2	BG	108.38	0.33	5.7	9.38	90	311
870–3	2–3	BG	86.61	0.36	5.7	9.2	362.9	295
870–4	3–4	BG	84.84	0.56	6.2	6.99	372.2	291.9

Table adapted from Table 4-8 of the SOWP (DOE 1999).

[a] Sample depths are not clearly documented in the SOWP; those listed above are inferred based on lithologic logs provided in Figure 4-10 of the SOWP.

mg/kg = milligrams per kilogram
EP = Evaporation Pond
NT = New Tailings Pile
HL = Heap Leach
BG = Background

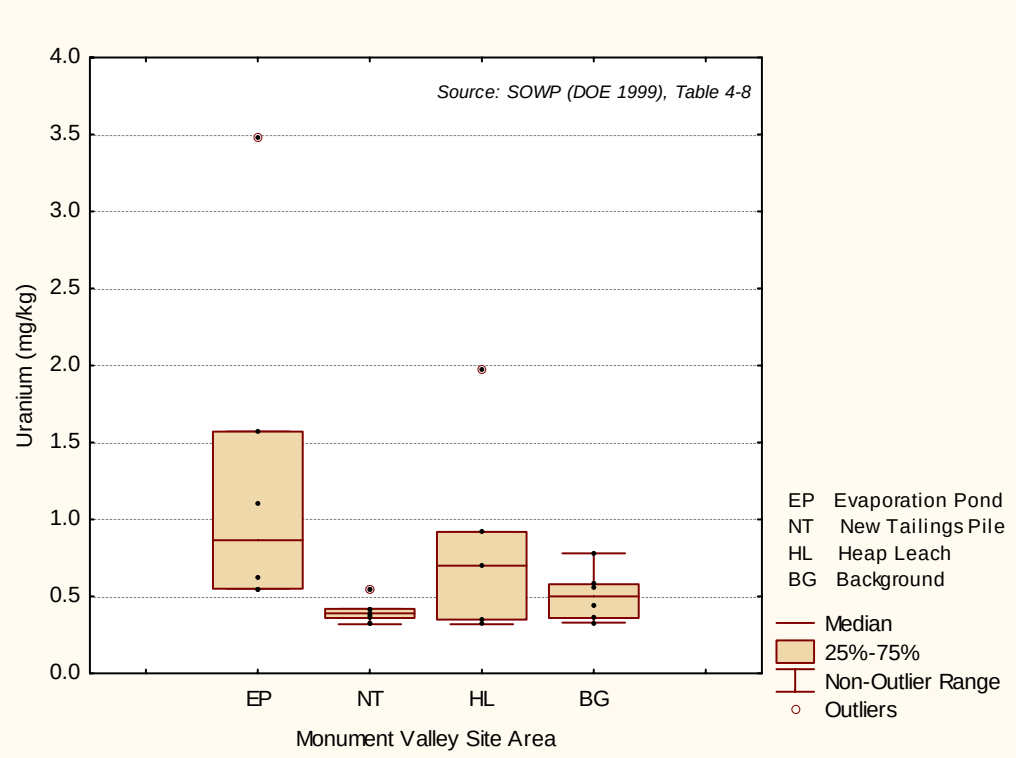


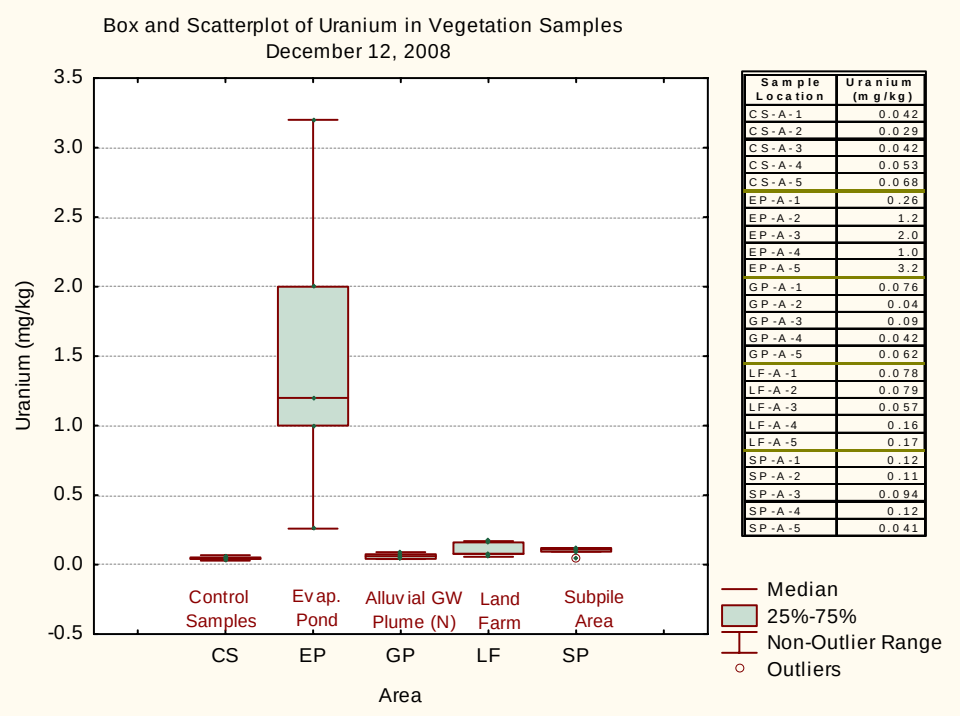
Figure 3–2. Distribution of Uranium in 1998 Subpile Soil Samples by Site Area

3.2 Salt Crust Evaluation

In September 2000, DOE undertook a more spatially comprehensive evaluation than the preceding subpile soil investigation, in that all site areas were addressed (DOE 2001b). These results are plotted in Figure 3–1 (see square symbols in this figure), which indicates that most uranium concentrations were less than 10 mg/kg, but above background (average crustal composition is 1.80 mg/kg). An exception to this was the result for SE-04, just east of the evaporation pond (Figure 3–1), where concentration is 402 mg/kg. Given that samples were not surveyed, the mapped sample location is approximate, so it is possible that this sample was actually located closer to or even within the former evaporation pond, coinciding more closely with areas exhibiting elevated radioactivity identified within the last year.

3.3 Pertinent Information from Phytoremediation Pilot Studies

To support a groundwater compliance strategy for the Monument Valley site, DOE initiated a native plant phytoremediation pilot study to remove ammonia and nitrite from subpile soils and groundwater in the summer and fall of 1999. Although most of these efforts were focused on the primary contaminant of concern, nitrate, some limited data were collected for uranium in vegetation samples. Figure 3–3 presents the results of this effort. This figure shows that the highest concentrations of uranium were found in the former evaporation pond. The concentrations in vegetation samples from the former evaporation pond were similar to, and in some cases higher than, those found in soils. Concentrations of uranium in vegetation from all other areas were significantly lower and similar to the control samples.



Sample Location	Uranium (mg/kg)
CS-A-1	0.042
CS-A-2	0.029
CS-A-3	0.042
CS-A-4	0.053
CS-A-5	0.068
EP-A-1	0.26
EP-A-2	1.2
EP-A-3	2.0
EP-A-4	1.0
EP-A-5	3.2
GP-A-1	0.076
GP-A-2	0.04
GP-A-3	0.09
GP-A-4	0.042
GP-A-5	0.062
LF-A-1	0.078
LF-A-2	0.079
LF-A-3	0.057
LF-A-4	0.16
LF-A-5	0.17
SP-A-1	0.12
SP-A-2	0.11
SP-A-3	0.094
SP-A-4	0.12
SP-A-5	0.041

Figure 3–3. Box and Scatter Plot of Uranium in December 2008 Vegetation Samples

3.4 Groundwater

It is not the objective of this evaluation to address groundwater – see instead the most recent (December 2009) Data Validation Package (DOE 2010a). However, to provide a more comprehensive presentation of all available data potentially relevant to this issue, and because groundwater is the primary medium being monitored at this and other LM sites—this discussion will examine uranium trends in all wells, and then focus on those in the evaporation pond area.

Three aquifers exist in the Monument Valley area: the alluvial (uppermost) aquifer, the Shinarump (directly underlying the alluvial aquifer), and the De Chelly (the deepest of the three aquifers). Of these, only the alluvial and De Chelly aquifers have shown evidence of site-related contamination.

3.4.1 Extent of Uranium Contamination in Groundwater

As stated previously, monitoring has focused on the nitrate plume; uranium has not been considered a primary contaminant of concern, in that its presence above the groundwater standard is not widespread. Figure 3–4 shows the locations of the groundwater monitoring locations at the Monument Valley site. As shown in Figure 3–5 through Figure 3–8, only a small subset of wells have had historical uranium concentrations exceeding the 0.044 milligram per liter (mg/L) standard in 40 CFR 192. These wells form a cluster in the northern section of the former tailings pile and batch-leaching area (see Figure 3–4).

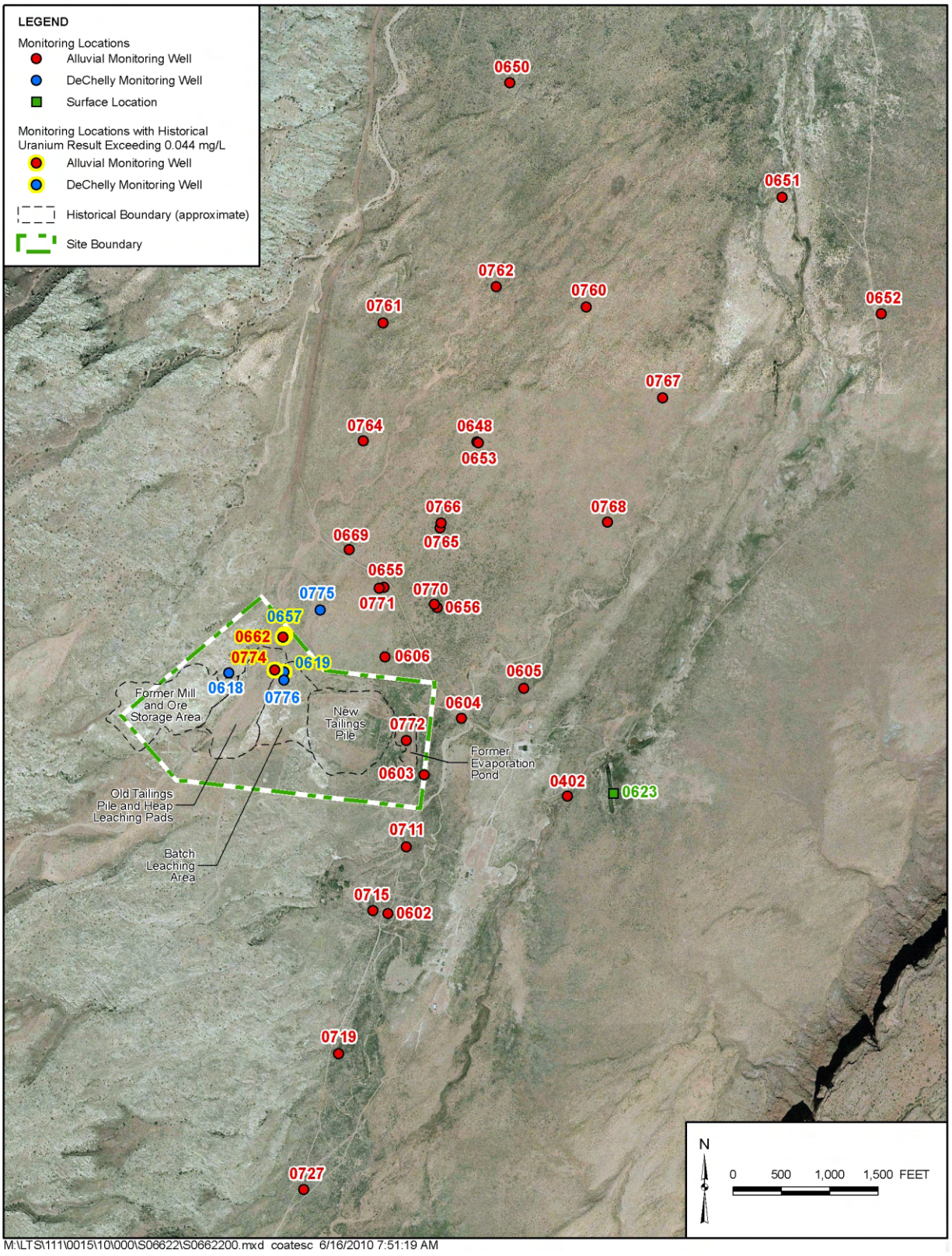
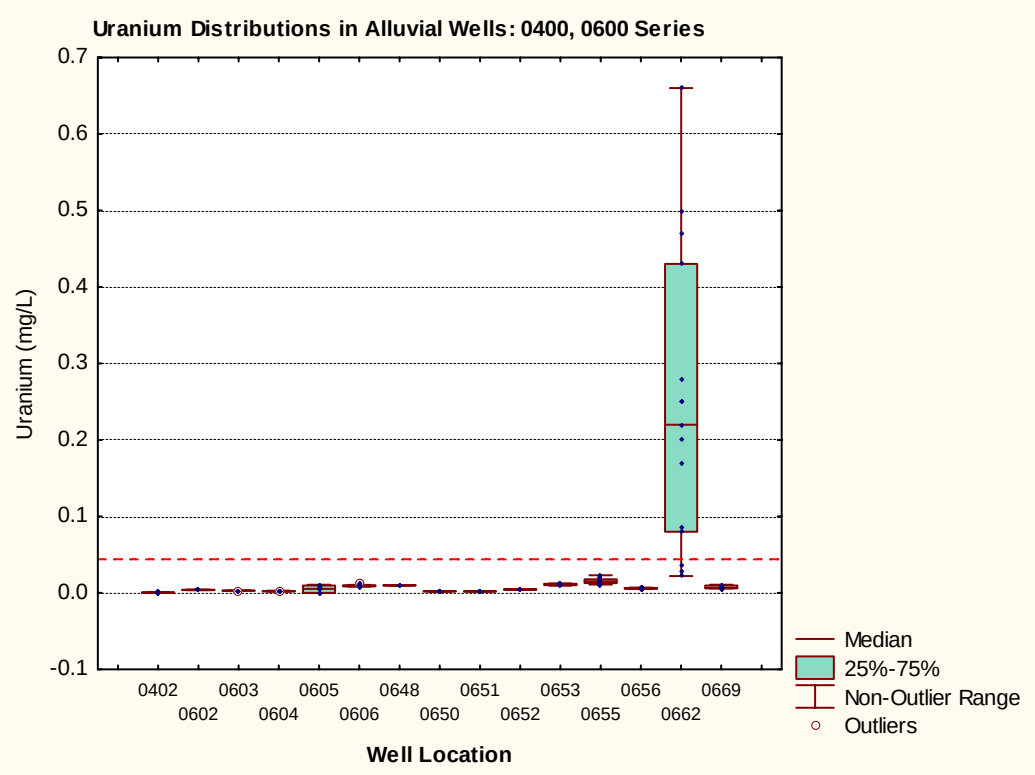


Figure 3–4. Monument Valley Processing Site Groundwater Monitoring Locations



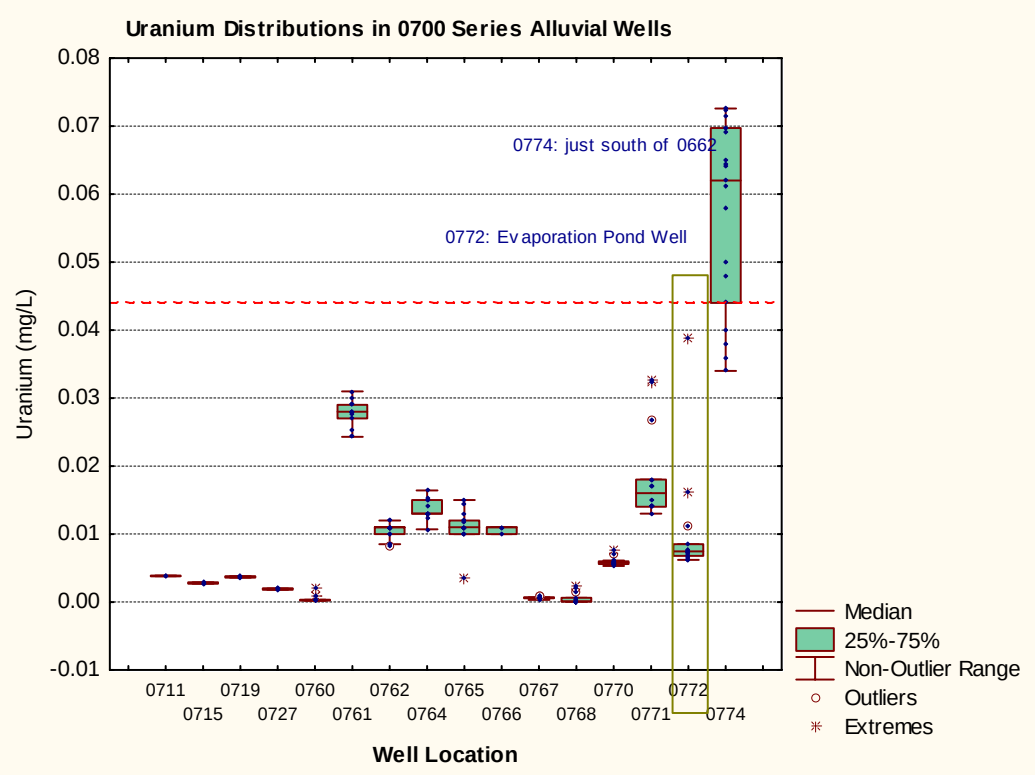


Figure 3–5. Uranium Distributions in Monument Valley Alluvial Wells

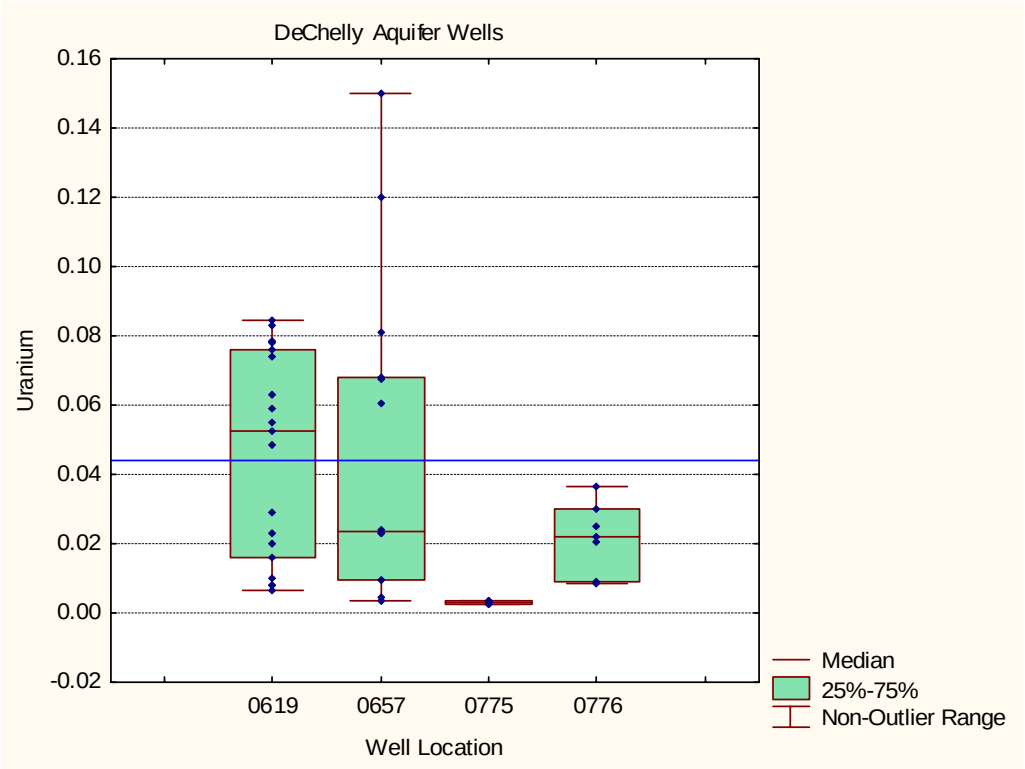


Figure 3–6. Uranium Distribution in De Chelly Aquifer Wells

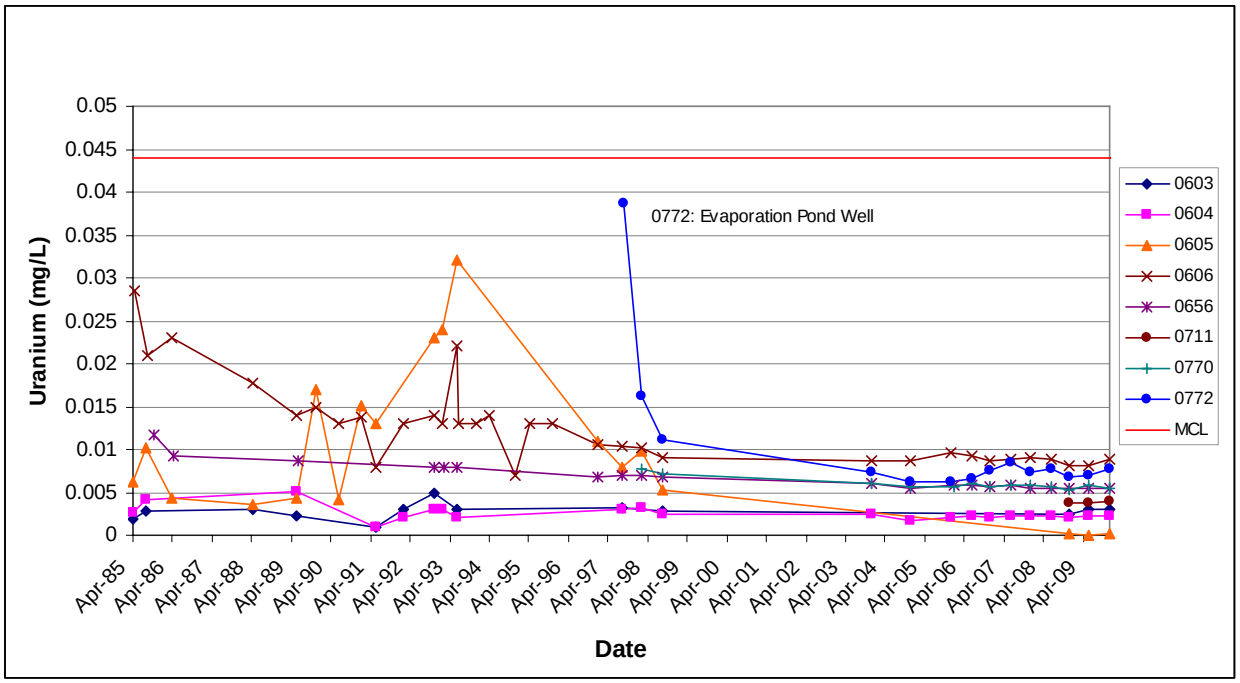


Figure 3–7. Time-Concentration Plots of Uranium in Evaporation Pond Area Wells

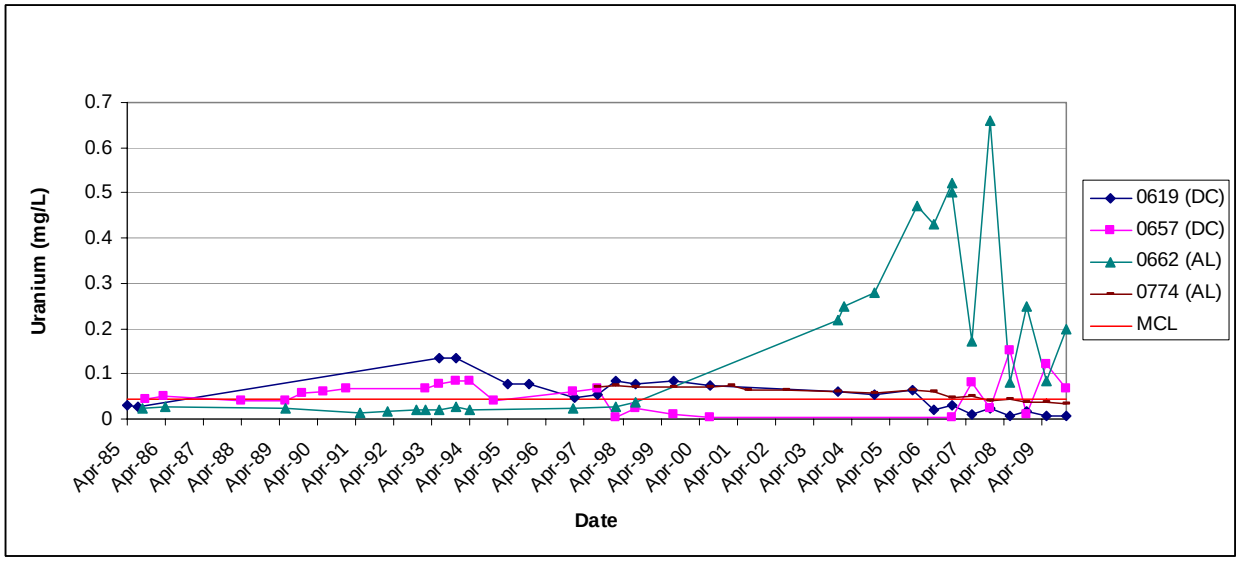


Figure 3–8. Time-Concentration Plots of Uranium in 0619 Area Wells

Elevated uranium concentrations in the groundwater do not appear to be widespread, although some elevated concentrations have been detected. Previous documents have focused on uranium in the De Chelly aquifer (wells 0619 and 0657), but it is present at elevated levels in two alluvial wells as well (0662 and 0774). Uranium concentrations at all other monitoring locations are below the standard and within the range of background concentrations established in the SOWP for the site region (<0.001−0.021 mg/L) (DOE 1999).

Given elevated levels in the evaporation pond soils discussed in this and subsequent sections, the fact that uranium is not elevated in evaporation pond alluvial well 0772 is surprising. This condition may change as water infiltrates through soil in this area.

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4.0 Summary of Recent Investigations in the Evaporation Pond and Surrounding Areas

Starting in 2007, personnel working on the phytoremediation pilot studies noticed poor plant growth in areas with discolored surface soils in the former evaporation pond. To investigate this phenomenon, soils samples were collected and analyzed for numerous elements that could be contributing to the negative impacts on plant growth. The results showed elevated soil concentrations of uranium in several samples. Subsequent investigations began in March 2010 (after snow melt) to better delineate the extent and nature of the uranium in the surface soils (Table 1–1 presented the chronology of these events). This section presents the results of these more recent investigations. **Note:** Data and findings presented in this section likely represent worst-case conditions, because soil-sampling results documented herein were biased samples collected from discolored soil areas.

4.1 University of Arizona Analyses, Samples Collected August 12, 2009

The University of Arizona collected and analyzed samples of the discolored soils in the former evaporation pond area on August 12, 2009. These results were documented in a letter dated December 17, 2009 (memo to: Jody Waugh, re: "Uranium in Former Evaporation Pond Area at Monument Valley," provided in Appendix C). Samples were collected from stained surface soils in the former evaporation pond area and an extended field west in the subpile soil area for a suite of heavy metals to determine if potential toxic substances were associated with the chemical stains observed in some areas of the site. Two samples—EP Y and EP YG—were collected in stained areas in the former evaporation ponds (EP prefix), and an additional two samples were collected in the extended field west (EFW prefix), by scraping samples from soils with yellow (Y), green (G) or red (R) staining. Samples were analyzed by the Water Quality Center Laboratory of the University of Arizona's Environmental Research Laboratory. Samples were analyzed for calcium, vanadium, manganese, iron, strontium, and uranium; analytical results are summarized in Table 4–1. These analyses showed elevated concentrations of uranium in stained soil samples collected from the former evaporation pond.

Table 4–1. Results of Heavy Metal Analyses of Surface Soils at Monument Valley Site: August 12, 2009

Sample Number	Location/ Description	Calcium (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Strontium (mg/kg)	Uranium (mg/kg)	Vanadium (mg/kg)
EP Y	Evaporation pond, yellow-stained soils	27,949	4301	134	107	442	2672
EP YG	Evaporation pond, yellow-green stained soils	21,067	4242	96	71	303	1352
EFW R	Extended field west, red-stained soils	31,117	54,741	148	134	2.31	895
EFW G	Extended field west, green-stained soils	31,585	2395	174	130	1.35	884

Calcium reported as calcium-40 (^{40}Ca); iron as Fe-56 (^{56}Fe); manganese as Mn-55 (^{55}Mn), strontium as Sr-88 (^{88}Sr); uranium as U-238 (^{238}U); vanadium as V-51 (^{51}V).

4.2 Scan Results, March–April 2010

Because of the elevated uranium levels in the surface soils, DOE conducted a radiological screening survey as a best management practice. The focus of this initial survey was the yellow- and green-stained soils in the former evaporation pond. The survey was performed using two types of instrumentation: (1) a crutch scintillometer capable reading gamma radiation and (2) a hand-held frisking instrument capable of reading gamma and beta radiation. The survey was performed by walking the area with the crutch scintillometer to identify areas of elevated gamma activity and placing the hand-held instrument directly above the soil to obtain a rough estimate of gamma and beta radiation in disintegrations per minute. The equipment used to conduct this screening-level survey was not appropriate to determine quantitative estimates of radiation. The main purpose was to determine the general level of radioactivity being emitted from the surface soils and to quickly screen the site for elevated radioactivity being emitted from surface soils outside the former evaporation pond. Besides the former evaporation pond, no other areas of the site exhibited elevated radioactivity levels. Table 4–2 provides a summary of the radiological scanning performed in March and April 2010 and the associated findings.

Table 4–2. Summary of March–April 2010 Screening Level Radiological Scanning Efforts and Findings

Scan Date	Instrument/ Specificity	Area(s) Scanned[a]	Findings	Comments
3/23/2010	Initial (screening) scan: Mt. Sopris Model SC132 ("crutch") scintillometer (gamma only)	Lower (southern) portion of former evaporation pond coinciding with phytoremediation test area and stained-soil areas (as shown in Figure 1–3)	Several areas with elevated (i.e., above background) gamma activity were identified in the southern portion of the former evaporation pond	The focus of this initial survey was the yellow- and green-stained soils in the former evaporation pond. In areas measurements exceeded background, some soils were stained (yellow or yellow-green, and in some cases gray), but some were not.
	Eberline Frisker[b] Model FH40G-L, FHZ732 Probe alpha/beta/gamma (α, β, γ)	Elevated areas confined to the teardrop-shaped area (as shown in Figure 1–3).	This was used to confirm the gamma scans. Although this instrument shows values in disintegrations per minute, it does not accurately depict radiation levels from a soil matrix.	

Scan Date	Instrument/ Specificity	Area(s) Scanned[a]	Findings	Comments
4/13/2010	Scintillometers (see above)	To address all areas potentially accessed by site personnel, the survey covered the entire former evaporation pond and all irrigated phytoremediation study areas (as shown in Figure 1–3).	A few more areas of elevated gamma activity (although of less magnitude than initial) were identified north of the initially identified teardrop-shaped area.	The focus of this survey was to better delimit the other areas of the site with elevated gamma activity and to more extensively evaluate the former evaporation pond.
	Eberline Frisker Model FH40G-L with FHZ732 Probe	Elevated areas in the northern portion of the evaporation pond (as shown in Figure 1–3)	Although this was used to confirm the gamma scans, it was not the appropriate instrument to yield quantitative radiation levels from soil.	

[a] The initial scan covered a broad area with the crutch scintillometers—these instruments are typically used to perform quick, large-area surveys. Once elevated levels were identified, the Ludlum Frisker (FH40G-L) was used. For all areas, the scan was performed on approximately 6–10-ft transects at normal walking pace.

4.3 Analytical Results of Soil Samples Collected March 22, 2010

As a follow-up to the results from the University of Arizona soil sampling, DOE collected additional soil samples from the former evaporation pond. Samples were collected from the same area where the University of Arizona collected the yellow- and green-stained soils. Discolored surface samples were collected, and soils up to a depth of 6 feet were also obtained. The analytical results were obtained on April 14, 2010. Table 4–3 summarizes the results, conversions of chemical to radiometric uranium (pCi/g), and some calculated values.

Table 4–3. Uranium and Vanadium Concentrations Measured in April 14, 2010, Soil Samples

Sample Number	Uranium (mg/kg)	Uranium (pCi/g)[a]	Uranium (pCi/g)[b]	Vanadium (mg/kg)
CS-1	300	204	275	1,200
CS-2	1,500	1,020	985	1,000
CS-3	100	68	72	1,700
CS-4	430	292	388	680
CS-4-3	84	57	57	1,300
CS-5	400	272	264	930
CS-5-3	70	48	31	1,000

Note: Sample numbers are denoted as CS-X, with X being the number 1 to 5. In cases where the sample number is denoted as CS-X-3, the samples were taken 3 inches below the surface. All other samples were taken at the surface. At each location, soil samples were taken on the surface and at 3 inches, 6 inches, 1 ft, 3 ft, and 6 ft below the surface. The samples were placed in bags, and all bags were scanned for gamma radiation; only bags with elevated radiological readings were sent for laboratory analysis. This approach resulted in the highest likely values for each sample location.
[a] Calculated from chemical uranium values.
[b] Measured ^{234}U plus ^{238}U.

The samples were also sent for isotopic analysis, as summarized in Table 4–4.

Table 4–4. Radiometric Results

Sample Number	Uranium (pCi/g)[a]	^{234}U (pCi/g)	^{238}U (pCi/g)	Ratio of ^{234}U to ^{238}U (pCi/g)	^{230}Th (pCi/g)	^{226}Ra (pCi/g)
CS-1	275	133	142	0.94	10.8	1.67
CS-2	985	488	497	0.98	26.4	1.59
CS-3	72	36.4	35.6	1.02	3.32	1.62
CS-4	388	194	194	1.00	16.9	0.883
CS-4-3	57	29.3	27.7	1.06	0.347	1.15
CS-5	264	129	135	0.96	5.87	1.50
CS-5-3	31	15	15.7	0.96	1.02	1.12

[a]Measured ^{234}U + ^{238}U

Data Interpretation

- Chemical uranium concentrations are reasonably close to concentrations from radiometric analyses (Table 4–3, columns 3 and 4). The differences are likely due to the relatively high reported uncertainties in the radiometric data (values not shown here but provided in the analytical report). This observation provides an element of confidence in using the radiometric results for the following interpretations.

- $^{234}U/^{238}U$ ratios (Table 4–4, column 5) are very nearly 1.0. Ratios near unity are characteristic of uranium ores. These ratios are also consistent with tailings. Ratios of unity are also possible in natural settings and in a situation where uranium is dissolved from rock and redeposited. Thus, at first glance, it doesn't seem as if the U isotopic ratios can be used to distinguish possible sources of the uranium in these soils.

- Activities of ^{230}Th and ^{226}Ra (Table 4–4, columns 6 and 7), both of which are in the ^{238}U-^{234}U decay scheme, are far less than the activities of ^{238}U and ^{234}U (Table 4–4, columns 3 and 4) indicating a non-equilibrium condition. The uranium ores milled at Monument Valley are old in geologic time and would have near equilibrium isotopic ratios due to radiometric ingrowth, provided no additions or depletions occurred from chemical transfer. Thus, it is expected that ^{230}Th and ^{226}Ra should be nearly in equilibrium with U isotopes if the uranium in the soils is due to solid ore particles. Tailings should have radiometric values of ^{230}Th and ^{226}Ra that are higher than ores, because the milling process selectively removes uranium. Thus, the thorium and radium data indicate that it is unlikely that the soils contain ore or tailings. In other words, the uranium and vanadium in the soils were deposited from solution and are not particulate remnants of ore or tailings.

- The molar concentrations of vanadium in the soils (Table 4–3, column 5) far exceed the molar concentrations of uranium (Table 4–3, column 2). The solutions that deposited the uranium and vanadium likely had higher concentrations of vanadium than uranium or the uptake by the sediments favored vanadium.
- The concentrations of uranium (up to 1500 mg/kg) and vanadium (up to 1700 mg/kg) in the soils are relatively high. Average crustal abundance of uranium is 1.8 mg/kg and vanadium is 135 mg/kg. The highest concentration of uranium (0.15 %) approximates that of low grade uranium ores.

4.4 Gamma Spectroscopy Semiquantitative Soil Sample Collected April 20, 2010

Radiological technicians visited the site and collected a surface soil sample for gamma spectroscopy analysis on April 20, 2010. This sample was selected from an area exhibiting high gamma readings using a scintillometer, and it was intended to show worst-case results. The analysis was done at the DOE, Environmental Management Office in Moab, Utah.

Review of the spectrum indicates that the gamma activity in the sample is due to uranium-238, uranium-235, and progeny nuclides[1]. Background concentrations of potassium-40 and radium 226 were found to be present, but no other gamma-emitting nuclides are evident based on this spectra analysis. The uranium concentration was estimated to be 790 pCi/g. The concentration is estimated by comparison to a uranium reference material. In addition to uranium, the gamma spectroscopy analysis showed a radium concentration of 0.1 pCi/g. The results reported should be considered semiquantitative, since certified, traceable standards were not used for calibration. Although these results are semiquantitative, they are similar and offer some confirmation of the analytical results from the soil samples collected on March 22.

[1] Progeny nuclides from U-238 are thorium-234, protactinium-234, and protactinium-234m; those from Ra-226 are bismuth-214 and lead-214.

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5.0 Risk Evaluation

Preliminary calculations were performed to evaluate the potential dose to workers from the uranium isotopes identified in the area of the former evaporation pond at the Monument Valley site. Two types of calculations were developed: (1) a deterministic calculation that results in one dose estimate and (2) a probabilistic calculation that provides bounding estimates using a distribution of potential input parameters for the most sensitive (important) calculation inputs. In both cases, the dose calculations were developed using numerous default parameters and conservative exposure assumptions. Dose calculations were performed using computer software that is widely accepted for this purpose (See Section 5.1). In addition to the technical approach in Section 5.1, Section 5 also includes a discussion of the assumptions (Section 5.2) and the results (Section 5.3).

5.1 Technical Approach or Methodology

The basic premise of risk assessment is that a receptor (person, animal) comes in contact with, or is exposed to, a contaminated medium (water, soil, air). Effects of this exposure will be dependent on the length, frequency, and amount of exposure (one time, every day, large or small volume); the manner in which the contact occurs (e.g., ingested, inhaled, or absorbed through the skin); and the toxicity of the contaminant. The exposure scenario, exposure pathways, and exposure assumptions are tailored to the site-specific conditions and activities being evaluated. The outcome of this evaluation is the estimated dose to the radiological constituents at a site, which can then be compared to established dose levels that are considered to acceptable to workers or members of the general public.

All dose calculations for this evaluation were performed using RESRAD (Version 6.5)[1], a code developed by Argonne National Laboratory (ANL 2001) used to estimate potential risks from radiological contaminants. This code has undergone extensive verification and validation and has been used by DOE, EPA, other federal agencies, and by academia to estimate potential risks from radiological contaminants.

As mentioned, both deterministic and probabilistic risk assessments were used to estimate potential doses to workers at the site. Deterministic risk assessments provide a single point estimate of risk using a single value for each of the input parameters. Probabilistic risk assessments generate a range of values from probability distribution functions. The primary advantage of a probabilistic evaluation is that it quantifies the degree of variability or uncertainty in the dose estimates. In RESRAD, this type of analysis uses a range of assumptions (focused on exposure) as input to thousands of individual dose estimations to come up with possible distributions or ranges of dose.

[1] RESidual RADioactivity (RESRAD) model and computer code, Argonne National Laboratory, October 30, 2005 (http://web.ead.anl.gov/resrad/home2/).

5.2 Assumptions

5.2.1 Exposure Pathways Evaluated

The Monument Valley site is in a sparsely populated area. Access to the site is limited to workers who maintain the irrigation system and care for the plants in the phytoremediation plots. The climate is arid; average annual precipitation is 6.4 inches. There are no known threatened or endangered species at or near the site, so this evaluation focuses on risks to human health.

After human exposure scenarios are conceived, the second key element to be considered in constructing representative exposure models is determining which pathways are potentially complete from source to receptor. The conceptual pathway model in RESRAD includes all conceivable pathways for human exposure to residual radioactivity associated with a site; a specific dose calculation is done by matching the applicable pathways to the scenario being evaluated (site workers).

Table 5–1 identifies the pathways that have been retained for the analysis and provides an explanation for those pathways that were not retained.

Table 5–1. Exposure Pathways Evaluated in this Risk Evaluation

Pathway	Retained	Comments
Direct Exposure	Yes	The source term found in the surface soils produces penetrating gamma radiation. Exposure from direct penetrating radiation is expected to be a significant contributor to the overall potential dose of workers at the site.
Particulate Inhalation	Yes	A potential pathway is for surface soils containing uranium isotopes to be liberated (via wind) and suspended in the breathing air of site workers.
Radon	No	The uranium in the surface soils is not a significant producer of radon. Moreover, the work at the site would not involve confined spaces or building structures where radon gas and associated daughter radionuclides would be expected to reach equilibrium concentrations.
Plant Ingestion	No	This site does not contain edible plants.
Drinking Water	No	This exposure scenario addresses surface soils only.
Meat Ingestion	No	This exposure scenario addresses surface soils only.
Milk Ingestion	No	This exposure scenario addresses surface soils only.
Aquatic Foods Ingestion	No	This exposure scenario addresses surface soils only.
Direct Ingestion	Yes	Site workers may ingest relatively small amounts of sediment through incidental contact with their hands.

5.2.2 Exposure Assumptions

A combination of default values from RESRAD and conservative exposure parameters were used to estimate dose. Table 5–2 presents the key parameters for the deterministic estimate, and Table 5–3 presents the key inputs for the probabilistic estimate.

Table 5–2. Most Sensitive Parameters Used to Model Dose Using the Deterministic Approach

Parameter	Units	Default Value	Modeled Value	Remark
Area of Contaminated Zone	m^2	10,000	325	Assumed a circular area of exposure. This was the approximate area found to have elevated gamma readings in the former evaporation pond.
Isotope Concentration in Soil	pCi/g	NA	500	Based on the recent isotopic data for uranium, 500 pCi/g (rounded value) was used for uranium-234 and uranium-238. This was consistent with the highest value found on site. As a worst-case assumption, all exposure is assumed to occur over an area having the highest on-site value.
Mass Loading Available for Inhalation	g/m^3	0.0001	0.0001	RESRAD default.
Depth of Contamination	m	2	2	RESRAD default. This default parameter was retained, although the highest levels of contamination appear to be in the surface soils.
Indoor Time Fraction	unitless	0.5	0.0	The exposure scenario is for a site worker; no exposures will occur indoors.
Outdoor Time Fraction	unitless	0.25	0.001	This parameter is the fraction of a total year spent outdoors exposed to elevated levels of uranium at the site. Exposure occurs only when the worker is on the area that has elevated levels of gamma radiation. Based on the time a site worker may spend in these areas in the former evaporation pond, it was assumed they would be there one day a month for one hour during the day. This corresponds to an annuitized exposure of 12 hours/year out of 8760 hours per year, or a yearly fraction of 0.001 (rounded). This value is conservative, since the areas with elevated gamma radiation (high isotopic uranium values) occur in a very small area compared to the total site area. A worker will spend nearly their entire day on site in areas that do not have elevated levels of uranium-234 and uranium-238.

m^2 = square meters
g/m^3 = grams per cubic meter

Table 5–3. Most Sensitive Exposure Parameters Used to Model Dose Using the Probabilistic Approach

Parameter	Units	Default Value	Range Modeled	Remark
Area of Contaminated Zone	m^2	10,000	100–40,000	Assumed a log uniform distribution of values. The estimated value from the gamma scans was 325 m^2. A log uniform distribution emphasizes higher-end values (more worst-case); the high range of this distribution is more than two orders of magnitude greater than estimated value.
Isotope Concentration in Soil	pCi/g	NA	566–605	Specific values from recent isotopic data for uranium-234 (605 pCi/g) and uranium-238 (566 pCi/g). These were the highest values found on site. As a worst-case assumption, all exposure is assumed to occur over an area having the highest on-site values for these isotopes.
Mass Loading Available for Inhalation	g/m^3	0.0001	0- 0.0001	RESRAD default value of 0.0001 g/m^3 is considered to be a worst-case value. A continuous linear distribution of values was assumed, with 0 g/m^3 being the low end of the distribution (no or very low wind).
Depth of Contamination	m	2	0.01–2	Assumed a lognormal distribution. In this case to better approximate field conditions (contamination in the surface soils), the RESRAD default was used as the upper part of the range.
Indoor Time Fraction	unitless	0.5	0.0	The exposure scenario is for a site worker; no exposures will occur indoors. A distribution was not used since it is known to be 0.
Outdoor Time Fraction	unitless	0.25	0.0014–0.047	This parameter is the fraction of a total year spent outdoors exposed to elevated levels of uranium at the site. Exposure occurs only when the worker is on the area that has elevated levels of gamma radiation. Based on the time a site worker may spend in these areas in the former evaporation pond, it was assumed they would be there one day a month for one hour during the day. This results in an annualized exposure of 12 hours/year out of 8760 hours per year, or a yearly fraction of 0.0014. To provide a worst-case analysis, the estimated annualized exposure was assumed to be the low end of the range for this parameter. A triangular distribution was used for this parameter. The high end of this distribution range equates to 412 hours of exposure per year (over an hour per day).

m^2 = square meters
g/m^3 = grams per cubic meter

5.3 Results

Dose estimates are compared to established benchmarks to evaluate if the contaminants at a site pose an unacceptable dose to the exposed population. Both public and occupational dose limits are set by federal agencies (i.e., EPA, NRC, and DOE). A widely accepted dose to members of the general public is 100 millirem per year (mrem/yr), as established by NRC. NRC has also established a more conservative criterion for site decommissioning of 25 mrem/yr. For the purposes of this assessment, calculated risks will be compared to the more conservative (protective) value of 25 mrem/yr.

The deterministic risk evaluation yielded a maximum dose of 0.0811 mrem/yr, which is well below the 25 mrem/yr benchmark. The results for the probabilistic evaluation are presented in Table 5–4.

Table 5–4. Dose Estimates Using the Probabilistic Approach in RESRAD

Result Type	Dose (mrem/yr)	Benchmark (mrem/yr)	Comments
Minimum	0.14	25	Result is similar to the deterministic approach, demonstrating the conservative input parameter distributions used in the probabilistic risk evaluation.
Mean	1.7	25	Most likely result; dose is approximately 15 times lower than the benchmark.
Maximum	3.7	25	Worst-case result; dose is still approximately 7 times lower than the benchmark.

This risk assessment demonstrates that the elevated levels of uranium-234 and uranium-238 found in the former evaporation pond at the Monument Valley site are well below established benchmarks and do not pose an unacceptable dose to site workers.

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6.0 Summary

- The site was remediated from 1992 to 1994. All areas of the site, including the former evaporation pond, were verified clean under the UMTRCA surface soil cleanup standard of 5 pCi/g Ra-226 and the subsurface standard of 15 pCi/g. NRC approved the Monument Valley cleanup on April 5, 2001.
- Initial radiological characterization studies (e.g., DOE 1985) indicated that the evaporation pond had the highest concentrations of radium at the site. Locations with highest concentrations coincide closely with the areas where elevated levels of radioactivity were observed based on both recent sampling and radiological scans. Therefore, the evaporation pond probably represents worst-case conditions in terms of contamination. Post-cleanup verification studies, as corroborated by NRC (2001) indicate that cleanup commitments were fulfilled.
- The plants in the area of the former evaporation pond had a poor growth rate compared to those in other areas of the site. In the summer of 2009, DOE contractor personnel noticed surface soils in the former evaporation pond with yellow and green stains. Samples of the stained surface soils were collected and sent to a laboratory for an analysis, the results indicated that the soils have elevated levels of uranium and vanadium. As a best management practice, DOE conducted a radiological screening because of the higher-than-expected uranium results. The survey was performed by walking the area with the crutch scintillometer to identify elevated gamma activity, and then rechecking with a radiological frisker. The results indicated higher-than-anticipated gamma levels in the former evaporation pond; other areas of the site did not have elevated gamma activity.
- As a follow-up to the radiological screening, soil samples from the former evaporation pond were sent to a contract laboratory for isotopic analysis. The results indicated measured values for uranium-234 plus uranium-238 from 31 to 985 pCi/g. The ratio between uranium-234 and uranium-238 was consistently close to 1. The concentrations of thorium and radium were much lower than those of uranium. The highest measured value for radium was less than 2 pCi/g.
- To ensure that workers have not been exposed to excessive dose levels from isotopic uranium in surface soils, risk calculations were performed using RESRAD. RESRAD is a widely accepted tool used to estimate risks from radiological constituents. Risks were estimated using an allowable exposure rate of 25 mrem per year, the highest measured results for the isotopes of uranium, and very conservative exposure assumptions. The results indicate that risks are well below the allowable exposure rate of 25 mrem per year.
- Residual uranium exists, but this does not this imply a deviation from DOE's commitments under UMTRCA.

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7.0 References

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Appendix A

DOE and NRC Correspondence, April 2010

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Department of Energy
Office of Legacy Management

APR 0 1 2010

Mr. Richard Chang
U.S. Nuclear Regulatory Commission
11545 Rockville Pike #2
Mail Stop T8 F5
Rockville, MD 20852-2738

Subject: Soil Contamination Area at the Monument Valley, Arizona, Site

Dear Mr. Chang:

The purpose of this letter is to inform the U.S. Nuclear Regulatory Commission (NRC) of a recent, unexpected discovery of radiologically contaminated soils at the U.S. Department of Energy, Office of Legacy Management (DOE-LM), site at Monument Valley, Arizona.

DOE removed radioactive tailings from Monument Valley, a former uranium millsite, in 1994. Nitrate and ammonium used during the milling process remain in a shallow ground water plume spreading from the former millsite area. DOE-LM is conducting pilot studies of remediation alternatives for contaminated soil and ground water at the site in collaboration with the University of Arizona. The pilot studies are investigating remedies that rely on natural and enhanced attenuation processes.

As part of the ongoing studies, sampling of stained soils in an area of the site associated with the former evaporation ponds were found to have elevated concentrations of uranium and vanadium. As a follow up to this discovery, DOE conducted radiological scans of the area where the stained soils are occurring. The initial scanning, completed last week, detected loose surface radiological contamination (location map enclosed) at levels up to 37,000 dpm/100cm2. This exceeds the loose contamination levels of 1000 dpm/100cm2 specified in 10 CFR 835, Appendix D, and the Legacy Management Radiological Control Manual, Table 2-2.

DOE is actively evaluating this issue to determine the nature and extent of this material and how it materialized. Additional soil samples have been collected and submitted for isotopic analysis, and the area with elevated readings (within the fenced area of the site) has been marked with barriers and sign postings to further restrict access to this area. With additional field investigations and analytical results pending, DOE will continue to inform you of additional information as it becomes available.

2597 B 3/4 Road, Grand Junction, CO 81503	☐	99 Research Park Road, Morgantown, WV 26505
1000 Independence Ave., S.W., Washington, DC 20585	☐	11025 Dover St., Suite 1000, Westminster, CO 80021
10995 Hamilton-Cleves Highway, Harrison, OH 45030	☐	955 Mound Road, Miamisburg, OH 45342
232 Energy Way, N. Las Vegas, NV 89030	☐	
REPLY TO: Grand Junction Office		

Please contact Tom Pauling (970) 248-6048 or me at (970) 248-6091 if you need additional information.

Sincerely,

Raymond M. Plieness, Director
Office of Site Operations

Enclosure

cc w/enclosure:
L. Benally, Jr., Navajo UMTRA
E. Rich, Navajo Nation Environmental Protection Agency
M. Roanhorse, Navajo UMTRA Program
D. Taylor, Navajo Nation Department of Justice
File: MON 30.10 (DOE)

cc w/o enclosure:
R. Bush, DOE-LM
T. Pauling, DOE-LM
C. Carpenter, Stoller (e)
D. Gail, Stoller (e)
M. Hurshman, Stoller (e)
J. Legare, Stoller (e)
D. Miller, Stoller (e)
J. Siler, Stoller (e)

April 28, 2010

Mr. Raymond M. Plieness, Director
Office of Site Operations
U.S. Department of Energy
2597 B ¾ Road
Grand Junction, CO 81503

SUBJECT: SOIL CONTAMINATION AREA AT THE MONUMENT VALLEY, ARIZONA SITE

Dear Mr. Plieness:

U.S. Nuclear Regulatory Commission (NRC) staff has reviewed your letter dated April 1, 2010. As discussed in your letter, please provide additional information, when it becomes available, regarding the nature and extent of the reported soil contamination, and how it materialized. Please confirm that areas not discussed in your April 1, 2010 letter are not impacted. Without this information, NRC staff is unable to complete its review. Specifically, NRC staff would like to compare measured values to previous U.S. Department of Energy commitments made in the remedial action plan for this site.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders," a copy of this letter will be available for public inspection in the NRC Public Document Room or from the Publicly Available Records component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

If you have any questions regarding this letter, please contact Richard Chang, either by telephone at (301) 415-7188, or by e-mail at Richard.Chang@nrc.gov.

Sincerely,

/RA by Robert Johnson for/

Lydia W. Chang, Branch Chief
Special Projects Branch
Decommissioning and Uranium Recovery
Licensing Directorate
Division of Waste Management
and Environmental Protection
Office of Federal and State Materials
and Environmental Management Programs

Docket: WM-70

cc: See next page

Mr. Raymond M. Plieness, Director
Office of Site Operations
U.S. Department of Energy
2597 B ¾ Road
Grand Junction, CO 81503

SUBJECT: SOIL CONTAMINATION AREA AT THE MONUMENT VALLEY, ARIZONA SITE

Dear Mr. Plieness:

U.S. Nuclear Regulatory Commission (NRC) staff has reviewed your letter dated April 1, 2010. As discussed in your letter, please provide additional information, when it becomes available, regarding the nature and extent of the reported soil contamination, and how it materialized. Please confirm that areas not discussed in your April 1, 2010 letter are not impacted. Without this information, NRC staff is unable to complete its review. Specifically, NRC staff would like to compare measured values to previous U.S. Department of Energy commitments made in the remedial action plan for this site.

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If you have any questions regarding this letter, please contact Richard Chang, either by telephone at (301) 415-7188, or by e-mail at Richard.Chang@nrc.gov.

Sincerely,

Lydia W. Chang, Branch Chief
Special Projects Branch
Decommissioning and Uranium Recovery
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Division of Waste Management
and Environmental Protection
Office of Federal and State Materials
and Environmental Management Programs

Docket: WM-70

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DATE	4/27/10	4/27/10	4/27/10	4/ /10

OFFICIAL RECORD COPY

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E. Rich, Navajo Nation Environmental Protection Agency
M. Roanhorse, Navajo UMTRA Program
D. Taylor, Navajo Nation Department of Justice

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Appendix B

NRC Technical Evaluation Reports

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UMT 89059

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

September 16, 1997

Mr. George Rael, Director
ERD/UMTRA
U.S. Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87185-5400

SUBJECT: FINAL COMPLETION REVIEW REPORT FOR THE MEXICAN HAT AND MONUMENT VALLEY URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT SITES

Dear Mr. Rael:

The U.S. Nuclear Regulatory Commission staff has completed its review of the U.S. Department of Energy's (DOE's) Final Completion Report (April 16, 1997) and associated documents pertinent to the Uranium Mill Tailings Remedial Action Project inactive uranium mill tailings sites at Mexican Hat, Utah and Monument Valley, Arizona. These documents include Completion Report page changes transmitted on June 4, June 16, and July 29, 1997.

The NRC staff's review is documented in the enclosed final Completion Review Report (Enclosure 1), which discusses the staff's evaluation of the completed remedial action against the previously approved plans and specifications. Based on its review of the Completion Report, NRC staff concurs that DOE has performed remedial action at the sites in accordance with the approved plans and specifications, with the exception of the selection and performance of a groundwater cleanup program at the Monument Valley, Arizona site. DOE, with NRC approval, has deferred this aspect of the remedial action to a separate groundwater remedial action program. I have, therefore, signed and enclosed the DOE Certification Summary (Enclosure 2) signifying concurrence in completion of the Mexican Hat and Monument Valley remedial action (other than groundwater cleanup at the Monument Valley, Arizona site.)

If you have any questions concerning this subject letter or the enclosures, please contact the NRC Project Manager for the Mexican Hat and Monument Valley sites, Harold Lefevre, at (301) 415-6678.

Sincerely,

Joseph J. Holonich, Chief
Uranium Recovery Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosures: As stated

cc: S. Arp, DOE Alb
F. Bosiljevac, DOE Alb
E. Artiglia, TAC Alb

SMON 13.2.5

ENCLOSURE 1

COMPLETION REVIEW REPORT

FOR THE

REMEDIAL ACTION

AT THE

MEXICAN HAT/MONUMENT VALLEY

URANIUM MILL TAILINGS
REMEDIAL ACTION PROJECT SITE

September 1997

DIVISION OF WASTE MANAGEMENT
U.S. NUCLEAR REGULATORY COMMISSION

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MEXICAN HAT/MONUMENT VALLEY UMTRA PROJECT SITE
COMPLETION REVIEW REPORT

INTRODUCTION

The sites near Mexican Hat, Utah, and Monument Valley, Arizona, were designated as two of the 24 abandoned uranium mill tailings sites to be remediated by the U.S. Department of Energy (DOE) under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). UMTRCA requires, pursuant to Section 104(f)(1), that the U.S. Nuclear Regulatory Commission concur with the DOE's determination that the remedial action has been properly completed. This Completion Review Report (CRR) documents the NRC staff's basis for its concurrence decision with respect to DOE's Certification Summary for the completion of surface remediation at the Mexican Hat and Monument Valley sites.

1.0 BACKGROUND

1.1 UMTRCA

Title I of UMTRCA provides for remedial action at abandoned uranium mill tailings sites and associated vicinity properties. The purpose of this legislation is to protect the public health and safety and the environment from radiological and non-radiological hazards associated with the process related materials at these sites.

UMTRCA directs DOE to select and perform remedial actions at 24 abandoned uranium mill tailings sites to ensure compliance with the general environmental standards promulgated by the U.S. Environmental Protection Agency (EPA) under Section 275(a) of the Atomic Energy Act of 1954, as amended by UMTRCA. UMTRCA also requires DOE to obtain NRC's concurrence with DOE's selection and performance of the remedial actions. Following completion of the remedial actions, UMTRCA authorizes NRC to license the long-term custody, maintenance, and monitoring of the disposal sites to ensure continued protection of the public health and safety and the environment. Appendix B includes a more detailed discussion of this legislation.

1.2 CONCURRENCE PROCESS FOR THE SELECTION OF DOE'S REMEDIAL ACTIONS

To document its selection of the remedial action to be implemented at a particular site, DOE develops and issues a Remedial Action Plan (RAP) under its Uranium Mill Tailings Remedial Action (UMTRA) Project. The RAP describes the series of activities and presents the design proposed by DOE to provide for the long-term protection of the public and the environment. Usually this involves cleanup of the processing site, adjacent windblown areas, and vicinity properties in addition to stabilization of the residual radioactive materials. In addition, DOE issues a Remedial Action Inspection Plan (RAIP), which establishes the quality control program of testing and inspection that will be employed for the remedial action. In accordance with UMTRCA Section 108(a)(1), the NRC staff reviews and concurs with the RAP and the RAIP, and any subsequent modifications. By its concurrence in the remedial action selection, the

NRC staff concludes that the planned remedial actions will comply with EPA's applicable standards in 40 CFR 192, Subparts A, B, and C. The basis for the concurrence in DOE's selection of remedial action is documented in a Technical Evaluation Report (TER).

1.3 CONCURRENCE PROCESS FOR THE PERFORMANCE OF DOE'S REMEDIAL ACTIONS

The remedial action work is performed by DOE contractors under Federal procurement regulations. During construction, DOE inspects and documents activities in accordance with the UMTRA Project Quality Assurance Plan, the RAIP, and the RAP. In addition, the NRC staff conducts independent inspections during construction, as determined necessary.

Upon completion of the remedial action, DOE compiles construction records and prepares a completion report to document that remedial actions were performed in accordance with the RAP or RAP modifications, and the RAIP. Based on this information, DOE certifies that all provisions of the RAP have been satisfied and, therefore, that the remedial actions comply with the applicable EPA standards in 40 CFR 192.

Based on its review of DOE's documentation, and on its site visits and observations, NRC makes a concurrence decision with regard to DOE's remedial action completion determination for each site, and then documents the basis for this concurrence decision in the Completion Review Report (CRR). By its concurrence in the remedial action performance, the NRC staff concludes that the remedial action has been completed in accordance with the NRC approved design. NRC's concurrence with DOE's completion determination fulfills the Commission's responsibility under UMTRCA Section 104(f)(1).

1.4 MEXICAN HAT/MONUMENT VALLEY SITES

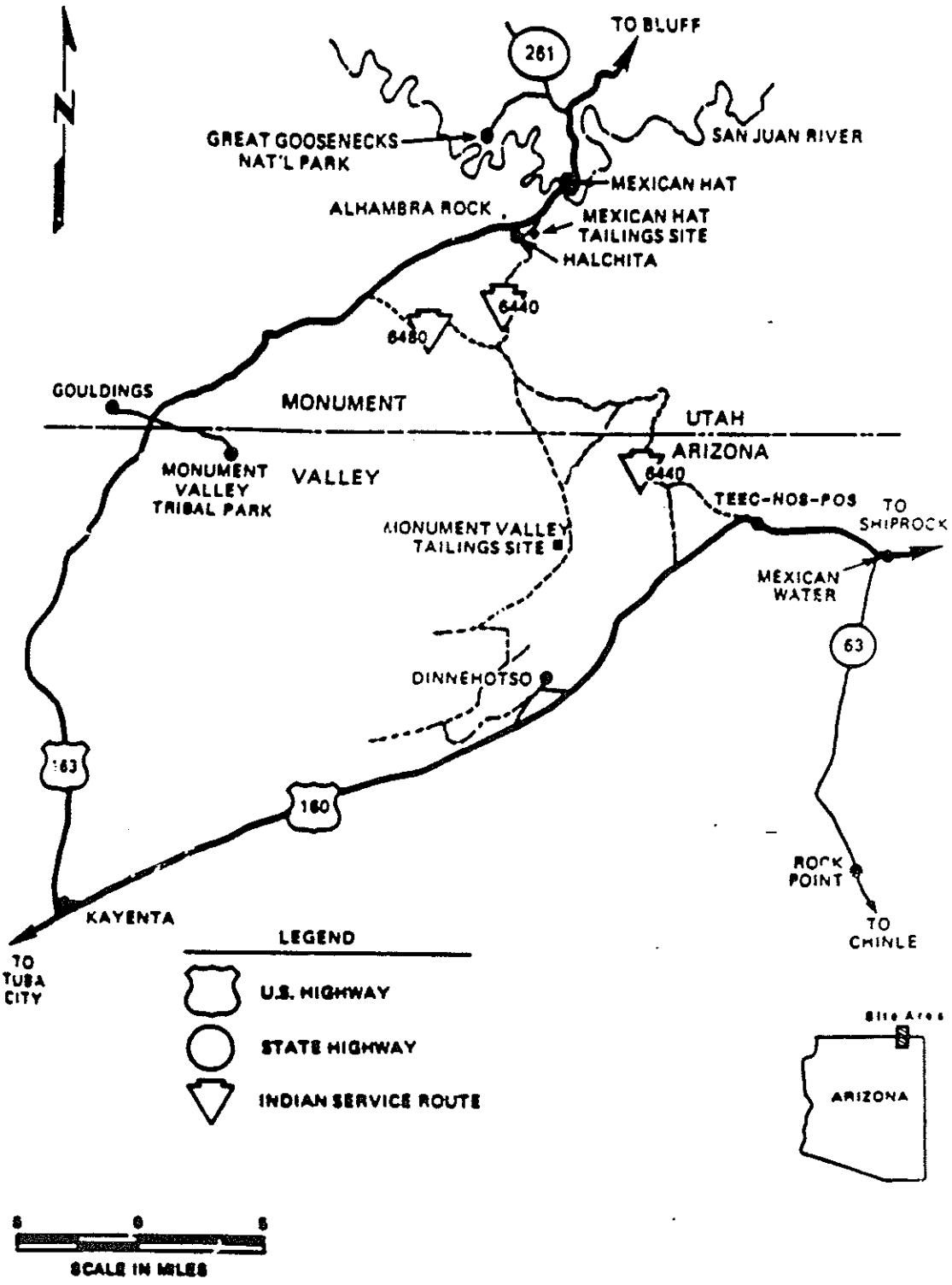
The principal feature of the remedial action is co-disposal and stabilization of the Mexican Hat and Monument Valley contaminated materials at the Mexican Hat disposal site.

Monument Valley Site

The Monument Valley site is a 100-acre property located on the Navajo Reservation in Arizona, 17 road miles south of the Mexican Hat disposal site (Figure 1.1). The tailings are on the west side of Cane Valley. The mill at the Monument Valley site was operated from 1955 to 1968 by Vanadium Corporation of America and its successor, Foote Mineral Company. According to the Completion Report (CR), the pre-remediated site consisted of two tailings piles covering approximately 28 acres and containing approximately 928,000 cubic yards of tailings; concrete building foundations; and debris.

During 1993 through early 1994, the Monument Valley contaminated materials were excavated and hauled to the Mexican Hat site for placement on the disposal cell, and the Monument Valley site was backfilled, graded to drain, and vegetated.

FIGURE 1.1
LOCATION OF THE MONUMENT VALLEY AND MEXICAN HAT SITES



1.5 COMPLETION REVIEW REPORT ORGANIZATION

The purpose of this CRR is to document the NRC staff review of DOE's Mexican Hat/Monument Valley Completion Report (CR) (DOE, 1997). Section 2 of this report presents the analysis of remedial action construction. This section is organized by technical discipline and addresses engineering and radiation protection aspects of the remedial action. Appendix A provides a listing of NRC staff visits to the Mexican Hat and Monument Valley sites. Appendix B provides a detailed description of the requirements of UMTRCA and the resulting phased process of the UMTRA project.

2.0 ANALYSIS OF DOE REMEDIAL ACTION PERFORMANCE

2.1 PREVIOUS ACTIONS

NRC staff, based on its review of the RAP (DOE, 1993a-f), and the RAIP (MK-F, 1994) concurred that the remedial action, as designed, would meet the applicable EPA standards. This concurrence was based on technical findings that there is reasonable assurance that the selection of the remedial action would meet the standards for long-term stability, radon attenuation, water resources protection, and cleanup of contaminated land and buildings.

Staff reviews included assessments in the areas of geology, geotechnical engineering, surface water hydrology, and health physics. The NRC concurred on the final RAP and the RAIP on February 27, 1996. The basis for the NRC staff's concurrence in DOE's selection of remedial action at the Mexican Hat and Monument Valley sites is documented in a Technical Evaluation Report (TER) issued in February 1996 (NRC, 1996).

2.2 REVIEW OF REMEDIAL ACTION PERFORMANCE

NRC staff's primary objective in reviewing DOE's certification of remedial action completion is to determine whether the remedial actions have been performed in a manner consistent with specifications provided in the RAP, RAP modifications or PIDs, and the RAIP, and if not, that deviations to these specifications still result in compliance with the EPA standards. In support of this action, the NRC staff participated in site reviews (See Appendix A), field observations, assessments of on-site data and records, and review of DOE Site Audit Reports. During remedial action construction activities, there were conditions encountered which required modifications of the original remedial action plan. These conditions and the associated design changes were submitted by DOE as five Class I PIDs, i.e., those related to meeting the EPA standards, and were concurred in by the NRC staff. These PID's are listed in the Executive Summary of Volume 1 of the CR and are reflected in the as-built conditions presented in the CR.

The following sections present the results of the review of remedial action performance by individual technical discipline. Note that for the Mexican Hat/Monument Valley remedial action completion review, the pertinent technical disciplines are: 1) geotechnical engineering, 2) surface water hydrology and erosion protection, 3) radiation protection, and 4) water resources protection.

2.2.3 Radiation Cleanup and Control

The NRC staff reviewed radiation cleanup aspects of remedial actions at the Mexican Hat, Utah and Monument Valley, Arizona sites to ensure that residual radioactive materials were cleaned up in accordance with specifications in the RAP and the final design. The remedial action involved the consolidation of contaminated materials from the Mexican Hat site into a single pile on site with contaminated materials from the Monument Valley site relocated and placed on top of the Mexican Hat materials. Areas of review included contaminated material excavation, cleanup verification procedures and data, and application of supplemental standards. In addition, the construction data for the disposal cell cover were reviewed to ensure compliance with the RAP design for limiting radon releases (see Section 2.2.1), and the final radon attenuation calculation was reviewed to ensure compliance with the long-term radon flux standard in 40 CFR 192.02. The review was based primarily on the staff's assessment of information presented in the DOE Mexican Hat/Monument Valley Completion Report (CR).

The criteria for site cleanup and radon attenuation design were established in the RAP and concurred in by NRC staff as providing assurance that the processing site and disposal cell would meet the EPA requirements of 40 CFR Part 192. The criterion for soil radium (Ra-226) requires cleanup at the processing site and on adjacent lands (EPA standards, 40 CFR 192.12) such that the average Ra-226 and Ra-228 levels above background in each 100-m^2 area do not exceed either 5 pCi/g in the top 15 cm of soil, or 15 pCi/g in any underlying 15-cm layer. The RAP also established a supplemental cleanup standard which requires that thorium (Th-230) be excavated such that the bulk (corrected for percent cobbles) 1000-year Ra-226 concentrations from present levels of Ra-226 and Th-230 meet the Ra-226 cleanup limits.

Two buildings remained on the Mexican Hat processing site. DOE indicated that the buildings did not require cleanup so cleanup criteria were not specified in the RAP.

The RAP final radon attenuation (barrier) design was based on construction of a compacted clayey (10 percent bentonite by weight) soil radon barrier 2 feet thick. The NRC staff in its TER evaluation of the RAP stated that measurements made during construction of the cell should be incorporated into the final flux analysis in the CR. A radon flux calculation was provided in the CR incorporating some final test data, as discussed below.

During the review, with respect to the above criteria and commitments, NRC staff noted the following:

1. Soil Cleanup: Appendix J of the CR indicates that all tailings contaminated areas on the Mexican Hat and Monument Valley sites were cleaned according to DOE UMTRA Project procedures.

2. Cleanup Verification: The CR indicates that standard DOE UMTRA Project procedures for soil verification were appropriately applied at the two sites, and the quality control program complied with plan criteria. The data indicate that all soil samples and areas scanned by the RTRAK or hand-held gamma detectors met the EPA soil Ra-226 standards. Measurements for Th-230 were conducted and the estimated 1000-year Ra-226 concentrations from present levels of Ra-226 and Th-230 were less than or equal to the radon standard. The CR indicates that by cleaning up Th-232 at the Mexican

Hat site to the appropriate criteria, Ra-228 would also be remediated. The data indicate that measurements for Th-232, as a surrogate for Ra-228, were done at the Mexican Hat site and met the 5 pCi/g criterion at any depth. No Th-232 measurements were done at the Monument Valley site because site characterization data indicated that there were no elevated levels of Th-232 at the site.

Appendix J of the CR states that the shop building had some elevated surface activity, but the activity met the NRC one square meter average limit. The data provided indicates that the building does meet all release criteria. Also, the CR indicates that the other building (former clinic) was assessed as part of a vicinity property inclusion survey and did not require remediation.

3. Radon Flux: Long-term radon flux estimates for the Mexican Hat disposal cell cover were provided in CR calculation 9-421-05-01. The radon flux model utilized average measured Ra-226 and emanation fraction values for as-placed contaminated materials, sampled at 20 locations on the cell.

   Th-230 was also measured, but the resulting 1000-year Ra-226 values were not used in the calculation because the influence would not be significant. Although, measured values for some of the radon barrier parameters were not obtained to replace earlier estimates and the modeled thickness of some of the contaminated material may not be conservative, the NRC staff considers the over-all DOE radon model conservative. The DOE calculation resulted in an average long-term radon flux of 12.8 pCi/m^2s from the top of the radon barrier.

   Radon flux measurements were performed on the radon barrier and averaged 0.05 pCi/m^2s. Based on this information and the findings discussed under Sections 2.2.1 and 2.2.2 of this CRR that the integrity of the radon barrier will not be significantly degraded for the design life of the cell, NRC staff concludes that there is adequate assurance that the long-term radon flux standard of 20 pCi/m^2s will be met.

Based on the above evaluations, the NRC staff concludes that commitments and requirements stated in the RAP were fulfilled and that data in the CR provides assurance that the soil cleanup and disposal cell cover radon control standards have been met at the Mexican Hat and Monument Valley sites.

2.2.4 Water Resources Protection Review Results

The NRC staff reviewed the construction activities conducted during the performance of remedial actions that relate to ground-water resource protection. During its review, the NRC staff noted the following:

1. No as-built drawings for well abandonment were included in the Completion Report for the Mexican Hat or Monument Valley sites, however two photographs showed well abandonment activities proceeding at the Mexican Hat site in 1988. No schedules or specifications for well abandonment for either site were included in the RAP (DOE, 1993). Discussion with the DOE project manager indicated that well abandonment was performed in 1988, as part of a previous DOE remedial action and was not specified as a part of this RAP. Some wells remain at both the Mexican Hat and Monument Valley sites and will be used or abandoned as part of the groundwater restoration program.

Based on the above discussion with the DOE project manager and results of NRC onsite inspections, the NRC staff concludes that the ground-water protection aspects of the remedial action were completed in accordance with the design and procedures identified in the RAP, and the RAIP.

3.0 SUMMARY

NRC staff reviewed geotechnical engineering, surface water hydrology and erosion protection, radiation protection, and water resources protection aspects of the remedial action performed at the Mexican Hat and Monument Valley uranium mill tailings sites. The purpose of this review was to determine whether DOE had performed remedial actions at the site in accordance with specifications in the RAP, RAP modifications, and other supporting project documents, and thus with the EPA standards in 40 CFR Part 192, Subparts A-C. Based on its review of the Final CR and on observations made during periodic on-site construction visits, the NRC staff concludes that DOE performed remedial action at the Mexican Hat and Monument Valley sites in accordance with the EPA standards. Therefore, NRC concurs with DOE's certification of completion of the Mexican Hat/Monument Valley remedial action.

4.0 REFERENCES

U.S. Department of Energy (DOE), Washington, D.C.

---, "Final Remedial Action Plan for Co-Disposal and Stabilization of Monument Valley and Mexican Hat Uranium Mill Tailings at Mexican Hat, Utah" and Appendices A-F, February 1993.

---, "Draft Completion Report, Mexican Hat/Monument Valley," Volumes 1-6A, November 1995.

---, "Final Audit Report of Remedial Action Construction at the UMTRA Project Mexican Hat, UT/Monument Valley, AZ Sites," November 1995.

---, "Final Completion Report, Mexican Hat/Monument Valley," Volumes 1-6A, April 1997, and page changes (June 4, 1997, June 16, 1997, and July 29, 1997).

MK-Ferguson, "Remedial Action Inspection Plan, Mexican Hat/Monument Valley Uranium Mill Tailings Sites," September 1994.

U.S. Nuclear Regulatory Commission, Washington, D.C., "Final Technical Evaluation Report for the Proposed Remedial Action Plan for the Co-Disposal of the Monument Valley and Mexican Hat Contaminated Materials at the Mexican Hat Tailings Site, Utah," February 1996.

---, Division of Low-Level Waste Management and Decommissioning, "NRC Staff Technical Position on Testing and Inspection Plans During Construction of DOE's Remedial Action at Inactive Uranium Mill Tailings Sites," January 1989.

APPENDIX A

NRC SITE VISITS TO THE

MEXICAN HAT AND MONUMENT VALLEY UMTRA PROJECT SITES

DATE	STAFF/DISCIPLINE	PURPOSE
4/21/92	M. Layton/hydrology T. Johnson/surface hydrology D. Rom/geotech. engineering E. Brummett/rad. protection M. Hague/project management	Site visit at Monument Valley and Mexican Hat.
11/5/92	T. Johnson/surface hydrology A. Mullins/geology M. Hague/project management	Discuss erosion protection design at Mexican Hat.
9/2/93	D. Rom/geotech. engineering	Construction progress review at Mexican Hat and Monument Valley.
10/27/93	D. Rom/geotech. engineering T. Johnson/surface hydrology	Construction progress review and discuss erosion protection design at Mexican Hat.
5/18/94	D. Rom/geotech. engineering T. Johnson/surface hydrology R. Carlson/project management	Construction progress review and discuss rock durability issues at Mexican Hat. Site visit of Monument Valley.
5/6/96	M. Layton/hydrology H. Lefevre/project management	Observe reclaimed Monument Valley processing site; and observe completed disposal cell and existing seeps at Mexican Hat.
2/25/97	T. Johnson/surface hydrology	Observe erosion protection at completed Mexican Hat disposal site.

APPENDIX B
UMTRCA, THE EPA STANDARDS, AND THE PHASED UMTRA PROJECT

Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) defines the statutory authority and roles of the DOE, the NRC, and the EPA with regard to the remedial action program for inactive uranium mill tailings sites.

The Standards

UMTRCA charged the EPA with the responsibility for promulgating remedial action standards for inactive uranium mill sites. The purpose of these standards is to protect the public health and safety and the environment from radiological and non-radiological hazards associated with radioactive materials at the sites. UMTRCA required that EPA promulgate these standards by no later than October 1, 1982. After October 1, 1982, if the EPA had not promulgated standards in final form, DOE was to comply with the standards proposed by EPA under Title I of UMTRCA until such time as the EPA had promulgated its standards in final form.

The final EPA standards were promulgated with an effective date of March 7, 1983 (48 FR 602; January 5, 1983); see 40 CFR Part 192 - Standards for Remedial Actions at Inactive Uranium Processing Sites, Subparts A, B, and C. These regulations may be summarized as follows:

1. The disposal site shall be designed to control the tailings and other residual radioactive materials for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years [40 CFR 192.02(a)].

2. The disposal site design shall provide reasonable assurance that radon-222 from residual radioactive material to the atmosphere will not exceed an average release rate of 20 picocuries per square meter per second, or will not increase the annual average concentration of radon-222 in air, at or above any location outside the disposal site, by more than one-half picocurie per liter [40 CFR 192.02(b)].

3. The remedial action shall be conducted so as to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site, the concentrations of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than 5 picocuries/gram averaged over the first 15 centimeters of soil below the surface and 15 picocuries/gram averaged over 15 centimeter thick layers of soil more than 15 centimeters below the surface [40 CFR 192.12(a)].

4. The objective of remedial action involving buildings shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL, and the level of gamma radiation shall not exceed the background level by more than 20 micro roentgens per hour [40 CFR 192.12(b)].

5. The portion of the EPA standards dealing with groundwater requirements, 40 CFR 192.20(a)(2)-(3) were remanded by the Tenth Circuit Court of Appeals on September 3, 1985. Based on this court decision, EPA was directed to promulgate new groundwater standards. EPA proposed these standards in the form of revisions to Subparts A-C of 40 CFR Part 192 in September 1987, and the final groundwater standards were promulgated January 11, 1995.

Before the groundwater standards were final, as mandated by Section 108(a)(3) of UMTRCA, the remedial action at the inactive uranium processing sites were to comply with EPA's proposed standards until such time as the final standards are promulgated. DOE performed remedial action at the inactive processing sites in accordance with NRC's concurrence with the remedial action approach based on the proposed EPA groundwater standards (52 FR 36000; September 24, 1987). Delaying implementation of the remedial action program would be inconsistent with Congress' intent of timely completion of the program. Modifications of disposal sites after completion of the remedial action to comply with EPA's final groundwater protection standards may be unnecessarily complicated and expensive and may not yield commensurate benefits in terms of human and environmental protection. Therefore, the Commission believes that sites where remedial action has been essentially completed prior to EPA's promulgation of final groundwater standards, will not be impacted by the final groundwater standards promulgated January 11, 1995. Although additional effort may be appropriate to assess and clean up contaminated groundwater at these sites, the existing designs of the disposal sites should be considered sufficient to provide long-term protection against future groundwater contamination. NRC does not view UMTRCA as requiring the reopening of those sites that have been substantially completed when NRC concurred with the selection of remedial action in accordance with applicable EPA standards, proposed or otherwise in place at the time such NRC concurrence was given.

DOE Selection (Design) Phase

For each site, UMTRCA requires that DOE select a plan of remedial action that will satisfy the EPA standards and other applicable laws and regulations, and with which the NRC will concur. For each site, this phase includes preparation by DOE of an Environmental Assessment or an Environmental Impact Statement, and a Remedial Action Plan (RAP). The RAP is structured to provide a comprehensive understanding of the remedial actions proposed at that site and contains specific design and construction requirements. To complete the first phase, NRC and the appropriate State or Indian tribe will review the RAP and then concur that the RAP will meet the EPA standards.

The Performance (Construction) Phase

In this phase the actual remedial action (which includes decontamination, decommissioning, and reclamation) at the site is done in accordance with the RAP. The NRC and the State/Indian tribe, as applicable, must concur in any changes to the concurred-in plan that arise during construction. At the completion of remedial action activities at the site, NRC concurs in DOE's determination that the activities at the site have been completed in accordance with the approved plan. Prior to licensing (the next phase), title to the disposed tailings and contaminated materials must be transferred to the United States and the land upon which they are disposed of must be in Federal custody to provide for long-term Federal control. Disposal sites on Indian land will remain in the beneficial ownership of the Indian tribe.

NRC concurrence in the DOE determination that remedial action at a processing site has been accomplished in accordance with the approved plan may be accomplished in two steps where residual radioactive material is not being moved from the processing site to a different disposal site. The Uranium Mill Tailings Remedial Action Amendments Act of 1988 allows for a two-step approach for Title I disposal sites. The Amendments Act will allow DOE to do all remedial actions, other than groundwater restoration, for the first step of closure and licensing. The second step, which can go on for many years, will deal with existing groundwater restoration. When groundwater restoration is completed, the Long-Term Surveillance Plan required under

the licensing phase will be appropriately amended. For sites that are being moved, licensing will occur in one step. There is no groundwater restoration at the disposal site and the processing site will not be licensed after completion of remedial action.

The Licensing Phase

Title I of UMTRCA further requires that, upon completion of the remedial action program by DOE, the permanent disposal sites be cared for by the DOE or other Federal agency designated by the President, under a license issued by the Commission. DOE will receive a general license under 10 CFR Part 40.27 following: (1) NRC concurrence in the DOE determination that the disposal site has been properly reclaimed, and (2) the formal receipt by NRC of an acceptable Long-Term Surveillance Plan (LTSP). NRC concurrence with DOE's performance of the remedial action indicates that DOE has demonstrated that the remedial action complies with the provisions of the EPA standards in 40 CFR part 192, Subparts A, B, and C. This NRC concurrence may be completed in two steps as discussed above. There is no termination date for the general license.

Public involvement has been and will continue to be provided through DOE's overall remedial action program for Title I sites. The local public will have an opportunity to comment on the remedial action or closure plans proposed and implemented by DOE and to raise concerns regarding final stabilization and the degree of protection achieved. NRC fully endorses State/Indian tribe and public input in all stages of the program. At the time the LTSP is submitted, the NRC will consider the need for a public meeting in response to requests and public concerns.

The Surveillance and Monitoring Phase

In this phase, DOE and NRC periodically inspect the disposal site to ensure its integrity. The LTSP will require the DOE to make repairs, if needed.

One of the requirements in the EPA standards is that control of the tailings should be designed to be effective for up to 1000 years without active maintenance. Although the design of the stabilized pile is such that reliance on active maintenance should be minimized or eliminated, the NRC license will require emergency repairs as necessary. In the event that significant repairs are necessary, a determination will be made on a site specific basis regarding the need for additional National Environmental Policy Act actions, and health and safety considerations based on 10 CFR Parts 19, 20, and 21.

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Appendix C

University of Arizona Letter

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Environmental Research Laboratory
Department of Soil, Water and Environmental Science
College of Agriculture and Life Sciences

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December 17, 2009

Memo to: Jody Waugh

Regarding: Uranium in Former Evaporation Pond Area at Monument Valley

We analyzed the stained surface soils in the former evaporation pond area and extended field west in the subpile soil area for a suite of heavy metals to determine if potential toxic substances were associated with the chemical stains observed in some areas of the site. This was part of Task 6, Mn Toxicity Field Study. Our original concern was that Mn was present in different oxidation states at some places on the site and might represent a hazard in blowing dust. However, we reported previously that although Mn nodules were present in the soil, the soil levels were within background levels found in other soils and did not present an apparent risk. Mn can account for the red and blue hues present in some stained areas. However, David Moore also noted that a spot in the former evaporation ponds had a yellow stain. Dr. Janick Artiola, head of ERL's Water Quality Center Laboratory, thought this could be due to uranium. Consequently, we analyzed stained soils for a suite of metals, including calcium, vanadium, manganese, iron, strontiuim and uranium. A summary of results is in Table I (below), and complete results are in an attached Excel spread sheet.

Following Table 1 are field notes from David Moore on the location and appearance of the samples, and photographs showing the different hues of the stained soils. Note that uraniuim levels are elevated in the yellow stained area from the evaporation pond relative to levels in the extended field west (the former pile area).

Ed Glenn

Table 1. Heavy metal analyses of surface soils at Monument Valley, 2009. Samples were collected in stained areas in the former evaporation ponds (EP), and the extended field west (EPW), by scraping samples from soils exhibiting yellow (Y), green (G) or red (R) colors. Samples were analyzed by ERL's Water Quality Center Laboratory.

Summary by Analyte

ALEC Log number	**Sample ID**	**WQCL Sample ID**	**Sample concentration**	
Analyte			**Ca40**	
WQCL 1537	EP Y	09044-1	**27949**	**ug/g**
WQCL 1538	EP YG	09044-2	**21067**	**ug/g**
WQCL 1539	EFW R	09044-3	**31117**	**ug/g**
WQCL 1540	EFW G	09044-4	**31585**	**ug/g**
WQCL 1541	EFW G	09044-4 dup	**33593**	**ug/g**
WQCL 1542		QC807 Mont	**21062**	**ug/g**
WQCL 1543		QQC808 Marine	**2262**	**ug/g**
Analyte			**V51**	
WQCL 1537	EP Y	09044-1	**2672**	**ug/g**
WQCL 1538	EP YG	09044-2	**1352**	**ug/g**
WQCL 1539	EFW R	09044-3	**895**	**ug/g**
WQCL 1540	EFW G	09044-4	**884**	**ug/g**
WQCL 1541	EFW G	09044-4 dup	**928**	**ug/g**
WQCL 1542		QC807 Mont	**26**	**ug/g**
WQCL 1543		QQC808 Marine	**261**	**ug/g**
Analyte			**Mn55**	
WQCL 1537	EP Y	09044-1	**134**	**ug/g**
WQCL 1538	EP YG	09044-2	**96**	**ug/g**
WQCL 1539	EFW R	09044-3	**148**	**ug/g**
WQCL 1540	EFW G	09044-4	**174**	**ug/g**
WQCL 1541	EFW G	09044-4 dup	**177**	**ug/g**
WQCL 1542		QC807 Mont	**567**	**ug/g**
WQCL 1543		QQC808 Marine	**1807**	**ug/g**
Analyte			**Fe56**	
WQCL 1537	EP Y	09044-1	**4301**	**ug/g**
WQCL 1538	EP YG	09044-2	**4242**	**ug/g**
WQCL 1539	EFW R	09044-3	**54741**	**ug/g**
WQCL 1540	EFW G	09044-4	**2395**	**ug/g**
WQCL 1541	EFW G	09044-4 dup	**2161**	**ug/g**
WQCL 1542		QC807 Mont	**13970**	**ug/g**
WQCL 1543		QQC808 Marine	**57474**	**ug/g**

Table 1 (continued).

Analyte			**Sr88**	
WQCL 1537	EP Y	09044-1	**107**	**ug/g**
WQCL 1538	EP YG	09044-2	**71**	**ug/g**
WQCL 1539	EFW R	09044-3	**134**	**ug/g**
WQCL 1540	EFW G	09044-4	**130**	**ug/g**
WQCL 1541	EFW G	09044-4 dup	**136**	**ug/g**
WQCL 1542		QC807 Mont	**50**	**ug/g**
WQCL 1543		QQC808 Marine	**61**	**ug/g**

Analyte			**U238**	
WQCL 1537	EP Y	09044-1	**442**	**ug/g**
WQCL 1538	EP YG	09044-2	**303**	**ug/g**
WQCL 1539	EFW R	09044-3	**2.31**	**ug/g**
WQCL 1540	EFW G	09044-4	**1.35**	**ug/g**
WQCL 1541	EFW G	09044-4 dup	**1.36**	**ug/g**
WQCL 1542		QC807 Mont	**0.88**	**ug/g**
WQCL 1543		QQC808 Marine	**6.35**	**ug/g**

David Moore's Field Notes and Photos:

Ben Stanley and I collected stained soil samples on 8-12-09.

In the Evaporation Pond, a solenoid had failed and there was no irrigation water for the week preceding this site visit. That combined with rain which preceded the visit resulted in the prominent red/green stained soil noted in the July trip fading away. While red/green had been common throughout the Evaporation Pond, it was not available for collection there. The yellow and yellow/green stained areas were still there as can be seen in the following photos. There was just one yellow stained area in the Evaporation pond, located in the northwest portion of the field.

We collected red and green stained soil from the Extended Field West. We found one fairly good sample as can be seen in the photo but most of the stained soil was faded there too, compared to July when it was much more common and darker.

Samples:
EP Y Evaporation Pond – Yellow 1st and 2nd photos
Collected from Evaporation Pond between rows 14 & 15 N to S, 14 paces in W to E. Stained area for yellow and yellow/green samples was approximately 4' (W/E) by 7' (N/S).

EP YG Evaporation Pond – Yellow/Green Area in 1st photo; stain not visible

Collected from Evaporation Pond between rows 12 & 13 N to S, 12 paces in W to E

EFW R	Extended Field West – Red	3rd photo
EFW G	Extended Field West – Green	3rd photo

Both red and green collected from Extended Field West Row 14 W to E, at plant 9 S to N. Stained area was approximately 4' x 4'.

David Moore

Yellow sample taken from foreground, tape measure area. Yellow green taken from near Ben Stanley.

Close-up of yellow stain in former evaporation pond area.

Stained soil yellow/green (July 09)

Red and green sampled here.