

EXECUTIVE SUMMARY

A Removal Site Evaluation (RSE) was conducted at the Northeast Church Rock (NECR) Mine (the Site), and nearby areas between August 14, 2006 and December 5, 2006. The RSE consisted of investigating surface and subsurface soils and sediments at various areas within and near the Site. The Site is located approximately 16 miles northeast of Gallup, McKinley County, New Mexico. The RSE was conducted in accordance with the *Removal Site Evaluation Work Plan* (MWH, 2006a) (RSEWP).

The primary ore mineral that was mined at the Site was coffonite ($U(SiO_4)_{1-x}(OH)_4x$), which was placed in small temporary stockpiles at NECR-1 and NECR-2 before transport to the Church Rock mill site. Ore and low-grade ore stockpiles were temporarily stored on the NECR-1 and NECR-2 pads prior to being transported off-site to the Church Rock mill. Following New Mexico's approval of a license amendment to permit placement of tailings in mine stopes for structural reinforcement in 1978, tailings material from ore processing at the mill was temporarily stored in three areas referred to as Sand Backfill Areas No. 1, No. 2 and No. 3 (see Figure 1-2) prior to placement in the mine stopes. The bulk of the tailings material from the sand backfill areas was placed in the mine stopes; the remaining tailings were removed and disposed of off-site during the 1986 NRC reclamation.

Stormwater and mine dewatering discharge were routed to three sediment ponds for treatment. Treated water was discharged to the Unnamed Arroyo pursuant to an NPDES permit. Sediment in these ponds was periodically removed and temporarily placed on the Sediment Pad prior to off-site transport to the mill site. Non-economic material (overburden and low-grade ore) was also placed in the Non Economic Material Storage Area (NEMSA). Refuse and other discarded equipment was placed in the Boneyard. Both the NEMSA and Boneyard were reclaimed in 1994 (UNC, 1994), which included placement of one foot of topsoil over the non-native materials and then seeding.

The Site was initially divided into eleven individual survey areas for the RSE, which included NECR-1, NECR-2, Ponds 1 and 2, Pond 3/3a, Sandfill 1, Sandfill 2, Sandfill 3, Sediment Pad, Boneyard, NEMSA, and the Unnamed Arroyo. Two additional areas were added during the field investigation based on preliminary radiological scans. These areas are Vent Hole 3/8 and the Trailer Park. Additionally, nine Home Sites located northeast of the Site were also investigated as part of the RSE and a soil removal action was subsequently carried out at five of these home sites (comprising three residences) based on the results of the RSE. These home sites are located between NECR and the Quivera mine and are situated on the Quivera mine lease. Potential impacts to the Home Sites may have occurred due to wind or water transport of materials stemming from historical operations at NECR, historical operations at the Quivera mine, or background conditions.

Several methods were employed in conducting this field investigation. Initially, static gamma measurements were conducted on random triangular grids. Equivalent Ra-226 concentrations were derived from the gamma survey results by developing correlations using regression analysis between the gamma survey results and co-located surface soil samples analyzed for Ra-226. Due to the presence of radiation containing materials on side-slopes or in a pile that can cause radiation shine (potentially causing an overestimation of Ra-226 soil concentrations), a lead collimator was used on the field detector to minimize interference.

Surface soil samples for laboratory analysis were collected at a minimum of 13 of the gamma measurement locations in each survey area. Subsurface samples were collected using a hollow-stem auger drill rig, test pits excavated with a backhoe, and a hand-auger.

Based on the constituents typically associated with uranium roll-front deposits, the following preliminary constituents of potential concern (COPCs) were evaluated:

- Ra-226
- Arsenic
- Molybdenum
- Selenium
- Uranium
- Vanadium

The metals not including Ra-226 were analyzed for screening purposes only and not for delineating the vertical and lateral extent of metals in soil. Progeny of Ra-226 were not analyzed during the investigation but were accounted for during the Site risk evaluation.

At the Boneyard, the full suite of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) as well as analysis of the eight Resource Conservation and Recovery Act (RCRA) metals by Toxicity Characteristics Leaching Procedure (TCLP) were also analyzed. Samples from each survey area were also collected for analysis of leachate using the Synthetic Precipitation Leaching Procedure (SPLP) procedure and analyzing the leachate for the COPCs.

A Field Screening Level for Ra-226 was developed for the RSE. The FSL for Ra-226 was based on an acceptable risk range of 10^{-4} for residential scenarios, which results in a FSL of 2.24 pCi/g (1.24 pCi/g plus the mean of the Ra-226 background concentration 1.0 pCi/g).

The results of the gamma radiation surveys indicated that surface soils within the initial boundaries of each of the on-site areas contain surface soils with Ra-226 concentrations above the 2.24 pCi/g FSL over the majority of the areas surveyed. Only small fractions of the survey points within the initial boundaries areas were below the FSL. The locations of exceedances of Ra-226 from the gamma survey were frequent and closely spaced such that delineation of any smaller, clean areas within the interior of the areas is not practical, except possibly in Sandfill 1, where about 11 contiguous survey grid points were below the FSL.

The results of the static gamma radiation survey show that the average surface soil Ra-226 concentrations, as determined by correlation with the gamma survey results (CPM), range from approximately four to twenty times the 2.24 pCi/g FSL within each survey area. The surface soil Ra-226 concentration range is wide, with high standard deviations near or above the average concentrations indicating sporadic occurrences of elevated Ra-226 surface soil.

Based on the results, an outer boundary delineating the extent of exceedances of the FSL (i.e., locations below the Ra-226 FSL) based on the static gamma radiation survey for each area was interpreted and termed the FSL boundary. The FSL boundary was drawn outside of most exceedances of the FSL.

Initially, while in the field, the locations of the FSL boundaries were estimated based on the following:

- Undisturbed ground, such as in wooded areas with native soils.
- Roads, structures, and fences.
- Topographic limitations such as precipices, and steep hillsides.
- Boundaries of adjoining survey areas.
- Knowledge of historical operations.

The FSL boundaries were definitely determined based on the results of the gamma radiation surveys and analytical results from the soil sampling. The above listed features merely helped to guide the field investigation and to confirm the boundaries based on the survey and analytical results.

Surface soil samples were collected at 20% of the 80-foot triangular grid nodes (sample locations), or at least 13 locations within each survey area, as well as the five scan locations with the highest CPM readings at each of the nine Home Sites. Additionally, judgmental samples were collected in Vent Hole 3/8 and the Trailer Park, based on any gamma hotspots observed during the gamma survey scans conducted at those two areas. The results show that although there may be some variation between Ra-226 surface soil concentrations by soil sampling versus static gamma radiation survey at some locations, the averages are comparable. Ra-226 and uranium exceed the screening levels at some locations, while all results for molybdenum, selenium and vanadium were below their respective screening levels. Ra-226, uranium and arsenic concentrations in surface soil were as follows:

- Ra-226 values ranged from 0.8 to 875 pCi/g with 70% of the 268 surface soil samples analyzed for Ra-226 [includes stepouts] exceeding the FSL of 2.24 pCi/g.
- Uranium values ranged from 0.7 to 3,970 mg/kg with 9% of the 230 samples analyzed for uranium exceeding the screening level of 200 mg/kg.
- Arsenic values ranged from non-detect to 14.9 mg/kg with 60% of the 230 samples analyzed for arsenic exceeding the screening level of 3.7 mg/kg. The data do not show any correlation between arsenic and Ra-226 or uranium concentrations, and there does not appear to be any spatial pattern in concentrations within the survey areas.

Subsurface soil samples (>0.5 feet bgs) were collected from each of the (original) eleven on-site survey areas, which includes the Unnamed Arroyo. Samples were collected in test pits, soil borings, and hand auger holes and analyzed for the preliminary COPCs. The results show that Ra-226, uranium and arsenic exceed the screening levels at some locations, while all results for molybdenum, selenium and vanadium were below their respective screening levels. Ra-226, uranium and arsenic concentrations in surface soil were as follows:

- Ra-226 values ranged from 0.6 to 438 pCi/g; 66% of the 145 subsurface soil samples analyzed for Ra-226 exceeded the FSL of 2.24 mg/kg.
- Total uranium values ranged from 0.7 to 760 mg/kg; 12% of the 145 samples analyzed for uranium exceeded the screening level of 200 mg/kg.
- Arsenic values ranged from non-detect (<0.5) to 13.9 mg/kg; 52% of the 145 samples analyzed for arsenic exceeded the screening level of 3.7 mg/kg. The relative concentrations of arsenic do not correlate with the concentrations of Ra-226 (e.g., high arsenic concentrations were not necessarily co-located with high Ra-226 concentrations).

Exceedances of the screening levels in subsurface soils was confined to the top 5 to 14 feet at all sample locations, except at NECR-1. At NECR-1, exceedances of the field screening levels were detected in one soil boring (SB-090) in all samples collected from 5 to 25 feet bgs.

The Ra-226 levels measured during the step-out static gamma radiation survey for the NECR-1 were above the FSL at the outermost locations in three primary areas: to the east within the parking area and across Red Water Pond Road, to the north towards and around the Home Sites, and in the IX Plant area. The area around the IX Plant consists of a near-vertical cliff that represents a natural, physiographic boundary, and does not warrant additional investigation. The areas to the north and east represent potential data gaps in the FSL boundary, however results to the north are increasingly likely to represent disturbances or impacts associated with historical mining or exploration activities

on the Quivera Mining Company lease, and results to the east appear to be related to the construction or historical use of the former Quivera mine haul road.

A human health risk assessment (HHRA) was conducted for the Site based on the laboratory analysis results for surface soils (<0.5 feet bgs), and subsurface soils to a depth of 10 feet bgs. The HHRA for Home Sites 4, 6, 7, 8, and 9 where EPA conducted removal actions is based on the post-removal confirmation sampling at these Home Sites. The HHRA is a quantitative and qualitative evaluation of potential impacts of Site-derived contaminants on human health, in the absence of remediation or institutional controls. Results of the HHRA, along with other factors are used to determine whether residual levels of contaminants in Site media are protective of human health and may be left in place, or consideration of remedial alternatives are warranted. The HHRA results also provide the basis for the development of alternatives and risk-based cleanup goals for the Site, as appropriate.

The HHRA described herein was conducted in accordance with methods described in Section 6.0 of the approved *Removal Site Evaluation Work Plan* (MWH, 2006). In addition, at the request of EPA and the Navajo Nation, a HHRA was conducted for a hypothetical future on-site resident. This HHRA is comprised of a site-specific conceptual site model (CSM), screening-level HHRA, and baseline HHRA. Risk characterization results expressed as cancer ILCR and non-cancer HI estimates for on-site receptors (current/future maintenance personnel, hypothetical future livestock grazers and hypothetical future on-site residents) and for off-site receptors (current/future residents and hypothetical future livestock grazers) exposed to soils and sediments at the NECR Site are described below.

For each off-site and on-site area, two scenarios were evaluated: Scenario 1 summarizes risks to receptors when only direct soil exposure pathways are considered (i.e., incidental ingestion and inhalation of fugitive dust), while Scenario 2 includes six exposure pathways included in the USEPA risk models for non-radiological and radiological constituents (i.e., incidental soil ingestion, inhalation of fugitive dust, consumption of home-grown produce, consumption of locally grown meat, consumption of locally raised eggs, and external radiation) (USEPA, 2007). However, for a future site maintenance worker, Scenario 2 does not include consumption of home-grown plants or consumption of locally raised meat and eggs. Additionally, for the on-site livestock grazer, Scenario 2 does not include consumption of locally raised eggs or homegrown plants.

Additionally, the total combined risk for each area was calculated across all exposure pathways. Because the risk calculation methodology generated results that exceeded EPA's risk range even at background levels, incremental risk was also calculated, which is the result of the background risk subtracted from the total combined risk. The incremental risk is the risk attributable to each survey area above the background risk.

Located within the main NECR Site, there are 12 areas of concern which include: NECR-1, NECR-2 Ponds 1 & 2, Pond 3/3a, Sediment Pad, Sandfill 1, Sandfill 2, Sandfill 3, NEMSA, Boneyard, Vents 3 & 8, and the Trailer Park. Each on-site location was evaluated for both current/future maintenance personnel and the hypothetical future livestock grazer and hypothetical future on-site residents. The results of the assessment indicated the following:

- For current/future maintenance personnel, under Scenario 1, no surface or subsurface soils in the on-site areas have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to $1E-06$ to $1E-04$ or $HQ > 1$.
- For current/future maintenance personnel under Scenario 2, surface soils in eight of the areas, and subsurface soils in five of the areas have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to $1E-06$ to $1E-04$ or $HQ > 1$. A surface

soil Ra-226 concentration of 50 pCi/g would result in an estimated incremental risk or HQ within the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ < 1.

- For the hypothetical future on-site livestock grazer, under Scenario 1, no surface or subsurface soils in the on-site areas have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ > 1.
- For the hypothetical future on-site livestock grazer, under Scenario 2, surface soils in all on-site areas, and subsurface soils in all but one of the areas have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ > 1. A surface soil Ra-226 concentration of 2.5 pCi/g would result in an estimated incremental risk or HQ within the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ < 1.
- For the hypothetical future on-site resident under Scenario 1, surface soils in all but three of the areas have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ > 1. Risk drivers under Scenario 1 were Ra-226 and uranium. A surface soil Ra-226 concentration of 110 pCi/g would result in an estimated incremental risk or HQ within the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ < 1. A surface soil uranium concentration of 48 mg/kg would result in an estimated incremental risk or HQ within the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ < 1.
- For the hypothetical future on-site resident under Scenario 2, surface soils in all of the areas have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ > 1. A surface soil Ra-226 concentration of 1.9 pCi/g would result in an estimated incremental risk or HQ within the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ < 1. A surface soil uranium concentration of 48 mg/kg would result in an estimated incremental risk or HQ within the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ < 1.

For a resident under scenario 2, in order to achieve the EPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ < 1, concentrations of Ra-226 in surface soil concentrations cannot exceed 1.9 pCi/g, which is below the naturally occurring average levels of Ra-226 levels on the Colorado Plateau.

Off-site areas include the nine Home Sites evaluated for residential receptors, the Unnamed Arroyo evaluated for the hypothetical future livestock grazer, and background data collected for the purpose of comparison to combined risk and hazard estimates for each area.

The results of the risk assessment, for residents of the Home Sites indicate the following:

- Scenario 1 - none of the Home Sites have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ > 1. Home Site #5 was associated with the highest ILCR (2E-05) estimated for any of the Home Sites under Scenario 1. However, the ILCR due to background soils under Scenario 1 was estimated as 1E-05.
- Scenario 2 – none of the Home Sites on the western side of the Unnamed Arroyo (Home Sites #1 through #5) have an incremental risk or HQ above the USEPA risk management range of cancer risk equal to 1E-06 to 1E-04 or HQ > 1.

- Scenario 2 - none of the Home Sites on the eastern side of the Unnamed Arroyo (Home Sites #6, #7, #8 and #9) have incremental ILCR or HQ estimates above the USEPA risk management range of cancer risk equal to $1E-06$ to $1E-04$ or $HQ > 1$, based on EPA's post-removal confirmation sampling results. The total ILCR for all Home Sites on the eastern side of the Unnamed Arroyo were equal to $1E-04$. For comparison, the total ILCR estimate for background soil was equal to $2E-04$. Both the site-related and background risk estimates presented in this baseline ILCR are likely over-estimated as described in the Uncertainty Analysis (Section 4.4).

Incremental risk estimates greater than $1E-04$ are attributable to the consumption of homegrown produce, the consumption of homegrown meat, and the external exposure pathways considered in Scenario 2. Actual exposures will be lower than those assumed if vegetable gardens are not used, livestock are not grazed in the area, and/or if a concrete slab is part of the foundation at these Home Sites. In addition, it may not be appropriate to consider the latter indirect exposure pathways given that the risk-based Soil Screening Levels (SSLs) for Ra-226 for external exposure, consumption of homegrown produce, and consumption of homegrown meat based on a risk level of 10^{-6} are 0.01 pCi/g, 0.069 pCi/g and 0.024 pCi/g, respectively, and are below the site-specific background level of 1.0 pCi/g. It should also be noted that the exposure and risk estimates described in this HHRA are biased high due to the soil sampling design. Field screening was used to identify biased locations for the collection of soil samples. In turn, the 95% UCL on the mean concentration of these biased soil samples was used to estimate exposure doses and risk estimates. In most cases, the concentrations observed at biased sample locations are representative of only a very minor portion of the entire home site.

However, as documented in USEPA's Home Site Investigation Trip Report September 11, 2007, (E&E, 2007), EPA has carried out a soil removal action at three properties referred to in the RSEWP as Home Sites 4, 6, 7, 8, and 9. As stated in the Request for Time-Critical Removal Action at the Northeast Church Residential Site Memorandum dated April 18, 2007, the goal of EPA's removal action was to "reduc[e] the UCL 95% radium concentration in the excavation footprint to a concentration that is less than the Site screening level."

The field screening level (FSL) is 2.24 pCi/g, which is based on the sum of the Site-specific background mean (1.0 pCi/g) and a risk-based value representing the upper end of the risk range (i.e., the 1 in 10,000 excess cancer risk for radium in residential exposure scenarios) or 1.24 pCi/g. It should also be noted that the exposure and risk estimates described in this HHRA are biased high for the Home Sites due to the soil sampling design. Field screening was used to identify biased locations for the collection of soil samples. In turn, the 95% UCL on the mean concentration of these biased soil samples was used to estimate exposure doses and risk estimates. In most cases, the concentrations observed at biased sample locations are representative of only a very minor portion of the entire home site.

For the hypothetical future livestock grazer within the Unnamed Arroyo evaluated under Scenarios 1 and 2, neither surface soil nor subsurface soil concentrations of any COPC has an incremental risk or HQ above the USEPA risk management range of cancer risk equal to $1E-06$ to $1E-04$ or $HQ > 1$.

For the background data, only surface soil samples were collected. For Scenario 1, no soil concentrations of any COPC have a cumulative risk or HQ above the USEPA risk management range of cancer risk equal to $1E-06$ to $1E-04$ or $HQ > 1$. For Scenario 2, arsenic and Ra-226 contribute to incremental risk estimates above the USEPA risk management range of cancer risk equal to $1E-06$ to $1E-04$ and/or $HQ > 1$ due to ingestion of soil, the consumption of homegrown produce and meat, and exposure to external radiation.

Different sources of uncertainty described in the report are incorporated into the risk estimate. Because the majority of these uncertainties err on the conservative side, the estimated risks presented in the IHRA for NECR most likely represent upper bound estimates; the actual risks are anticipated to be less. The protective nature of these assumptions is demonstrated by risk estimates associated with background concentrations of Ra-226 and non-radiological constituents in soil. The total ILCR for Ra-226 across all exposure pathways (i.e., Scenario 2) was estimated as 1E-04, and the total ILCR for measured concentrations of all constituents in background soil (assuming scenario 2) was estimated as 2E-04. Therefore, it is appropriate to consider both Scenario 1 and 2 in making risk management decisions.