Final Status Survey Plan for Release of Former Land Application Areas

Grants Reclamation Project

Cibola County, New Mexico

Revision 1

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1. INTRODUCTION

1.1 Background

A land application irrigation program was conducted by Homestake Mining Company of California (HMC) near the Grants Reclamation Project in Cibola County, New Mexico (Site) from 2000 through 2012 by irrigating areas ranging from 100 to 394 acres with water containing slightly elevated uranium and selenium concentrations (Figure 1). This program applied locally impacted groundwater as part of groundwater restoration efforts at the Site. A detailed description of the land application program is provided in the Land Application Assessment Report submitted to the U.S. Nuclear Regulatory Commission (NRC) on September 25, 2017 (Hydro/ERG, 2017).

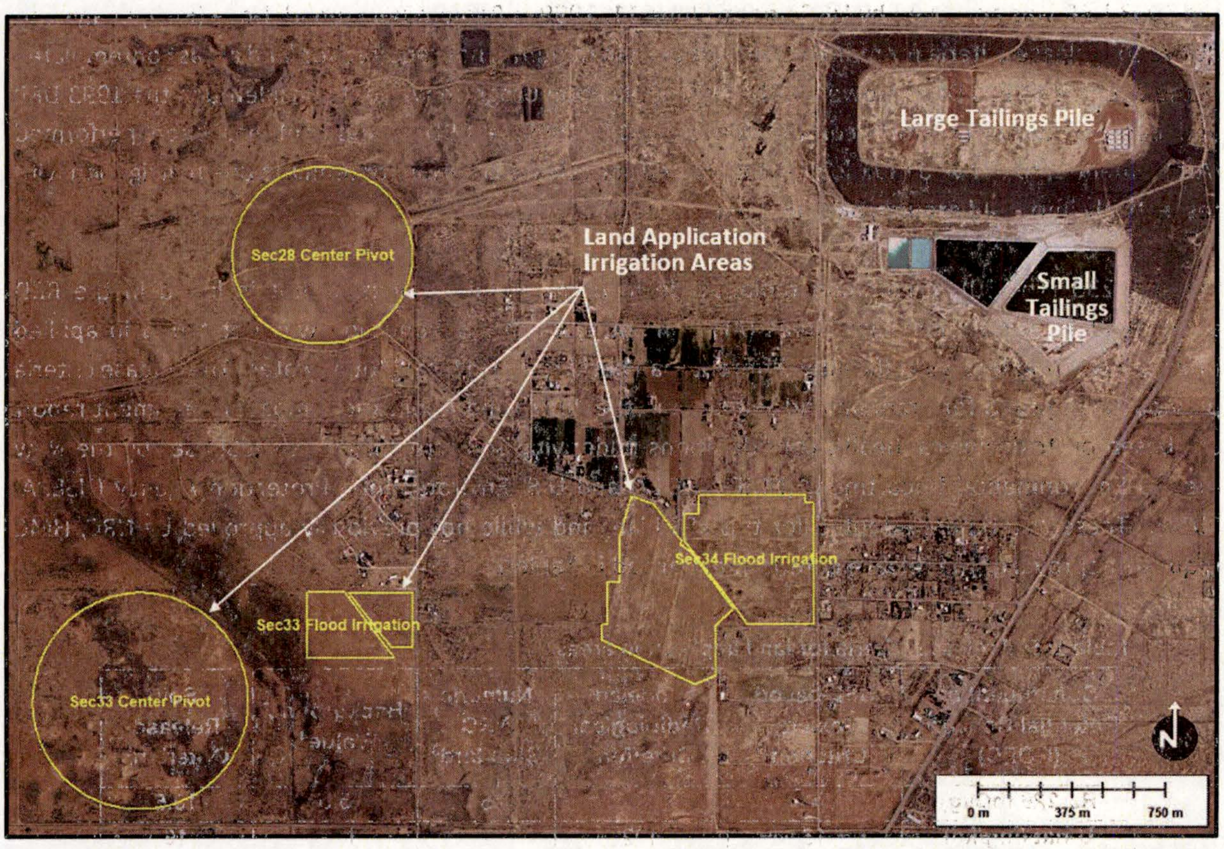


Figure 1: Former land application areas in relation to large and small tailings piles at the HMC Grants Reclamation Project Site

1.2 Objectives

Based on monitoring data for soils in the land application areas, there is evidence that impacts to soils from the irrigation program were minimal (Hydro/ERG, 2017). HMC intends to perform final status surveys (FSS) to demonstrate that these areas have concentrations of constituents of potential concern

(COPCs) that do not exceed proposed criteria for unrestricted release from Radioactive Materials License SUA-1471 with the NRC. This document provides a FSS Plan for former land application areas at the Site.

2. CRITERIA FOR UNRESTRICTED RELEASE

2.1 Proposed Release Criteria

The COPCs in the applied irrigation water were primarily limited to uranium and selenium and respective release criteria have previously been proposed (Hydro/ERG, 2017). In accordance with 10 CFR 40, Appendix A, Criterion 6(6), radium-226 (Ra-226) is a radionuclide for which a numeric soil release standard of 10.5 pCi/g (inclusive of an NRC-approved background value of 5.5 pCi/g) currently exists under an approved Decommissioning and Reclamation Plan (DRP) (AKG and Jenkins, 1993a and 1993b). Because the 1993 DRP was approved by NRC prior to June 11, 1999, a Radium Benchmark Dose (RBD) analysis to derive soil release criteria for radionuclides other than radium is not required for land areas contemplated in the approved 1993 DRP. However, the land application program was not considered in the 1993 DRP and because this program occurred after June 11, 1999, a RBD assessment has been performed (Attachment 1) to derive a radiological dose-based soil release criterion for uranium due to irrigation with respectively impacted groundwater in these areas.

Thorium-230 (Th-230), a common radionuclide in uranium mill tailings, is not included in the RBD assessment for land application areas (Attachment 1) as this radionuclide was not found in applied irrigation water at levels significantly different than background in local groundwater. The release criteria previously proposed for uranium and selenium in the 2017 Land Application Impact Assessment report are based on toxicological health considerations underlying soil screening levels (SSL) set by the New Mexico Environmental Department (NMED, 2017) and U.S. Environmental Protection Agency (USEPA, 2017). These criteria are adopted for this FSS Plan, and while not previously approved by NRC, HMC requests approval of the release criteria summarized in Table 1.

Table 1: Soil release criteria for land application areas.

Constituent of Potential Concern (COPC)	SSL-based Toxicity Criterion[1]	Modeled Radiological Criterion[2]	Numeric NRC Standard[3]	Background Value[4]	Soil Release Criterion[5]
Ra-226 (pCi/g)	-	-	5	5.5	**10.5**
U-nat (mg/kg)	16	192	-	N/A	**16**
Selenium (mg/kg)	5.17	-	-	N/A	**5.17**

[1]Based on Soil Screening Levels from USEPA (2017) or NMED (2017).

[2]Most restrictive value from Radium Benchmark Dose analysis (Attachment 1).

[3]From 10 CFR 40, Appendix A, Criterion 6(6).

[4]As established in Amendment 15 to License SUA-1471 (USNRC, 1993). Background is not applicable (N/A) for SSL-based criteria.

[5]Most restrictive value from potentially applicable soil release criteria.

Note that 10 CFR 40, Appendix A release criteria include spatial specifications that the average radionuclide concentration in surface soils (0-15 cm depth) across any 100 m^2 area must not exceed respective limits for release of surface soils. As demonstrated by previous monitoring data (Hydro/ERG, 2017), levels of uranium and selenium in soils due to the land application program are greatest at the soil surface, and if surface soils meet respective release criteria, subsurface soils are expected to meet these criteria as well. It is understood by HMC that the NRC will perform independent verification measurements and sampling in the land application areas prior to any decision on release of these areas from the license.

2.2 *Compliance Evaluation*

2.2.1 General Considerations

For radiological contamination, the NRC, EPA and other agencies have developed unified guidance for performing final status surveys to demonstrate compliance with release criteria in the Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM) (USNRC, 2001). Because the COPCs in Table 1 are not limited to radiological constituents, EPA guidance on use of SSLs as preliminary remediation goals (PRGs) based on toxicological health endpoints (USEPA, 1996) was reviewed. SSLs for uranium and selenium are based on a non-carcinogenic Hazard Quotient (HQ), and EPA guidance indicates that HQ effects should be considered additive only for COPCs with the same toxicity endpoint and/or mechanism of action (USEPA, 1996). Because toxicity effects differ for uranium and selenium, use of a sum-of-fractions calculation (a.k.a. "Unity Rule") as specified in Appendix A of 10 CFR 40 [Criterion 6(6)] for multiple COPCs is not appropriate for determination of compliance, and each COPC will be evaluated separately for compliance with the soil release criteria given in Table 1.

2.2.2 Compliance with Release Criterion for Ra-226

With respect to the NRC-approved release criterion for Ra-226 in surface soil (10.5 pCi/g), this standard is assumed applicable to any land area impacted by 11e.(2) byproduct material at the Site, and a FSS based on a modified MARSSIM approach will be performed in each land application area to demonstrate compliance. MARSSIM assumes that soil concentrations will be relatively uniform after remediation, and does not call for sampling individual 100-m^2 areas to evaluate compliance. Instead, larger "survey units" are evaluated based on discrete soil sampling and gamma surveys (with gamma/radionuclide correlations) to assess compliance with individual wide-area derived concentration guideline levels (termed "$DCGL_W$").

For the purposes of this FSS Plan, the release criteria (RC) values proposed in Table 1 are analogous to $DCGL_W$ criteria, and for Ra-226, a statistical non-parametric Sign test[1] will be performed to determine whether the median concentration in each "survey unit" (see Section 2.4) exceeds 10.5 pCi/g. If not, it will be concluded that the survey unit meets the Ra-226 criterion for release from the license for

[1] Because there is an NRC-approved background value for Ra-226 (5.5 pCi/g), a statistical Sign test for compliance with the total (gross) soil release criterion given in Table 1 is appropriate, and use of a background reference area and Wilcoxon Rank Sum (WRS) testing is not necessary.

unrestricted future use. Otherwise, the survey unit will be remediated as needed until compliance with this RC value is demonstrated.

With respect to small elevated areas (hotspots), MARSSIM specifies a different DCGL (termed "$DCGL_{EMC}$") based on area factors (AFs) (NRC, 2000), but in the case of the land application areas at the HMC Site, any identified hotspots will be remediated as needed such that average COPC concentrations across any corresponding 100 m^2 area will meet the soil release criteria specified in Table 1. If any single discrete sampling location has a Ra-226 concentrations that exceeds 10.5 pCi/g, a 5-point composite surface soil sample (0-15 cm) will be collected from a 100 m^2 area, with the original discrete sample location situated at the center of the 100 m^2 area. The composite sample will be analyzed to determine whether the average concentration of Ra-226 across the 100 m^2 area is > 10.5 pCi/g. This protocol is analogous to an "elevated measurement comparison" (EMC) as described in MARSSIM, but is modified to accommodate the 100 m^2 spatial criterion specified in 10 CFR 40, Appendix A.

2.2.3 Compliance with Release Criteria for Uranium and Selenium

With respect to soil release criteria for uranium and selenium (Table 1), a non-parametric statistical Sign test is also appropriate to demonstrate that median concentrations in each survey unit do not exceed the soil release criteria given in Table 1. Appendix H of NUREG-1620 indicates that chemical toxicity should also be considered in deriving a soil release criterion for uranium, and based on this NRC guidance, it is assumed for the purposes of this FSS Plan that 10 CFR 40 spatial requirements (average across any 100 m^2 area) are appropriate for uranium and selenium.[2] For the purposes of this FSS Plan, the FSS soil sampling design and associated protocols to demonstrate compliance with the Ra-226 criterion as detailed in the previous Section will be adopted for each land application area to demonstrate compliance with Table 1 soil release criteria for uranium and selenium. This includes both wide-area evaluations as well as hotspot assessments.

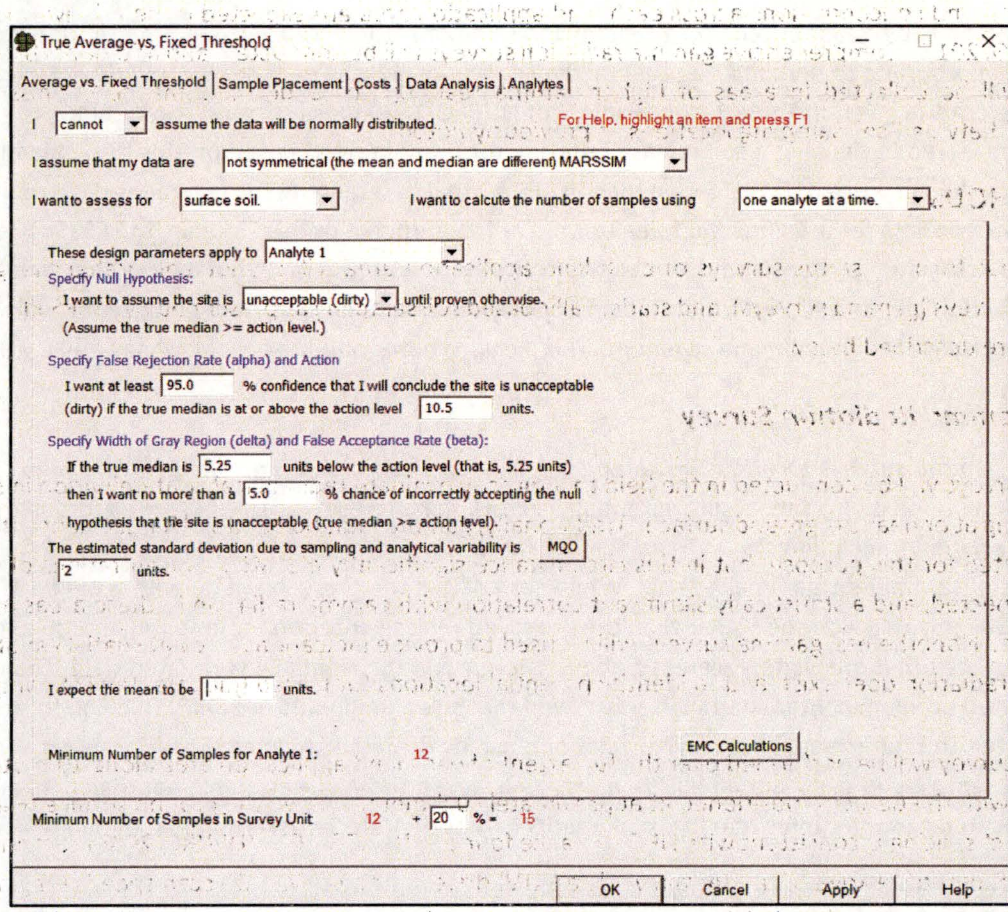
Regarding gamma surveys for areas between sampling locations, it is acknowledged that these surveys will not detect selenium, but could potentially detect elevated levels of short-lived uranium decay products (progeny), including Th-234 and Pa-234 (both have low-energy gamma emissions that could slightly increase ambient gamma levels). While scan MDCs for these progeny with a single 1-second gamma reading would likely be higher than the proposed release criterion for uranium, multiple readings in the same area that are slightly elevated above background (i.e. spatially correlated data) could result from elevated uranium contamination in soil. Given that selenium inputs are likely to be co-located with uranium (due to uniform application via irrigation), use of gamma survey data as a basis for additional biased soil sampling in each land application area is believed to be a reasonable approach. In addition, slightly elevated gamma survey readings could reflect areas of preferential accumulation of impacted fine

[2] Note that SSL-based cleanup goals are conceptually based on averages across all impacted areas to which a receptor may be exposed over time. A 100-m^2 spatial criterion is technically not appropriate for toxicity-based criteria, but it is conservative and consistent with NUREG-1620 guidance and ALARA principles to apply this spatial criterion to all COPCs considered in this FSS Plan.

soil particles due to erosional processes as smaller particle size fractions tend to have enhanced adsorption of contaminants due to larger specific surface area and higher cation exchange capacity (Whicker and Schultz, 1982).

2.3 Statistical Sampling Design

As described in MARSSIM, the applicable statistical parameter to be evaluated with a Sign test for compliance with release criteria (analogous to $DCGL_W$ values in MARSSIM) for individual radionuclides is the median measured soil concentration for each radionuclide. Determination of the number of samples needed depends on the expected variability in radionuclide concentrations after any remediation, along with specified limits on Type 1 and 2 decision errors and the lower bound on the grey region (NRC, 2000). Although variability in the COPCs appears to be relatively low (Hydro/ERG, 2017; HDR/USEPA, 2016), more conservative (higher) estimates of standard deviations for each COPC, based on experience with soil cleanup at other uranium recovery sites, were used to calculate the number of samples needed. Figure 2 shows the calculation of the number of samples required for Ra-226 as generated with Virtual Sample Plan software (VSP, 2016).


True Average vs. Fixed Threshold

Average vs. Fixed Threshold | Sample Placement | Costs | Data Analysis | Analytes

I cannot assume the data will be normally distributed. For Help, highlight an item and press F1

I assume that my data are not symmetrical (the mean and median are different) MARSSIM

I want to assess for surface soil. I want to calcute the number of samples using one analyte at a time.

These design parameters apply to Analyte 1

Specify Null Hypothesis:

I want to assume the site is unacceptable (dirty) until proven otherwise.

(Assume the true median >= action level.)

Specify False Rejection Rate (alpha) and Action

I want at least 95.0 % confidence that I will conclude the site is unacceptable (dirty) if the true median is at or above the action level 10.5 units.

Specify Width of Gray Region (delta) and False Acceptance Rate (beta):

If the true median is 5.25 units below the action level (that is, 5.25 units) then I want no more than a 5.0 % chance of incorrectly accepting the null hypothesis that the site is unacceptable (true median >= action level).

The estimated standard deviation due to sampling and analytical variability is MQO 2 units.

I expect the mean to be units.

Minimum Number of Samples for Analyte 1: 12 EMC Calculations

Minimum Number of Samples in Survey Unit 12 + 20 % = 15

OK Cancel Apply Help

Figure 2: MARSSIM-based calculation of the number of FSS samples to be collected in each survey unit (each land application area) based on a 1-sample Sign test.

Additional parameters used to determine the appropriate sample size included a lower bound on the gray region (LBGR) of 5.25 pCi/g (MARSSIM default value of 50% of the DCGL), and limits on Type I (α) and Type II (β) decision error rates set at 0.05 each. The MARSSIM-based calculation of minimum sample size in VSP results is 15 samples per survey unit (Figure 2). Similar results were obtained for uranium and selenium. Because of the large size of the survey units, this number will be increased to 20 samples per survey unit (per land application area), each of which will be analyzed for each COPC listed in Table 2 (see Section 3.2).

2.4 Survey Units and Classification

Based on previous soil monitoring results for the land application areas (Hydro/ERG, 2017) relative to the soil release criteria given in Table 1, each individual land application area will be categorized as a Class 3 survey unit. Under MARSSIM (USNRC, 2000), Class 3 survey units represent areas that may have been impacted, but concentrations of COPCs are expected to be present only at a small fraction of the release criteria. Each land application area will be considered as a single survey unit based on a distinct history with respect to the mechanism of impacts to soil. MARSSIM does not place limits on the size of Class 3 survey units, and concentrations across each land application area are expected to be relatively uniform (Hydro/ERG, 2017). Comprehensive gamma radiation surveys will be conducted, and additional biased soil samples will be collected in areas of higher gamma readings to reduce the chance of missing any "hotspots" between soil sampling locations as previously noted.

3. METHODS

The methods for final status surveys of each land application area will include comprehensive gamma radiation surveys (gamma surveys), and statistically-based soil sampling as prescribed by MARSSIM. These methods are described below.

3.1 Gamma Radiation Survey

Gamma surveys will be conducted in the field to indirectly evaluate radiological contamination in surface soils residing at or near the ground surface. Traditionally, gamma radiation and soil Ra-226 concentrations are correlated for this purpose, but in this circumstance significantly elevated concentrations of Ra-226 are not expected, and a statistically significant correlation with gamma radiation in these areas may not be possible. Nonetheless, gamma surveys will be used to provide indications of what spatial variability in terrestrial radiation does exist, and to identify potential locations for biased (judgmental) FSS sampling.

A gamma survey will be performed over the full extent of each land application area along 10-meter scan transects, with the detector positioned at approximately 0.5 meters above the ground surface (Figure 2). This transect spacing is consistent with NRC guidance found in NUREG-1620 (USNRC, 2003). Scanning will involve GPS-based walkover or all-terrain vehicle (ATV) drive-over surveys with scan speeds ranging from about 0.5 to 1.5 meters/second (typical walking speeds) depending on terrain. Instrumentation will include a Ludlum 44-10 sodium iodide (NaI) detector coupled to a Ludlum 2221 ratemeter/scaler, or similar. Simultaneous gamma/GPS readings will be recorded on a 1-second data output schedule.

Prospective (a priori) estimates of the minimum detectable concentration of Ra-226 in soil while scanning, referred to in MARSSIM as the "scan MDC" (USNRC, 2000), were calculated based on the above specifications on scan speed and detector height, along with an assumed background count rate of 15,000 counts per minute (cpm).[3] A resulting graph of scan MDC versus size (diameter) of area of contaminated soil (referred to as a "hot spot") is shown in Figure 3.

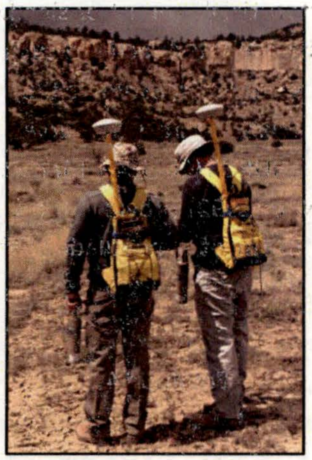


Figure 2: Example gamma survey systems for walkover scanning.

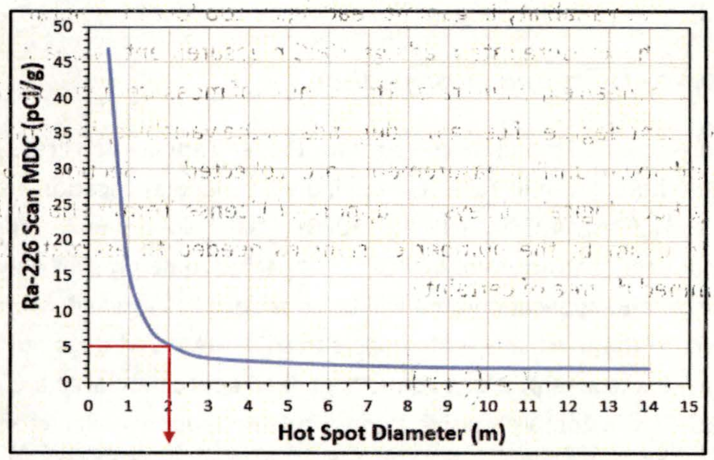


Figure 3: Scan MDC versus hotspot diameter for the gamma survey method.

The soil release criterion specified in 10 CFR 40, Appendix A for Ra-226 in surface soil (0 to 15 cm depth) is 5 pCi/g Ra-226 above background, averaged across any 100-m^2 area. Calculated scan MDCs for the walkover survey (Figure 3) show that a single 1-second count rate reading with this method will be able to detect Ra-226 concentrations in surface soil at the release criterion (5 pCi/g) for hotspots as small as about 2 meters in diameter (representing a contaminated area of about 4 m^2). The gamma scanning method specified in this FSS Plan has sufficient sensitivity to meet applicable survey objectives as defined herein.

Comprehensive gamma survey maps will be produced for each survey unit (land application area) and evaluated for any areas of elevated terrestrial gamma radiation. Additional biased samples will be collected in such locations, but the number will depend on the magnitude of differences in gamma readings relative to apparent background levels in the area.

In addition to gamma count rate surveys as specified above, exposure rate measurements are indicated as a final step in the decommissioning process under 10 CFR 40.42. Considered the most accurate instrument available for measurement of external exposure rate in a radiation field comprised of both cosmic and terrestrial sources (Whicker and Chambers, 2015), high-pressure ionization chamber (HPIC)

[3] Scan MDCs were calculated based on a recently published method (Alecksen and Whicker, 2016) and online calculator (ERG, 2017) designed specifically for electronically recorded, GPS based gamma surveys, along with conservatively estimated Site-specific background gamma readings.

will be used to estimate the average exposure rate at 1 meter above the ground surface in each survey unit. Ideally this value will be estimated based on cross-calibration of gamma scanning detectors against the HPIC at 10 or more locations representative of the range of gamma readings observed across all land application areas, followed by conversion of all scan data to units of exposure rate and calculation of the mean value for each survey unit.

In the event that variability in gamma readings is too low to generate a statistically robust or significant correlation with exposure rate readings, HPIC measurements alone may be used to directly calculate an estimate of the mean exposure rate. The number of measurement locations needed to estimate the mean with a significant degree of certainty depends on the variability in gamma radiation across the survey unit, which is unknown until measurements are collected. Section 8.6 of NUREG/CR-5849 Manual for Conducting Radiological Surveys in Support of License Termination (USNRC, 1992) provides the below equation to estimate the number of samples needed to estimate the mean of a population with a pre-determined degree of certainty.

$$N > \left(\frac{t}{r}cv\right)^2 \qquad \text{Equation 4}$$

Where:
N = sample number
cv = coefficient of variation (standard deviation divided by mean)
t = t-statistic for chosen confidence level
r = relative fraction error estimate of the mean

Figure 2 shows the plot of Equation 4 for a relative fraction error (r) of 10% and 20% and a confidence level of 95% (t = 1.645) for various coefficient of variation (CV) values. Figure 4 demonstrates that as the CV increases, the number of samples needed to achieve a given relative fraction error of the true mean increases rapidly. Assuming a true CV between 20 and 30 percent, which is reasonably consistent with CV values observed for the COPCs in Table 1 across the land application areas (Hydro/ERG, 2017), it seems reasonable that 10 measurements of exposure rate collected across each background area is adequate to estimate the mean exposure rate to within 10 to 20 percent (e.g. within ± 1-2 µR/hr in a 10 µR/hr gamma field).

Based on this assessment, if the alternative approach of direct HPIC measurements is used to estimate the mean exposure rate, a randomized triangular grid for 10 HPIC measurements will be generated with VSP, and the HPIC measurements will be taken across each land application area survey unit. These data will be included in the FSS Report along with calculated mean exposure rate values for each survey unit. Note that there are no release criteria associated with this FSS parameter, it is simply a regulatory requirement to document the final external exposure rates for removal of these areas from regulatory control under license SUA-1471 and release for unrestricted future use.

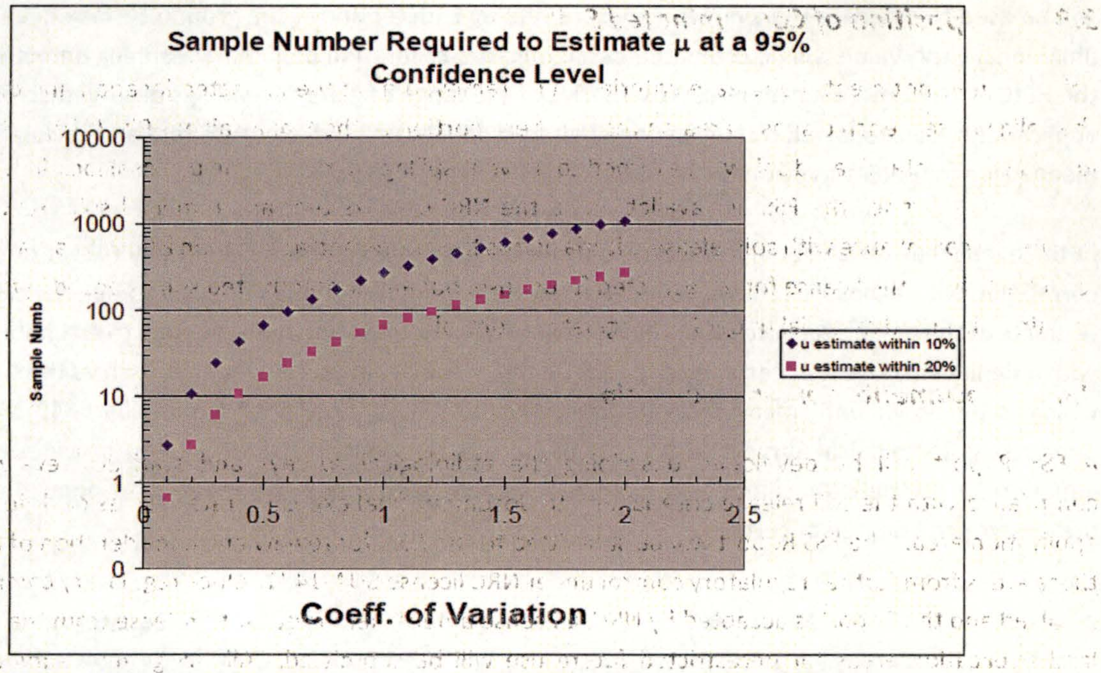


Figure 4: Number of samples required to estimate the mean at a 95% confidence level.

3.2 Soil Sampling

Soil samples will be collected with a manual auger-type barrel sampler, shovel, hand trowel or similarly appropriate sampling equipment. Sampling tools will be cleaned between each sample collection to prevent cross-contamination of samples. Twenty samples of surface soil (0-15 cm) will be collected across each survey unit on a randomized triangular grid using VSP (VSP, 2016) to plot the sampling locations. Subsurface soil samples will not be collected as it is expected that any areas that exceed the release criteria given in Table 1 will be excavated until these criteria are met. In the event of an exceedance, a 5-point composite sample from a 100 m^2 area centered on the original sample location will be collected to determine whether average concentrations exceed any of the release criteria. If not, compliance with Table 1 release criteria will be concluded for the location, otherwise, the area will be excavated to the depth necessary to attain compliance. All soil samples will be analyzed for the radionuclides shown in Table 2 by Energy Laboratories, Inc. (Casper, WY), an accredited National Environmental Laboratory Accreditation Council (NELAC) laboratory.

Table 2: Analysis parameters, methods and LLD values.

Radionuclide	Method	LLD (pCi/g)
U-nat	EPA 200.8/6020	0.3 mg/kg
Selenium	EPA 200.8/6020	0.3 mg/kg
Ra-226	EPA 901.1 (M)	0.2

3.3 Disposition of Contaminated Soil

Soil that does not meet the release criteria will be removed from the impacted location and disposed at the solid waste trench disposal area on the southern portion of the Small Tailings Pile (STP). Haul trucks loaded with contaminated soil will be tarped to prevent spillage in rout to the disposal location. Once the analytical results for the FSS are available and the NRC concurs that any remedial soil excavation has resulted in compliance with soil release criteria across the entire land application area, the area will qualify for release from the license for unrestricted future use, but any contaminated soil disposed in the STP will remain as licensed material under NRC regulatory control.

3.4 Documentation and Reporting

A FSS Report will be developed describing the radiological surveys and statistical evaluations of compliance with the soil release criteria, and to document final exposure rates across each former land application area. The FSS Report will be submitted to the NRC for review and consideration of release of these areas from further regulatory control under NRC license SUA-1471. Once regulatory comments are resolved and the Report is accepted by NRC, a license amendment request to release from the license all land application areas for unrestricted future use will be submitted. All FSS gamma survey and soil sampling data will be retained until the radioactive materials license with the NRC is terminated.

4. Quality Assurance / Quality Control

All gamma surveys, soil sampling, and laboratory measurements used to guide any remedial excavations and to conduct final status surveys will subject to the data QA/QC protocols as described in this Section. The purpose of these protocols is to ensure that the analytical data to be generated will be of sufficient quality to reliably support correct decisions regarding compliance with the soil release criteria given in Table 1 of this FSS Plan. To meet this objective, analytical uncertainties introduced by variability in instruments, laboratory methods, and survey techniques will be minimized and qualitatively and quantitatively assessed in terms of data accuracy and precision.

In general, quality assurance (QA) includes qualitative aspects of the FSS Plan necessary to ensure an appropriate analytical design and proper implementation of planned methods and procedures. Quality control (QC) includes quantitative measures to monitor analytical method performance and to allow respective estimation of data uncertainty (accuracy and precision). A generalized summary of QA/QC protocols/requirements is as follows:

Program QA Summary:

- All gamma surveys, soil sampling, and supporting measurements used for the FSS will be subject to the data QA/QC protocols outlined in this Section.
- Applicable SOPs listed in Table 3 (Section 4.1) and as provided in Attachment 2 will be followed for all gamma surveys and soil sampling.

- Radiological survey objectives for soil decommissioning were used as the basis for the analytical approaches developed in this FSS Plan in order to produce data of the type, quantity and quality necessary to reliably support correct decisions regarding compliance with soil release criteria and release of these areas from the license for unrestricted future use.
- The radioanalytical approaches and methods to be used are consistent with relevant regulatory guidance (e.g. MARSSIM, NUREG-1620).
- Detailed field notes will be kept in field logbooks to document daily activities and any relevant observations regarding environmental conditions or equipment-related performance that could affect data quality.
- The proposed offsite laboratory is fully qualified and appropriately accredited for analysis of the COPCs specified in Table 1.
- Standard chain-of-custody protocols will be followed for sampling shipping and offsite laboratory analyses.

Project QC Summary:

- Calibration of gamma detectors will be performed within one year prior to use for the FSS. Calibration certificates will be kept on file and included in appendices to applicable portions of the FSS report.
- Daily QC measurements will be performed as specified in the applicable Standard Operating Procedures (Section 4.1 and Attachment 2) for all field survey instruments to ensure proper instrument performance. This data will be evaluated in terms of measurement precision and data reproducibility.
- The commercial laboratory used for analysis of soil/sediment samples will perform routine QC measurements for each batch of sample results (e.g. duplicate sample analyses, sample spikes, method blanks, etc.) in order to provide quantitative indications of accuracy and precision. All data will be qualitatively and quantitatively reviewed by an experienced health physicist and evaluated in terms of data quality with respect to FSS objectives.

4.1 Standard Operating Procedures

All FSS elements will be conducted in accordance with applicable Standard Operating Procedures (SOP) provided in Attachment 2. A summary listing of SOP titles is provided in Table 4.

Table 3: Standard Operating Procedure (SOP) numbers and titles for implementation of this FSS Plan.

SOP ITC.101	Calibration of a Radiological Survey Meter
SOP ITC.102(R1)	Calibration of a Radiological Survey Detector
SOP ITC.201	Operational Checkout of Single-Channel Detector with Meter
SOP PWT.105	Performing a GPS-Based Gamma Radiation Survey
SOP PWT.106	Making Exposure Rate Measurements Using a High Pressure Ionization Chamber (HPIC)
SOP PWT.108	Soil Sampling for Analytical Purposes

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ATTACHMENT 1 (Radium Benchmark Dose Analysis)

A1.1 Introduction

Homestake Mining Company of California (HMC) is the Licensee on Radioactive Materials License SUA-1471 with the U.S. Nuclear Regulatory Commission (NRC). This former uranium milling facility is located about 5 miles north of the town of Milan, New Mexico in Cibola County (Site). The facility is now known as the HMC Grants Reclamation Project (Site) based on ongoing efforts to restore groundwater to meet regulatory standards, along with remaining areas of soil contamination. Most areas of the Site have been successfully remediated to meet NRC-approved soil standards for release of land areas from the license for unrestricted future use (ERG, 1995). In accordance with 10 CFR 40, Appendix A, Criterion 6(6), the applicable standards for radium-226 (Ra-226) are as follows:

- Surface Soil (0-15 cm) = 5 pCi/g above background, averaged over any 100 m^2 area.
- Subsurface Soil (any 15-cm increment below the top 15 cm) = 15 pCi/g above background, averaged over any 100 m^2 area.

These standards are commonly referred to as the "5/15 rule", and are the only soil standards currently approved by NRC for the Site. The 5/15 rule is applicable to all land areas contemplated in the approved 1993 Decommissioning and Reclamation Plan (AKG and Jenkins, 1993a and 1993b), as well as any other areas impacted by 11e.(2) byproduct material. The NRC-approved Ra-226 background soil concentration for the Site is 5.5 pCi/g as incorporated in the release criteria given in Amendment No. 15 of License SUA-1471 in 1993 (USNRC, 1993). Based on the established background concentration of Ra-226 in soil and Criterion 6(6) specifications as noted above, the effective (gross) soil release standards for Ra-226 at the Site are 10.5 pCi/g in the upper 15 cm of the soil profile and 20.5 pCi/g below the top 15 cm of the soil profile.

With respect to radionuclides other than Ra-226, on April 12, 1999, the NRC issued a Final Rule (64 FR 17506) requiring use of the existing soil radium standard (the 5/15 rule) to derive a dose-based criterion for the release of soils containing residual byproduct radionuclides other than radium. This amendment to Criterion 6(6) of 10 CFR 40, Appendix A became effective on June 11, 1999. Because the currently approved DRP was accepted by NRC prior to June 11, 1999, derivation of release criteria for radionuclides other than radium based on a "Radium Benchmark Dose" (RBD) analysis to is not required for licensed activities and associated lands contemplated in the approved 1993 DRP. For areas irrigated with impacted groundwater during the 2002-2012 Land Application Program, the RBD assessment provided in this Attachment is applicable to uranium as these areas were irrigated with respectively impacted groundwater, and this remedial activity was not contemplated in the approved 1993 DRP. A detailed description of the land application program is provided in the Land Application Assessment Report submitted to the NRC on September 25, 2017 (Hydro/ERG, 2017).

The RBD approach specified in Criterion 6(6) requires NRC licensees to model the site-specific dose from the existing soil radium standard (the 5/15 rule) and to use this RBD to determine the maximum concentrations of other radionuclides in soil that would result in the same dose to the average member

of the critical group. This Attachment documents the modeling and assumptions used to derive a dose-based soil standard for natural uranium (U-nat) using the RBD Approach. Mill-related radionuclides other than U-nat are not expected to be present in significant concentrations above background in the Land Application areas, and corresponding dose-based standards are not developed herein.[4]

A1.2 Radium Benchmark Dose Modeling

The RBD for the HMC Grants Site was modeled based on NRC regulatory guidance found in Appendix H of NUREG-1620 (USNRC, 2003). Modeling software and assumptions are described below.

A1.2.1 Receptor Scenario Selection

A number of potential land uses and corresponding receptor scenarios were considered for RBD modeling. These included ranching, mining, home-based business, light industry and resident farmer scenarios as described in Appendix H of NUREG-1620 (USNRC, 2003). A rural residential scenario with limited agricultural production was selected as the most plausible land use within the foreseeable future (within 200 years) as this is consistent with current/historic land uses in this part of Cibola County, New Mexico.

A1.2.2 Modeling Code and Parameter Selections

The RBD for the Site was modeled using the RESRAD computer code, Version 7.2 (ANL, 2016). The dose pathways included for the rural resident scenario included external gamma, inhalation, and ingestion of meat, plants and well water, along with incidental ingestion of soil particles. The radon pathway was excluded per 10 CFR 40, Appendix A specifications. The milk and aquatic foods pathways were excluded per guidance found in Appendix H of NUREG-1620 (USNRC, 2003).

The assumed zone of contaminated soil was set at the RESRAD default (10,000 m^2 or approximately 2.5 acres), which is reasonably consistent with the typical size of rural residential lots in local community developments. The contaminated zone was assumed to contain residual byproduct Ra-226 in surface soil (0-15 cm) at a concentration of 5 pCi/g. For subsurface soil (15-30 cm), a Ra-226 concentration of 15 pCi/g was assumed, covered by 15-cm of clean soil (i.e. the RBD attributable to surface and subsurface soil contamination was modeled separately). Per NUREG-1620 guidance (USNRC, 2003), Pb-210 was assumed to be in equilibrium with Ra-226 levels in soil.

The hypothetical receptor (rural resident) was assumed to be present outdoors in the contaminated zone 25% of the time and indoors 50% of the time (RESRAD default occupancy factors). Precipitation was set at 0.27 meters per year. It was further assumed that only 10% of livestock feed for meat consumption is grown in the contaminated zone (supplemental feed is necessary due to small lot size and dry climate), and that 10% of ingested plant foods are grown in a garden within the contaminated zone. Irrigation

[4] Thorium-230 (Th-230), a common radionuclide in uranium mill tailings, is not included in the RBD assessment for land application areas as this radionuclide was not found in applied irrigation water at levels significantly different than background in local groundwater.

within the contaminated zone was set at 0.72 m/yr based on average irrigation water applied during the land application program, and livestock are watered entirely from an onsite groundwater well. All other modeling parameters were assumed equivalent to RESRAD default values.

A1.2.3 RBD Modeling Results

Radium Benchmark Dose modeling results indicate that a rural resident at the Site would receive a maximum TEDE of 30 mrem/yr due to Ra-226 and Pb-210 concentrations of 5 pCi/g each residing in the top 15 cm of the soil profile (Figure A1-1). The maximum dose rate (the RBD) is received at t = 0 years, the majority of which (27.2 mrem/yr) is due to external gamma radiation from Ra-226 in soil with smaller internal dose contributions from plant ingestion (1.8 mrem/yr) and soil ingestion (1.2 mrem/yr) (Figure A1-2). Other dose pathways are negligible.

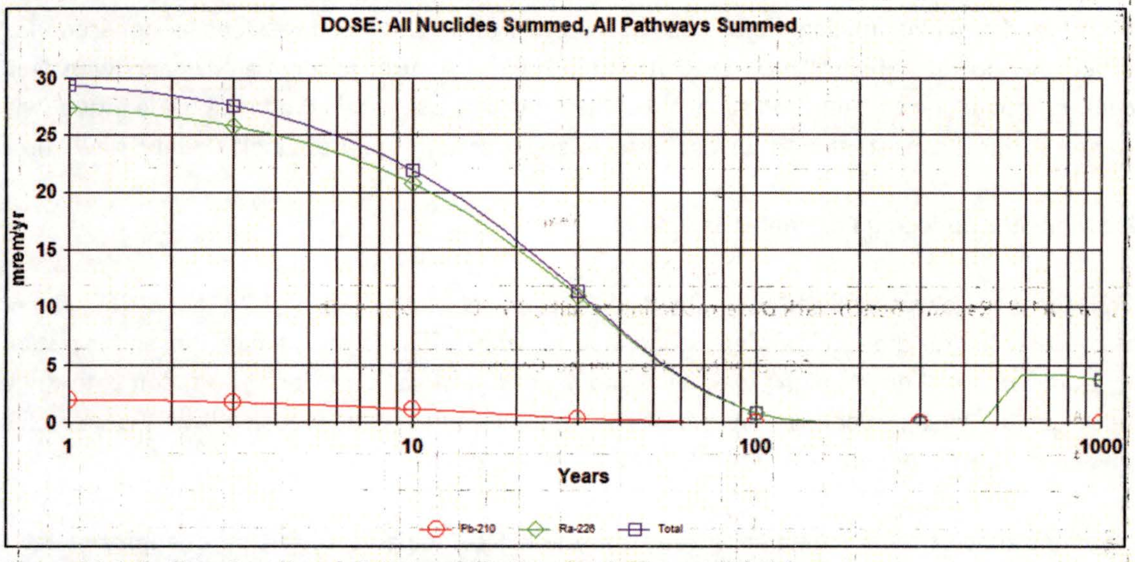

Figure A1-1: Radium Benchmark Dose modeling results, 0-15 cm soil depth.

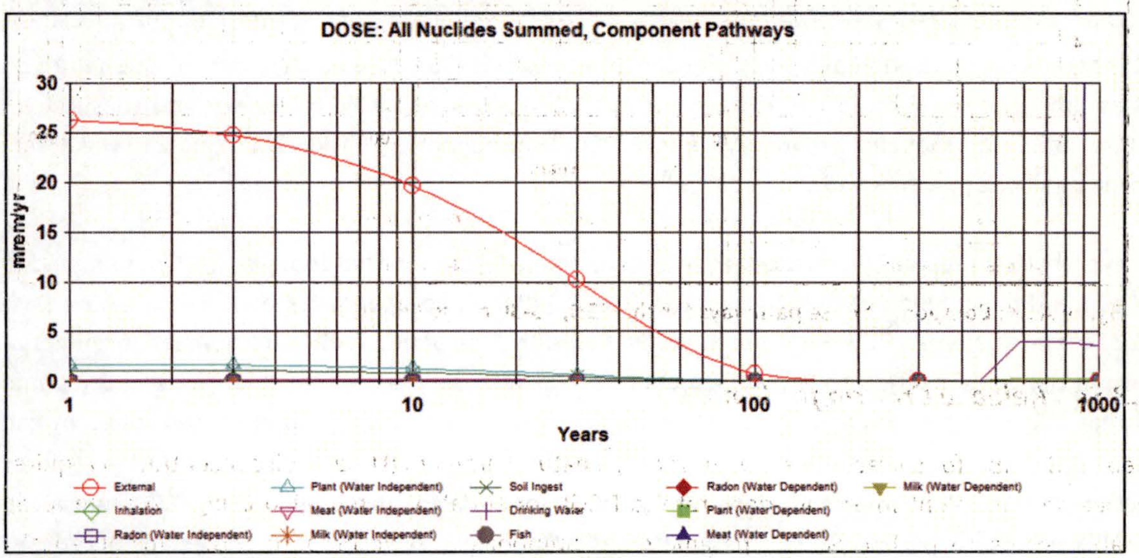

Figure A1-2: Component dose pathways for the RBD, 0-15 cm soil depth.

With respect to subsurface soils, RBD modeling results indicate that a rural resident at the Site would receive a maximum TEDE of 18.4 mrem/yr due to Ra-226 and Pb-210 concentrations of 15 pCi/g each residing in the 15-30 cm layer of the soil profile (Figure A1-3). The maximum dose rate (the RBD) is received at t = 0 years, with external gamma radiation responsible for 12.9 mrem/yr, plant ingestion responsible for 5.4 mrem/yr, and negligible doses expected from other pathways (Figure A1-4).

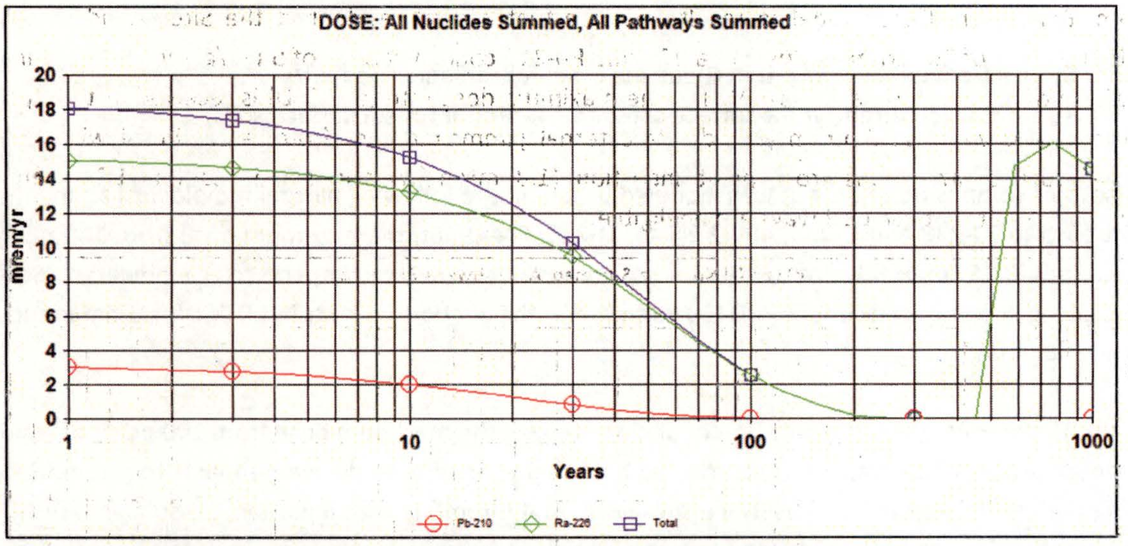

Figure A1-3: Radium Benchmark Dose modeling results, 15-30 cm soil depth.

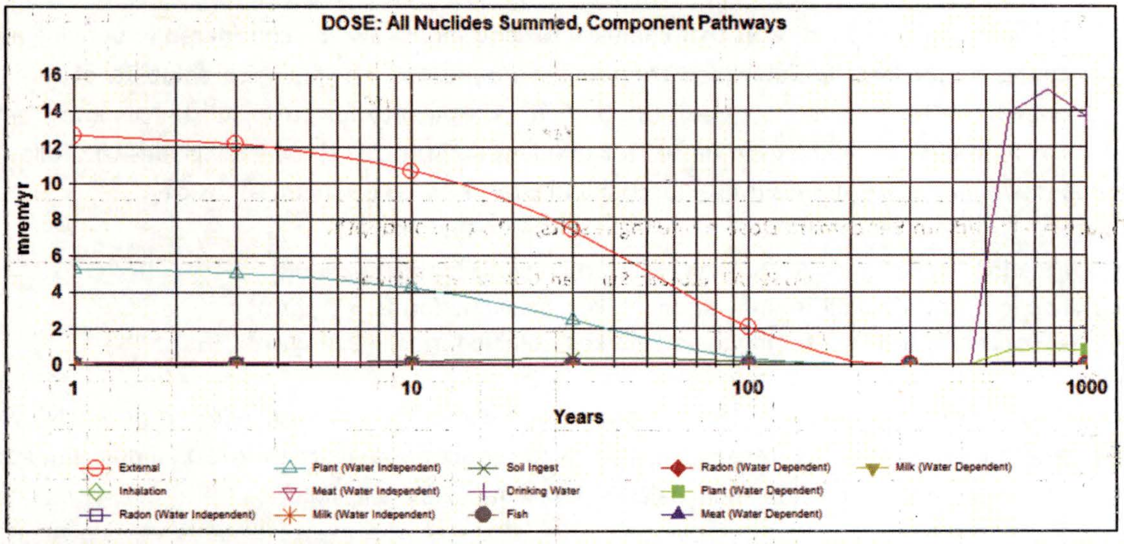

Figure A1-4: Component dose pathways for the RBD, 15-30 cm soil depth.

A1.3 Soil Release Criteria for U-nat

Based on the RBD for surface soils (30 mrem/yr), a natural uranium (U-nat) soil concentration required to produce an equivalent maximum dose rate (a DCGL for U-nat) was modeled using the same receptor scenario, exposure pathways, and parameter assumptions. To accomplish this, a hypothetical and

mathematically convenient soil concentration of 100 pCi/g was modeled for use in a scaling equation (Equation 1) to determine the DCGL for U-nat at the RBD. Equation 1 is provided as follows:

$$\frac{DCGL}{RBD} = \frac{\text{Radionuclide Conc. of 100 pCi/g}}{\text{Max Dose from 100 pCi/g}} \qquad \text{Equation 1}$$

Where:

DCGL = Derived Concentration Guideline Level for radionuclide (pCi/g)

RBD = RBD (30 mrem/yr for surface soils, 18.4 mrem/yr for subsurface soils)

The isotopic composition of U-nat was modeled based on the following natural radiological abundances: 48.9% each for U-238 and U-234, and 2.2% for U-235. For U-nat, the maximum dose from 100 pCi/g in surface soils (0-15 cm) is 8.1 mrem/yr (at t = 1,000 years due to delayed impacts to groundwater). Scaling this result against the surface soils RBD (30 mrem/yr) with Equation 1 results in a DCGL for U-nat in surface soils of 370 pCi/g.

For subsurface soils (15-30 cm with 15 cm of clean cover), the maximum dose from 100 pCi/g of residual byproduct U-nat is 9.6 mrem/yr (occurring at t = 1,000 years due to delayed impacts to groundwater). Scaling this result against the subsurface soils RBD (18.4 mrem/yr) with Equation 1 results in a DCGL for U-nat in subsurface soils of 192 pCi/g.

Appendix H of NUREG-1620 indicates that chemical toxicity should also be considered in deriving a soil uranium concentration limit if soluble forms of uranium are present. The biological solubility of potential residual uranium at the Site has not been established. The Agency for Toxic Substances and Disease Registry has published a toxicological profile for uranium (ATSDR, 2013), which includes the following recommended Minimal Risk Levels (MRC) for uranium intakes based on chemical toxicity:

- Ingestion intake limit = 51.2 mg/yr (based on toxicity for a 70 kg adult)
- Air concentration limit for inhalation intakes (insoluble forms) = 8 μg/m^3
- Air concentration limit for inhalation intakes (soluble forms) = 0.4 μg/m^3

The calculated DCGLs for U-nat in surface soil and subsurface soil (370 and 192 pCi/g respectively), were used to generate estimates of corresponding intakes to compare against these ATSDR limits. Equations for calculation of relevant ingestion and inhalation intake metrics are as follows:

$$Ingestion\ (^{mg}/_{yr}) = \left(SC\frac{pCi}{g}\right)\left(\frac{^{mg}/_{kg}}{0.677\,^{pCi}/_{g}}\right)\left(0.001\,^{kg}/_{g}\right)\left(SIR\,^{g}/_{yr}\right)$$

$$Air\ Conc.\,(^{\mu g}/_{m^3}) = \left(SC\frac{pCi}{g}\right)\left(\frac{^{mg}/_{kg}}{0.677\,^{pCi}/_{g}}\right)\left(1000\,^{\mu g}/_{mg}\right)\left(0.001\,^{kg}/_{g}\right)\left(MLI\,^{g}/_{m^3}\right)$$

Where:

		Value used	Parameter Source
SC =	soil concentration	DCGL	Calculated
SIR =	soil ingestion rate	36.5 g/yr	(RESRAD default)
MLI =	mass loading for inhalation	0.0001 g/m^3	(RESRAD default)

These calculations assume that the concentration of uranium in ingested or inhaled soil particles is equivalent to that residing in bulk soil. Resulting uranium intake pathway estimates are shown in Table A1-1. These results indicate that chemical toxicity is not a limiting consideration with respect to the calculated DCGL for radiological dose from uranium in surface or subsurface soils. In other words, the radiological DCGLs as calculated above for uranium based on the RBD Approach are more conservative.

Table A1-1: Calculated uranium intake estimates based on DCGL values in comparison to corresponding ATSDR limits.

Intake Toxicity Parameter	Recommended Limit (ATSDR)	Potential Uranium DCGL (pCi/g)	
		370 (surface)	192 (subsurface)
Ingestion Intake (mg/yr)	51.2	19.9	10.4
Inhalation air conc. (µg/m^3)	8^a / 0.4^b	0.05	0.03

a) Limit for insoluble forms of uranium
b) Limit for soluble forms of uranium

The above toxicity assessment is Site-specific in that the DCGL values used in the calculations were derived from a Site-specific receptor/land use exposure scenario. Due to uncertainties inherent in dose modeling, it is reasonable to consider more conservative generic "Soil Screening Levels" (SSLs) from the U.S. Environmental Protection Agency (USEPA, 2017) and/or New Mexico Environment Department (NMED, 2017) as preliminary remediation goals (PRGs) based on toxicological health considerations. A uranium concentration of 16 mg/kg was proposed as soil release criterion for uranium in the 2017 Land Application Impact Assessment report (Hydro/ERG, 2017). This soil release criterion is adopted as a conservative and appropriate standard for U-nat in soil at the Site.

A1.4 Summary of Soil Release Criteria

The final soil decommissioning criteria derived based on the Radium Benchmark Dose Approach as required by 10 CFR 40, Appendix A, Criterion 6(6), and inclusive of NUREG-1620 specifications regarding uranium toxicity, are summarized in Table A1-2. These criteria represent the maximum above-background concentrations of residual 11.e(2) byproduct radionuclides in soil that will meet NRC criteria for release of land application areas for unrestricted future use.

Table A1-2: Final soil release criteria for the Grants Reclamation Project based on regulatory specifications given in 10 CFR 40, Appendix A.

Soil Decommissioning Criteria for Surface Soils (0-15 cm)					
Radionuclide	**RBD (mrem/yr)**	**Modeled DCGL**	**Numeric Standard**	**Background**	**Final Soil Release Criterion**
Ra-226 (pCi/g)	30	-	5a	5.5	**10.5**
U-nat (pCi/g) [d]	"	370	10.8 [b, c]	-	**10.8**
U-nat (mg/kg) [d]	"	547	16 [b, c]	-	**16**

Soil Decommissioning Criteria for Subsurface Soils (> 15 cm)					
Radionuclide	**RBD (mrem/yr)**	**Modeled DCGL**	**Numeric Standard**	**Background**	**Final Soil Release Criterion**
Ra-226 (pCi/g)	18.4	-	15 [a]	5.5	**20.5**
U-nat (pCi/g) [d]	"	192	10.8 [b, c]	-	**10.8**
U-nat (mg/kg) [d]	"	284	16 [b, c]	-	**16**

[a] Above the NRC-approved background Ra-226 soil concentration of 5.5 pCi/g.

[b] Inclusive of the background U-nat concentration in soil.

[c] Based on toxicological health considerations.

[d] 0.677 pCi/g per mg/kg assumed for activity/mass concentration conversions.

ATTACHMENT 2 (Standard Operating Procedures)