Assessment of Proposed Changes to Soil Cleanup Standards and Implications for the Cañon City Milling Facility and Surrounding Environs

Radioactive Materials License CO-369-01
Cañon City Milling Facility

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Table of Contents

Introduction.....1

Future Land Uses, Receptor Scenarios, and Previous Soil Cleanup Standards.....2

Constituents of Concern.....6

Comparison of Radiological Cleanup Standards for Uranium Mills and CERCLA Sites 9

Radiological Soil Cleanup Criteria Required to Meet CERCLA Standards.....12

Implications of Proposed Changes to Radiological Soil Cleanup Criteria.....17

Summary and Conclusions 20

References.....23

Cover Photo: Natural Pinyon-juniper woodlands and semidesert shrublands east of the Cañon City Milling Facility that could be at risk from proposed revisions to soil cleanup standards.

Introduction

On March 30, 2011, Cotter Corporation (N.S.L.) (Cotter) submitted a detailed Soil Remediation Plan for the Cañon City Milling Facility (CCMF) (Cotter, 2011) to the Radiation Management Unit of the Colorado Department of Public Health and the Environment (CDPHE or Department). The Department has since indicated (CDPHE, 2011a) that the Soil Remediation Plan must simultaneously address requirements of radioactive materials license (RML) termination as well as soil cleanup requirements associated with the Remedial Action Plan (RAP), the Consent Decree, and delisting of the site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Concerns have also been raised that the Soil Remediation Plan does not address non-radiological constituents.

More specifically, the Department has informed Cotter that soil cleanup criteria should be revised to meet CERCLA standards found in various OSWER Directives[1] from the EPA (CDPHE, 2011b and 2011c). These directives describe acceptable cleanup criteria in cases where uranium mill site decommissioning is subject to U.S. Nuclear Regulatory Commission (NRC) or Agreement State regulations and CERCLA actions. The Department believes that radiological soil cleanup criteria previously developed for the CCMF using the Criterion 6(6) radium benchmark dose approach should be revised to meet a dose rate standard of 15 mrem/yr and a lifetime cancer risk of less than 1×10^{-4} in accordance with these OSWER Directives.

Preliminary assessments of radiological soil cleanup criteria that could meet these dose and risk standards suggested the potential to require cleanup of vast amounts of un-impacted, background level soils, environmental degradation across much of Cotter property, negative environmental impacts to adjacent lands, increased risks to public health, and excessive cost requirements. To help better understand these issues and potentially to help address the concerns of CDPHE, the U.S. Environmental Protection Agency (EPA) and local citizens, this report provides a comprehensive assessment of the following:

1. Future land uses and receptor scenarios which are key parameters for the development of appropriate soil cleanup criteria, along with previously specified or applied soil cleanup criteria with respect to RML termination, the RAP, the Consent Decree, and site delisting from the National Priorities List (NPL) under CERCLA.
2. Past studies in which constituents of concern (COCs) were identified for the site.
3. Consistency of regulation with respect to radiological cleanup standards for uranium mills and CERCLA sites.
4. Radiological soil cleanup criteria expected to meet CERCLA standards, and implications of such criteria for human health and the environment.

[1] Technical guidance documents from the EPA's Office of Solid Waste and Emergency Response (OSWER).

Future Land Uses, Receptor Scenarios, and Previous Soil Cleanup Standards

The Consent Decree, a legally binding agreement between the State of Colorado and Cotter Corporation with respect to settlement of issues related to CERCLA actions at the CCMF and Lincoln Park, became effective in December of 1987. The RAP was incorporated into this agreement as Appendix A to the Consent Decree. The Consent Decree specifies the following:

> The parties agree and the court hereby finds that the regulations codified at 40 CFR Part 192 are legally applicable standards, requirements, criteria or limitations [*and*] as such are defined pursuant to Section 121, including, but not limited to, Section 121(d), of CERCLA. The activities to be conducted pursuant to the RAP are designed to attain, and if implemented as required by this Consent Decree are expected to attain, and Cotter shall comply with the standards, requirements, criteria and limitations codified at 40 CFR Part 192.

Soil cleanup criteria specified by the EPA in 40 CFR 192 are as follows:

> 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 pCi/g, averaged over the first 15 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 soil cleanup criteria, commonly referred to as the "5/15 rule," were developed by the EPA as directed by the Uranium Mill Tailings Radiation Control Act (UMTRCA). Specifically pertaining to uranium milling facilities, the 5/15 rule is also codified by the NRC in 10 CFR 40, Appendix A. In 1999, the NRC amended Appendix A with Criterion 6(6) in order to address radionuclides other than Ra-226. As an Agreement State with the NRC, the State of Colorado specifies identical standards for uranium mills [6 CCR 1007-1, Part 18, Appendix A, Criterion 6(6)]. The 5/15 rule and Criterion 6(6) are directly applicable to license termination at the CCMF, and completion of the RAP is a license condition.

Consistent with the Consent Decree, the RAP also specifies the 5/15 rule for cleanup of onsite soils as well as sediments in perennial stream channels, both onsite and offsite. In accordance with RAP requirements, background levels were established in a study of five nearby sub-basins selected based on similarity to the sub-basin in which the mill site is situated. Background soil/sediment study parameters included uranium, molybdenum, Ra-226, and thorium-230 (Th-230) concentrations. Background gamma radiation levels (which typically vary with soil Ra-226 concentration) were also measured at each soil/sediment sampling location.

With respect to non-radiological COCs for soils, only molybdenum is specified in the RAP. The RAP indicates that "target" parameters measured in the background sub-basin study are to be

used to evaluate soil remediation. If acceptable levels for these target parameters are achieved, other constituents that may be associated with the CCMF should also be reduced to acceptable levels. Furthermore, the RAP indicates that correlation techniques can potentially be used to limit soil analysis requirements to Ra-226 and molybdenum for assessment of acceptable remedial levels.

The above legal and regulatory framework indicates that soil cleanup criteria developed in the March 30, 2011 Soil Remediation Plan are consistent with the requirements for RML termination, the RAP, and the Consent Decree. Although molybdenum or other non-radiological parameters were not specifically addressed, the primary mechanisms responsible for contamination beyond historic milling facilities and the Old Ponds Area (OPA) include truck spillage, vehicle tracking, and erosional transport processes (wind and stormwater runoff). These transport mechanisms generally involve deposition of contaminated solid phase particulates on the soil surface and thus, contamination across the vast majority of impacted areas resides in the top 6-12 inches of the soil profile (Tetra Tech, 2008).

Consistent with the cleanup strategy defined in the RAP, the cleanup strategy outlined in the Soil Remediation Plan is based on expectations that excavation of soils containing elevated levels of Ra-226 will, in general, simultaneously address other radionuclides and non-radiological constituents. This expectation is supported by past cleanup experience at the CCMF and other uranium mills. Cotter agrees with CDPHE that further investigation of non-radiological constituents in the vicinity of the 1979 mill is warranted and has committed to this, though cleanup of a majority of radium contaminated soils is expected to precede such characterization. Further characterizing soils that are already known to require excavation and disposal is unnecessary.

The March 30, 2011 Soil Remediation Plan provides a formal assessment/rationale for assuming limited agricultural land uses at the site in the foreseeable future along with a corresponding receptor scenario. However, based on relevant information contained in the RAP and other historical documents, such land use may not be realistic to assume in all areas of the site.

The 2003 Environmental Assessment Report (MFG, 2003) indicated that the primary legal constraint on future land use surrounding the CCMF is zoning. MFG (2003) provided recent and specific information indicating that land on which the mill complex and tailings impoundments are situated (Section 16) is currently zoned as Industrial. The remainder of Cotter-owned land surrounding Section 16 is zoned as Agricultural-Forestry, which allows for livestock and wildlife grazing. Agricultural-Forestry zones are consistent with the receptor scenario assumed in the Soil Remediation Plan.

OSWER Directive 9355.7-04 (EPA, 1995) indicates that future land use assumptions should be determined based on input from local land use planning authorities and the public, and should be conducted early on in the CERCLA process. According to the Remedial Investigation (GeoTrans, 1986a), and later reiterated in the RAP, future land uses specified in the Cañon City Fringe Area Land Use Plan include residential development within Cañon City limits northwest of the Cotter site, and commercial and industrial development immediately west and northwest of the Cotter site. The land immediately north, east and south of the mill site will be open range used for pasture and grazing (GeoTrans, 1986a).

In the mid 1990's land uses were further and systematically evaluated in an initiative conducted jointly by the State, EPA, Cotter, and others known as the Total Quality Environmental Management (TQEM) Project (TQEM, 1995). Initial land use zone designations developed in the TQEM Project are described below and are mapped in Figure 1:

- **Zone A**: An **outer zone** acceptable for public use without restriction.
- **Zone C**: An **intermediate zone** moderately impacted in some areas but generally expected to be available for unrestricted release after any necessary remediation. These largely undisturbed areas serve as a controlled buffer zone surrounding the mill complex.
- **Zone L**: An **inner zone**, most of which has been disturbed by past site operations. Aside from the final tailings repository, most of this land can likely be reclaimed and available for commercial or industrial uses.
- **Zone R**: Final tailings repository.

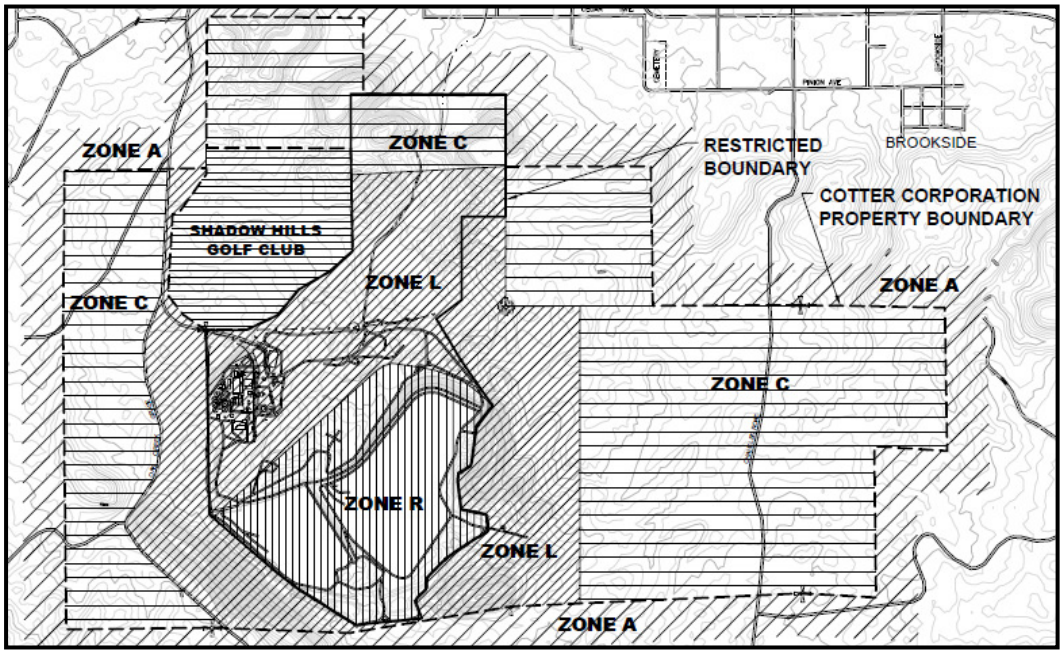

Figure 1: Initial land use zone map from the TQEM Project (reproduced from MFG, 2003).

The TQEM Project indicated that areas designated as "Zone C" could be released for unrestricted public use under a "Zone A" designation provided that these areas can be demonstrated to meet the soil Ra-226 cleanup criteria outlined in Table 1. Future land use in "Zone L" was considered limited to industrial or commercial uses and a workplace occupancy scenario, and less restrictive soil Ra-226 criteria were developed accordingly.

Table 1: Future land uses and corresponding soil Ra-226 cleanup criteria from the TQEM Project (Volume 2, Decommissioning Team Summary Report).

NO-FURTHER-ACTION IS NECESSARY FOR SOIL RADIOACTIVITY DISPERSED BY AIR OR WATER BASED ON THESE LEVELS:	Zone C: Currently controlled yet likely to be released for public use governed by local land use zoning as residential (home indoor occupancy anticipated)	Zone L: Interim licensee control; possible public use such as an industrial or commercial zone (workplace occupancy anticipated)
1. **Calculated total radium at 1000 years, *inclusive of* background**	*Observed Levels Do Not Exceed*:	*Observed Levels Do Not Exceed*:
1.1 **Average activity** concentration of *all* sampled 100 m^2 grids	**0.15 Bq/g (4.0 pCi/g)**	0.25 Bq/g (6.8 pCi/g)
1.2 **Maximum activity** concentration of *any* sampled 100 m^2 grid	**0.25 Bq/g (6.8 pCi/g)**	1.0 Bq/g (27 pCi/g)

These same soil cleanup criteria were reaffirmed in 1995 by the EPA, CDPHE, and Cotter as remedial action goals (RAGs) for Superfund remediation at the mill facility and Lincoln Park (EPA, 2002a). According to the 2002 Record of Decision (ROD) for Lincoln Park soils (EPA, 2002a), "RAGs consist of chemical concentrations that are protective and serve as specified numerical goals for cleanup actions." These RAGs were "… established to aid in the development of both a decommissioning plan and management/reclamation plan for the mill facility and Lincoln Park." The ROD goes on to state: "Both of these plans are to be implemented under Cotter's Canon City mill Radioactive Materials License." (EPA, 2002a). In 1999 the EPA and CDPHE developed qualitative Remedial Action Objectives (RAOs) which incorporated these quantitative RAGs for protection of human health and the environment (EPA, 2002a).

After several years of offsite soil cleanup efforts based on the above RAGs, the 2002 ROD for soils in the Lincoln Park Study Area (CERCLA Operable Unit 2) provided final determination that no further offsite soil cleanup action is required (EPA, 2002a). Offsite soil cleanup locations included the following:

- 4th Street railroad depot site (1992-1994; released to City for unrestricted use).
- Land adjacent to the golf course (1994; allowed golf course expansion to 18 holes).
- Team Track Railroad site (1993-1999; released for unrestricted use).
- Sand Creek (1993-1999; released for unrestricted use).
- NONAC mine site (1995-1999; released for unrestricted use).

The ROD clearly established that in terms of soil remediation, Operable Unit 2 (OU-2) satisfies the requirements for removal from the NPL under CERCLA, and other offsite locations are also considered successfully remediated to acceptable levels for unrestricted public use. It also established that an average soil Ra-226 concentration of 4 pCi/g (including background) was considered by the CDPHE and the EPA to be an appropriately protective standard for unrestricted public land uses on Cotter property ("Zone C" areas in Figure 1), and that an average concentration of 6.8 pCi/g (including background) is appropriate for future industrial or commercial uses on Cotter property ("Zone L" areas in Figure 1).

The ROD also indicates that additional Cotter property surrounding the mill site will serve as a buffer zone that will effectively prevent commercial or residential development from occurring close to Operable Unit 1 (OU-1). It is unclear whether the statement to this effect was intended to indicate a permanent future land use. Operable Unit 1 has not been clearly defined in historical documents, but is qualitatively assumed to approximate Cotter property designated as "Zone L" in Figure 1, an area slightly larger than the current restricted area at the CCMF. As previously indicated, Section 16 (a significant portion of OU-1) is currently zoned for industrial land use.

Constituents of Concern

The recent discovery of elevated levels of trichloroethylene (TCE) in groundwater near the mill complex has led to questions regarding the adequacy of identification and characterization of COCs in soils, particularly non-radiological COCs. There have been numerous studies regarding this issue. In the mid 1980's, a Remedial Investigation Feasibility Study (RI/FS) was conducted in accordance with the CERCLA process (GeoTrans, 1986a and 1986b). The Remedial Investigation (RI) examined a comprehensive array of radiological and non-radiological constituents in various environmental media sampled in impacted, or potentially impacted, areas in the vicinity of the site.

The RI focused particular attention on the chemical characteristics of suspected source term materials at the site (various ores, alternate feedstocks, tailings, tailings pond liquids, soils underlying the old tailings ponds). The report describes extensive listings of detected constituents, but a formal, quantitative analysis to define COCs according to EPA guidelines was

not provided. Nevertheless, the RI concluded that COCs for groundwater, surface water, and soils include uranium, Ra-226, molybdenum, cobalt, nickel, copper, arsenic, cadmium, lead and zinc.

Metals in this list were referred to in the RI as "Cotter specific metals," but assertions that zinc, lead, cadmium, and arsenic are specific to the CCMF are misleading. The New Jersey Zinc Company operated a large zinc smelter about one mile northwest of the CCMF from 1902 to 1968, and these same contaminates have been identified in soils surrounding the smelter site, including soils in the northwest portions of Cotter property (E&E, 1994; HRAP, 1991; Weston, 1996; Weston, 1998).

Also mentioned in the RI are major chemical reagents and organic compounds historically associated with ore processing including sulfuric acid, ammonia, ammonium sulfate, kerosene, tertiary amines, sodium and calcium salts, potassium permanganate, zinc sulfate, organic flocculants, polychlorinated biphenyls (pcb[2]) and TCE. With respect to the latter two compounds, pcb-contaminated materials were once processed resulting in some localized soil contamination. To dispose of these soils, TCE was used to extract pcb. The RI mentioned pcb and TCE as priority toxic pollutants.

Groundwater samples from a number of locations at the mill were analyzed for organic constituents in the RI, including alamine, kerosene, and various pcb's, none of which were detected (GeoTrans, 1986a; data appendices). In addition, the RI indicated that potential pcb and TCE contamination was investigated by the EPA and results were still under review (GeoTrans, 1986a). Cotter has no record of receiving the results of this investigation and has recently requested the 1986-era report from the EPA.

Several major human health risk assessments for the site were conducted in the 1990's (HRAP, 1991; Weston, 1996; Weston, 1998). Constituents of potential concern were thoroughly evaluated according to criteria consistent with EPA guidelines. A final list of constituents of potential concern for various environmental media was presented in the Phase III Human Health Assessment (Weston, 1998) and in the 2002 ROD for Lincoln Park soils (Table 2). Constituents excluded from potential concern are shown in Table 3. As previously mentioned, the RAP specified a subset of four key COCs (uranium, Th-230, Ra-226 and molybdenum), while in the ROD, the EPA focused on Ra-226 and Th-230 for evaluating the acceptability of soil remediation under CERCLA (EPA, 2002a). None of the reagents or organic compounds historically associated with processing as identified in the RI were included as constituents of potential concern in the above cited human health assessments or in the 2002 ROD (Table 2).

[2] In this paper "pcb" refers to the non-regulated substance. The non-regulated compound polychlorinated biphenyl "pcb" when used in the production of uranium is excluded from the definition of "chemical substance" (40 CFR 761.3), a necessary precursor to being designated the regulated substance "PCB", because of the byproduct material designation for uranium mill wastes under the Atomic Energy Act.

Table 2: Constituents of potential concern (Weston, 1996; EPA, 2002).

Ground water	Air	Soil	Food
Non-Radioactive Arsenic Mercury Molybdenum Nickel Lead Selenium Sulfate Uranium	Non-Radioactive Aluminum Arsenic Barium Chromium Cobalt Manganese Vanadium	Non-Radioactive Arsenic Beryllium Cadmium Manganese Selenium[a]	Non-Radioactive Arsenic Barium Cadmium Chromium Cobalt Lead Manganese Mercury Molybdenum Nickel Strontium Vanadium Uranium Zinc
Radioactive Lead-210 Polonium-210 Radium-226 Uranium-234 Uranium-238	Radioactive Lead-210 Polonium-210 Radium-226 Thorium-230 Uranium-234 Uranium-238 Radon-222	Radioactive Lead-210[a] Polonium-210[a] Radium-226 Thorium-230 Thorium-228[a] Uranium-234 Uranium-235 Uranium-238	Radioactive Uranium-234 Uranium-235 Uranium-238 Lead-210 Polonium-210 Radium-226 Thorium-228 Thorium-230

[a] This chemical was not measured in samples used in risk-based screen, but was measured (and detected) in samples from Lincoln Park. Therefore, the chemical was retained for evaluation in the detailed risk assessment.

Table 3: Constituents excluded from potential concern (Weston, 1996).

Basis for Exclusion	Ground water	Air	Soil	Food
Chemical was never detected	Aluminum Fluoride	Selenium	Antimony Tin	Arsenic Beryllium Cobalt Mercury Nickel Lead Silver
Chemical was detected but no toxicity factor is available		Strontium Titanium	Aluminum Titanium	
Chemical was detected, but is a beneficial mineral required for good health; estimated intakes from environmental media in Lincoln Park are within the beneficial range	Calcium Chloride Copper Iron Potassium Magnesium Sodium	Calcium Copper Iron Potassium Magnesium Sodium	Calcium Copper Iron Potassium Magnesium Sodium	Calcium Copper Iron Potassium Magnesium Sodium
Chemical was detected, but maximum concentration does not yield a significant risk (HQ < 0.1, cancer < 1E-06)	Cadmium Manganese Ammonium ion Nitrate Vanadium Zinc Thorium-230	Beryllium Cadmium Lead Molybdenum Nickel Silver Uranium Zinc	Barium Boron Chromium Cobalt Mercury Molybdenum Nickel Silver Strontium Uranium Vanadium Zinc	

EPA selection criteria for COCs include harmful levels of essential nutrients, exceedance of background, detection frequency, exceedance of Applicable or Relevant and Appropriate Requirements (ARARs), historical evidence, concentration, and toxicity (EPA, 1994). The key criteria for determination of constituents of potential concern in all three health risk assessments conducted in the 1990's involved screening of the maximum measured constituent levels in various environmental media from maximally impacted areas of the site, against EPA health risk criteria including a hazard quotient >1 (for non-cancer risks) and a lifetime cancer risk $>1x10^{-6}$ for the reasonable maximally exposed individual (HRAP, 1991; Weston, 1996; Weston, 1998).

Comparison of Radiological Cleanup Standards for Uranium Mills and CERCLA Sites

Protectiveness for carcinogens under CERCLA is generally determined based on a lifetime cancer risk range of 1×10^{-4} to 1×10^{-6} (EPA, 1997a). OSWER Directive 9200.4-18 (EPA, 1997a) describes the EPA's rationale for rejecting the NRC Decommissioning Rule for License Termination (a maximum allowable radiological dose rate of 25 mrem/yr) in favor of more stringent standards at radioactively contaminated CERCLA sites. The EPA has consistently concluded that a radiological dose rate standard of 15 mrem/yr is protective and achievable at such sites (EPA, 1997a).

A dose standard of 15 mrem/yr is approximately equivalent to a lifetime cancer risk of 3×10^{-4} (EPA, 1997a). The EPA has also concluded that "a risk level of 3×10^{-4} is essentially equivalent to the presumptively safe level of 1×10^{-4}" (EPA, 1997a). Thus, the EPA has determined that a dose rate of 15 mrem/yr or a lifetime cancer risk of 3×10^{-4} are the maximum radiological health metrics that can be considered protective at CERCLA sites.

With respect to uranium mills such as the CCMF, where the UMTRCA 5/15 rule is explicitly defined for soil cleanup under EPA, NRC, and State regulations, the EPA has further concluded that an above background soil Ra-226 concentration of 5 pCi/g residing in the top 15 cm of the soil profile is consistent with the minimally acceptable dose limit of 15 mrem/yr for a rural residential exposure scenario (excluding dose from radon) (EPA, 1997b). The EPA reached this conclusion based on generic RESRAD[3] dose modeling with a source term defined by the 5/15 rule. Key model parameter assumptions used in this EPA evaluation included:

- Contaminated zone area = 100 m^2 (per the 5/15 rule in 40 CFR 192).
- Contaminated zone thickness = 15 cm (per the 5/15 rule in 40 CFR 192).
- Contaminated zone soil Ra-226 conc. = 5 pCi/g (per the 5/15 rule in 40 CFR 192).
- Gamma shielding factor = 0.4 (versus a RESRAD default of 0.7).

[3] Radiological dose assessment computer code developed by Argonne National Laboratory for the U.S. Department of Energy, U.S. Nuclear Regulatory Commission, and other regulatory agencies.

Two additional key model parameters, not mentioned in the EPA's evaluation report, are indoor and outdoor exposure time fractions (occupancy factors). It is assumed that occupancy factors used in the EPA evaluation were reasonably consistent with RESRAD default values for a resident farmer exposure scenario (50% indoors, 25% outdoors). Value selections for each of the above noted parameters are crucial for assessing doses from Ra-226 in soil because the total dose (excluding radon) is largely due to external gamma radiation (Cotter, 2011; EPA, 1997b).

Using the above model parameter values along with RESRAD defaults for all others, Cotter was able to corroborate the EPA's generic evaluation results using RESRAD (version 6.5) and RESRAD-OFFSITE[4] (version 2.5). Resulting doses were 16 and 15 mrem/yr, respectively. The slight difference in modeled dose between the two computer code versions is likely due to slight variability in default parameters and greater modeling complexity in RESRAD-OFFSITE.

Although EPA results are supported by Cotter's independent generic RESRAD modeling, the EPA conclusion that 15 mrem/yr is consistent with the 5/15 rule is unrealistic. First, it assumes that the survey unit being evaluated (the contaminated zone) is limited to 100 m^2, all soils surrounding this survey unit are free of residual Ra-226, and that the residential farmer occupies an indoor dwelling, works outdoors, and derives sustenance entirely within this 10 m × 10 m plot of land. Secondly, as detailed below, site-specific dose modeling for a resident farmer at the CCMF under Ra-226 source term specifications equivalent to the 5/15 rule (and assuming no other source term) indicates that the total dose would be much less than 15 mrem/yr.

The effect of contaminated areas of various sizes versus dose was evaluated in the Soil Remediation Plan (Cotter, 2011). Using site-specific model parameters and realistic exposure pathways and site layout for a residential farmer, the total dose to a hypothetical receptor residing in a dwelling situated on top of a 100 m^2 area with a soil Ra-226 concentration of 5 pCi/g (in the top 15 cm) was only 2.75 mrem/yr (Figure 2). The primary reason that this result differs significantly from the EPA's generic analysis for the same 100 m^2 contaminated area is that the size of a realistic dwelling exceeds 100 m^2 and thus, no outdoor (unshielded) exposures are possible.

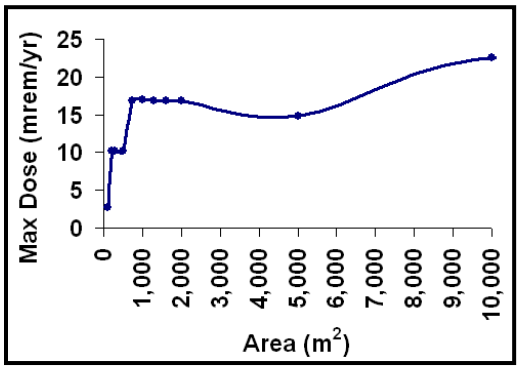

Figure 2: Relationship between contaminated area size and dose for Ra-226 in soil (adapted from Cotter, 2011).

For a 200 m^2 area at the site, the total dose to a resident farmer would increase to about 10

[4] Updated version of RESRAD that allows calculation of both onsite and offsite doses to receptors, with improved user interface tools, groundwater and air transport models, and sensitivity/uncertainty analysis utilities.

mrem/yr. If the contaminated zone were to exceed about 680 m^2, the dose would be expected to exceed 15 mrem/yr. The overall relationship between dose and size of contaminated area (Figure 2) is non-linear with several thresholds, asymptotically approaching a maximum of about 23 mrem/yr for areas greater than 10,000 m^2.

The preceding analysis indicates that if an average soil Ra-226 concentration of 5 pCi/g above background (to a depth of 15 cm) were left behind in a single 680 m^2 area at the CCMF, this remedial outcome would meet the EPA's minimally acceptable dose and risk standards for protectiveness under CERCLA. For a single 100 m^2 area, a soil Ra-226 concentration much greater than 5 pCi/g could be left behind and still meet CERCLA dose or risk standards for a resident farmer exposure scenario.

Based on site-specific dose/area factors (from Figure 2) and guidance found in MARSSIM[5], up to 40 pCi/g of Ra-226 could be left behind within a 100 m^2 "hot spot" at the CCMF and still meet MARSSIM requirements for demonstrating compliance with the radium benchmark dose. MARSSIM is a comprehensive technical manual developed by the NRC, EPA and DOE to provide a unified, multi-agency methodology for conducting site surveys and demonstrating compliance with cleanup criteria based on dose standards (NRC, 2000).

Radium-226 is not the only radionuclide of concern at the CCMF (uranium isotopes, Th-230, and possibly Th-232 are also present). For this reason, a Criterion 6(6) benchmark dose assessment is necessary to determine acceptable soil cleanup standards for radionuclides of concern other than Ra-226. The Department has raised concerns that the radium benchmark dose calculated in the Soil Remediation Plan (25.8 mrem/yr) is not protective because it exceeds EPA dose and risk standards for protectiveness at CERCLA sites.

The benchmark dose developed in the Soil Remediation Plan was based on a resident farmer living within a large, 310-acre area having a relatively uniform average Ra-226 concentration of 5 pCi/g above background (to a depth of 15 cm). Had the benchmark dose been developed based on a contaminated zone of 680 m^2, it would have met a 15 mrem/yr dose standard. However, a 680 m^2 survey unit size is not realistic in terms of resident farmer land use requirements, nor is it practical in terms of demonstrating compliance with cleanup standards.

Under MARSSIM protocols, use of a 680 m^2 survey unit size to evaluate compliance would require thousands of individual survey units, tens of thousands of soil samples, and many years to complete final status survey activities. Moreover, if two or more adjacent survey units just satisfied soil cleanup criteria for a 15 mrem/yr standard, actual dose would exceed 15 mrem/yr. This fact highlights a clear inconsistency between the EPA's 5/15 rule for uranium mill sites as codified in 40 CFR 92, and EPA radiological dose and risk standards under CERCLA.

[5] Multi-Agency Radiation Survey and Site Investigation Manual (NRC, 2000).

Radiological Soil Cleanup Criteria Required to Meet CERCLA Standards

Inconsistencies in EPA standards aside, the Department has indicated that radiological soil cleanup criteria developed in the Soil Remediation Plan in accordance with Criterion 6(6) benchmark dose assessment requirements (6 CCR 1007-1, Part 18, Appendix A) should be revised to meet a dose standard of 15 mrem/yr and a lifetime cancer risk of less than 1×10^{-4} in accordance with applicable OSWER Directives.

OSWER Directive 9200.4-35P (EPA, 2000), recommends a *reverse* application of the Criterion 6(6) methodology. In this Directive, a radium benchmark dose is set *a priori* at a level not to exceed 15 mrem/yr and the soil radionuclide concentration criteria that satisfy this benchmark dose are determined for each radionuclide of concern, followed by application of the unity rule (*see* MARSSIM) during cleanup to ensure that the dose from all radionuclides of concern combined will not exceed the radium benchmark dose.

Furthermore, OSWER No. 9200.4-18 indicates that at some sites, background levels may equal or exceed cleanup goals established for a site and for some ARARs, including the soil radium standard codified in 40 CFR 192, the ARAR is established as increments above background levels of risk (EPA, 1997a). In this situation, EPA states that the "general guidance cited above," which includes the dose rate standard of 15 mrem/yr and a cancer risk of less than 1×10^{-4}, should not be followed (see especially footnote 12 in referenced document).

A series of Criterion 6(6) dose assessments were performed for three potential future land uses and corresponding receptor exposure scenarios according to OSWER Directive 9200.4-35P recommendations. These exposure scenarios included a resident farmer, an urban resident, and an industrial worker. An *above background* radiological dose threshold of 15 mrem/yr (equivalent to an above background cancer risk threshold of 3×10^{-4}), and an *above background* cancer risk threshold of 1×10^{-4}, were each evaluated under each land use/exposure scenario to develop soil Ra-226 cleanup criteria required to meet these CERCLA dose and risk standards.

It was beyond the scope of this report to evaluate radionuclides other than Ra-226, but in general, soil cleanup criteria for Ra-226 are expected to be the most restrictive of all radionuclides based on relative benchmark dose and concentration criteria for Th-230 and uranium as detailed in the Soil Remediation Plan (Cotter, 2011). Moreover, evaluation of soil Ra-226 cleanup criteria that would be required to meet CERCLA dose and risk standards is sufficient to reveal problems associated with application of such criteria such as widespread environmental/ecological damage and a potential undermining of the fundamental goal of reducing overall risks to human health.

Radiological dose pathways and the most sensitive model parameter selections for the three exposure scenarios are shown in Table 4. Values for less sensitive model parameters were based

on site specific data or RESRAD defaults as previously used in the Soil Remediation Plan (Cotter, 2011). Modeling was performed with RESRAD-OFFSITE (version 2.5) using EPA approved dose and risk conversion factors from FGR 11[6] for doses from inhalation and ingestion, FGR 12[7] for external doses, and FGR 13[8] for cancer risk (slope) factors.

Table 4: Dose pathways and key model parameter selections for RESRAD dose/risk modeling.

DOSE PATHWAY / MODEL PARAMETER	PARAMETER SELECTIONS BY SCENARIO			RATIONALE / COMMENTS	SOURCE / REFERENCE
	Resident Farmer	Urban Resident	Industrial Worker		
Dose Pathway					
External Gamma	X	X	X	Appropriate for each scenario, both indoor and outdoor	RESRAD Version 6 User's Manual
Inhalation	X	X	X	Appropriate for each scenario, both indoor and outdoor	RESRAD Version 6 User's Manual
Plant Ingestion	X	X		Industrial worker not expected to derive any fraction of diet from onsite areas	RESRAD Version 6 User's Manual
Milk Ingestion	X			Urban resident / industrial worker not expected to consume any milk from onsite areas	RESRAD Version 6 User's Manual
Aquatic Foods				Unrealistic for onsite areas, all scenarios	RESRAD Version 6 User's Manual; lack of onsite surface waters
Drinking Water	X			All urban residents and industrial/commercial facilities are expected to use treated city water	RESRAD Version 6 User's Manual and based on current regional practices
Soil Ingestion	X	X	X	Appropriate for each scenario, both indoor and outdoor	RESRAD Version 6 User's Manual
Radon				Excluded based on regulatory definitions	40 CFR 192; OSWER No. 9200.4-18
Occupancy Factors					
Fraction onsite indoor occupancy	0.5	0.5	0.17	Per guidance provided in cited source/reference	RESRAD Version 6 User's Manual
Fraction onsite outdoor occupancy	0.25	0.25	0.06	Per guidance provided in cited source/reference	RESRAD Version 6 User's Manual
Fraction per agricultural area	0.05	N/A	N/A	4 agricultural areas, included in "onsite outdoor occupancy" with remaining 0.05 fraction spent in other onsite areas	RESRAD-OFFSITE Version 2.5 User's Manual
Gamma Shielding					
Gamma penetration factor	0.45	0.45	0.45	Mean of 0.3 - 0.6 range cited in NUREG-1620	Appendix H, NUREG-1620
Contamination Zone					
Area (acres)	310	310	310	Includes OPA, current mill building areas, parts of the surrounding areas	OPA Gamma Survey and Soil Volume Reports (Tetra Tech)
Thickness (m)	0.15	0.15	0.15	Defined by regulatory cleanup criteria	10 CFR 40, Appendix A

Based on iterative dose/risk modeling with RESRAD-OFFSITE, *above background* soil Ra-226 cleanup criteria (pCi/g) that would meet EPA/CERCLA dose and risk standards at the CCMF were determined for each land use/exposure scenario (Table 5). MARSSIM protocols for demonstrating compliance with soil cleanup criteria include a systematic combination of soil sampling and radiological scanning with portable survey instruments (NRC, 2000).

[6] Federal Guidance Report No. 11 (EPA, 1988).
[7] Federal Guidance Report No. 12 (EPA, 1993).
[8] Federal Guidance Report No. 13 (EPA, 1999).

For Ra-226, scanning with portable gamma survey instruments is particularly effective as gamma emissions from Ra-226 and its short-lived decay products residing at or near the soil surface are readily detected in the field. A major component of the remedial strategy for the CCMF is to use gamma survey instruments to guide excavations and to provide a probabilistic basis for demonstrating compliance with soil Ra-226 cleanup criteria during final status surveys. Development of correlations between soil Ra-226 concentrations and gamma radiation levels is a widely utilized and accepted methodology to achieve such purposes (NRC, 2000; Johnson et al., 2006; Meyer et al., 2005a and 2005b; Whicker et al., 2006; Whicker et al., 2008).

Table 5: Modeled soil Ra-226 cleanup criteria required to meet and demonstrate compliance with EPA/CERCLA dose and risk standards.

EPA / CERCLA Standard	Soil Cleanup Parameter	Modeled Cleanup Criterion by Exposure Scenario		
		Resident Farmer	*Urban Resident*	*Industrial Worker*
15 mrem/yr Maximum Dose Rate	*Maximum Above Background Soil Ra-226 Concentration (pCi/g)*	2.9	2.9	11.7
	Gamma Screening Level (μR/hr) to demostrate 50% probability of compliance (incl. background)	21.8	21.8	57
	Gamma Screening Level (μR/hr) to demonstrate 95% probability of compliance (incl. background)	13.8	13.8	49
$1x10^{-4}$ Maximum Cancer Risk	*Maximum Above Background Soil Ra-226 Concentration (pCi/g)*	1	1	3.8
	Gamma Screening Level (μR/hr) to demonstrate 50% probability of compliance (incl. background)	14.2	14.2	25.4
	Gamma Screening Level (μR/hr) to demonstrate 95% probability of compliance (incl. background)	6.2	6.2	17.4

=reasonably achievable
=not reasonably achievable (cleanup below upper range of background)

Several Ra-226/gamma correlations have previously been developed at the CCMF and surrounding areas (Cotter, 2011). One of these correlations (from Tetra Tech, 2008) was used to estimate approximate gamma screening levels that would be required to demonstrate compliance with each modeled soil Ra-226 criterion at confidence levels (probabilities) of 50% and 95% (Table 5). A 95% probability is typically specified by regulators in order to limit Type I error rates for such surveys to 5% (i.e. $\alpha = 0.05$).

The gamma screening levels in Table 5 are based on measurements that included background radiation from both cosmic and terrestrial sources. Cosmic background is generally relatively constant across any given region, but terrestrial background can vary considerably across small areas depending on naturally occurring levels of Ra-226 in rocks and soils, especially in mountainous western states such as Colorado (Stone et al., 1999). Variable geologic formations surround the site, and a natural sub-economic uranium deposit is known to exist just 2.5 miles to the northwest (MFG, 2003).

Note that gamma screening levels in Table 5 are color coded to indicate values that are considered reasonably achievable, or in cases where they would be expected to require soil cleanup to levels below the upper range of background gamma radiation, not reasonably achievable. EPA policy with respect to background at CERCLA sites is that cleanup levels are not set at concentrations below natural background levels, and the CERCLA program does not clean up to concentrations below natural or anthropogenic background levels (EPA, 2002b).

Background gamma radiation levels were previously assessed according to RAP protocols in the background sub-basin study (TQEM, 1995; CDPHE, 2005; EPA, 2002a). The average background gamma radiation level from that study was 14.6 μR/hr, with an upper range (mean plus two standard deviations) of 18.6 μR/hr.

Assuming that background gamma levels from the sub-basin study are representative of background gamma levels across Cotter property, cleaning up soils to levels commensurate with many of the gamma screening levels shown in Table 5 would require excavating large amounts of background level soils, particularly to demonstrate a 95% probability of compliance with corresponding soil Ra-226 cleanup criteria.

In addition, comprehensive gamma surveys of the site revealed evidence that soils and rocks on Cotter property associated with geomorphic ridges east of the facility have naturally elevated gamma radiation levels that are well in excess of many of the gamma screening levels shown in Table 5 (approaching 23 μR/hr in some locations). Areas suspected of having naturally elevated levels of Ra-226 and associated gamma radiation (Figure 3) are based on spatial associations with geomorphic ridges, along with observations in the field of gamma emission characteristics of soils and bare rock outcrops in these areas.

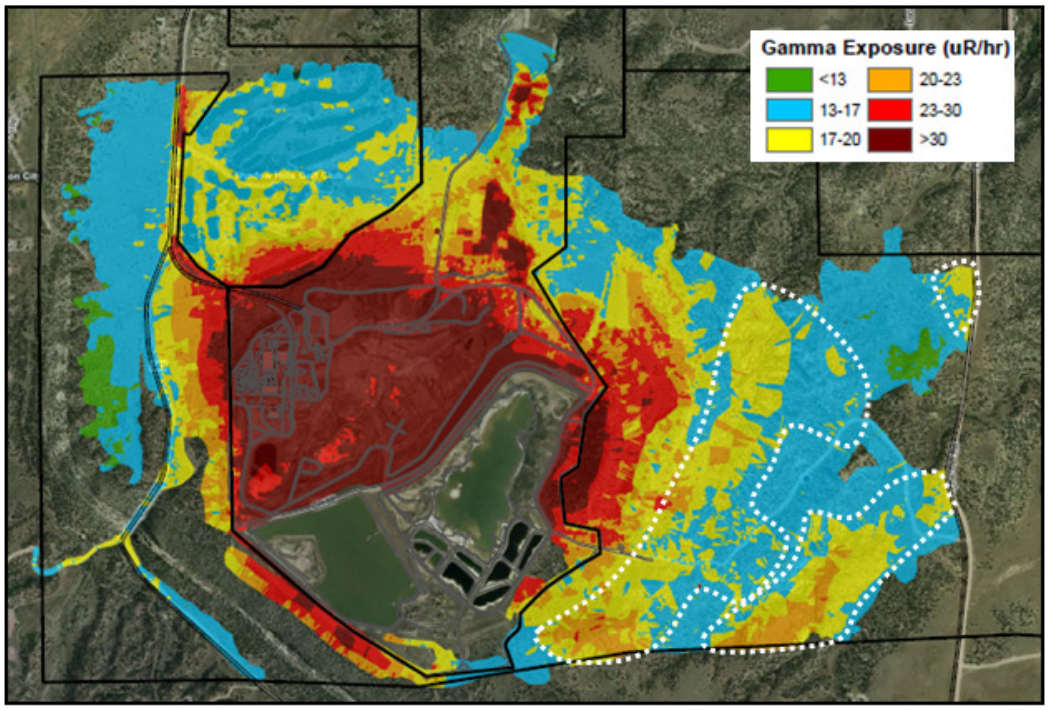

Figure 3: Gamma survey map showing general areas (within white dashed lines) suspected of having naturally elevated Ra-226 concentrations and associated gamma radiation (adapted from Cotter, 2011).

To further evaluate these areas, windblown Ra-226 migration at corresponding downwind locations relative to the mill and impoundments was modeled with RESRAD-OFFSITE using parameter values selected to maximize the potential for windblown migration. These parameters included a high average Ra-226 concentration (1,200 pCi/g, based on the highest level reported in the RI for tailings), maximum plausible parameter values related to wind-driven releases of soil to air (reasonable for bare tailings), an upper-range deposition velocity, and site-specific meteorological wind data. The results over a 50-year period (Figure 4) indicate that it is highly unlikely wind-driven transport mechanisms during the site's history are responsible for gamma readings observed in areas highlighted in Figure 3.

A Ra-226 concentration of 1 pCi/g within an infinite plane of soil will produce a terrestrial gamma exposure rate at 1 meter above the surface of about 1.8 µR/hr (NCRP, 1987). Modeled results for downwind locations in Figure 4 are simply too low to be detectable beyond natural background with portable gamma survey instruments. Because model parameters were selected to maximize the potential for windblown migration, actual Ra-226 accumulations in areas east of the restricted area are likely to be much lower than those shown in Figure 4. Further investigation and characterization of background gamma radiation in portions of Cotter property not previously surveyed is planned as soon as weather and ground conditions permit.

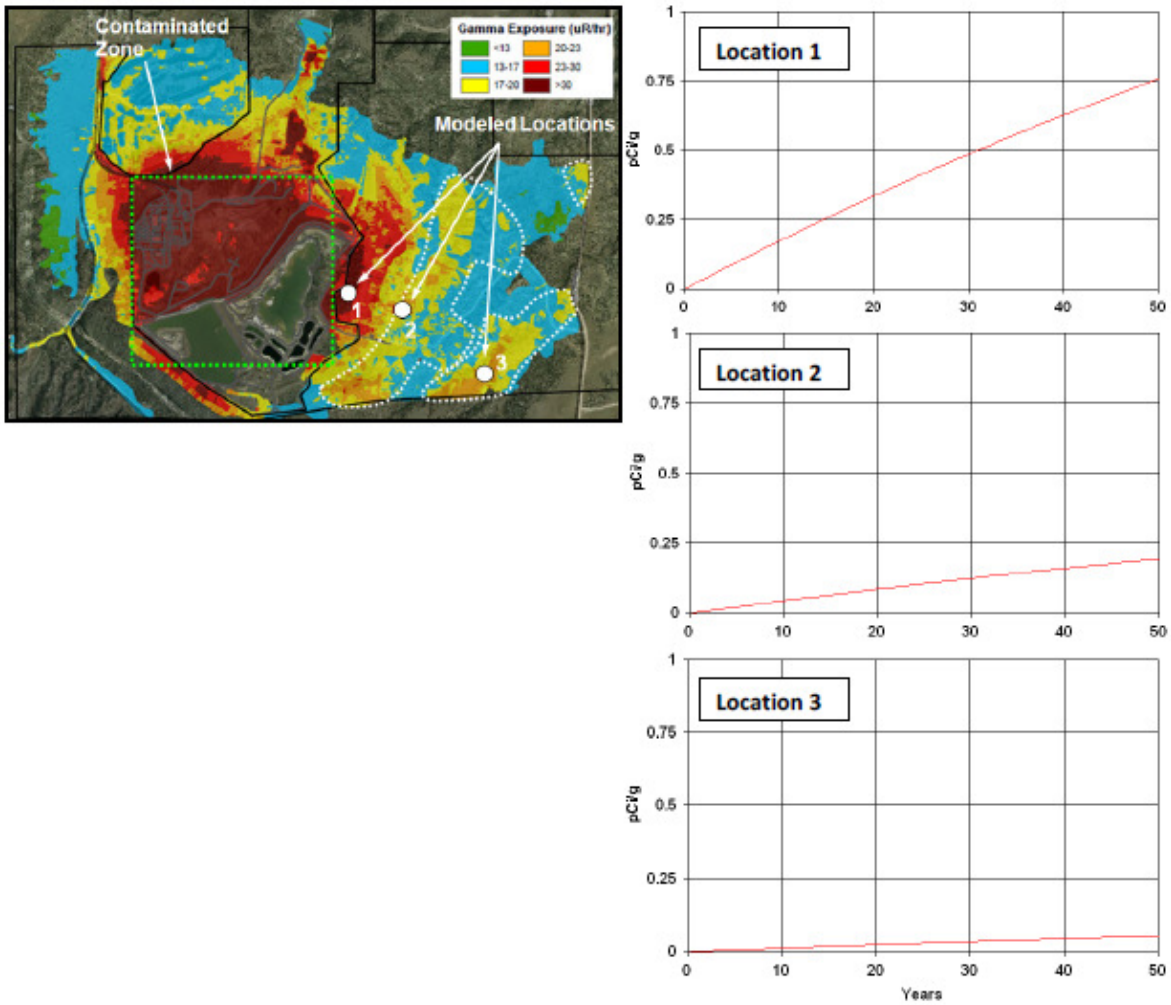

Figure 4: Windblown scenario layout (left) and modeled locations of Ra-226 concentrations in soil immediately adjacent to the contaminated zone (location 1), and at downwind locations (locations 2 and 3) that are suspected of having naturally elevated concentrations.

Implications of Proposed Changes to Radiological Soil Cleanup Criteria

The implications of applying soil Ra-226 cleanup criteria based on CERCLA dose and risk standards, particularly in conjunction with accepted MARSSIM survey protocols, are problematic. If, for example, the most likely future land uses for the majority of the site are either agricultural (resident farmer) or urban residential development, and CERCLA standards are to be applied, cleaning up soils to gamma levels of 13.8 µR/hr to demonstrate a 95% probability of compliance with a 1 pCi/g above background soil Ra-226 cleanup criterion would require excavating virtually all land areas within Cotter property as well as the golf course.

Moreover, it is unlikely that such intensive excavations could ever reduce gamma radiation to levels approaching 13.8 μR/hr because naturally occurring background exceeds this level in most areas of the site. This is likely true even if all soils across the entire property were to be stripped to bedrock. Clearly anything approaching such an endeavor would result in a disastrous outcome for local ecosystems and wildlife, negative environmental impacts in adjacent lands, and long-term or even permanent loss of potentially valuable future uses of the site.

Even if a less restrictive remedial goal, such as cleaning up to a gamma screening level of 21.8 μR/hr in order to attain a 50% probability of compliance, were to be applied in all areas of the site, significant environmental degradation would occur in many natural areas that are currently protected and remain largely undisturbed by human activities. Similar degradation is likely to occur if cleanup criteria specified in the ROD for Lincoln Park soils were to be applied in these areas.

The property surrounding the restricted area (buffer zone) consists of Pinyon-juniper and oak woodland, semidesert shrubland, grassland and wetland communities (MFG, 2003). These ecosystems help to support a wide variety of local wildlife including a large heard of elk, deer, rabbit, mice, kangaroo rat, chipmunk, squirrel, porcupine, coyote, fox, small birds, raptors, lizards, snakes, turtles, frogs, and an occasional bear, bobcat or mountain lion.

On a smaller scale, this buffer zone has resulted in local environmental benefits similar to those observed at many U.S. Department of Energy (DOE) weapons complex sites such as Savannah River, Los Alamos, Hanford, and Rocky Flats (Whicker et al., 2004), as well as the Chernobyl nuclear facility in the Ukraine. Buffer zones at these sites have low-level radiological impacts, but levels are far below any threshold that can cause ecological detriment. Wildlife populations at all of these sites are flourishing because buffer zones prevent human occupation and development, resulting in ecologically productive natural areas. These wildlife sanctuaries have been shown to have positive environmental spillover effects in adjacent populated areas, such as cleaner air and water (Whicker et al., 2004).

Public perceptions and regulatory pressures at other sites have forced unnecessary environmental cleanup of relatively low levels of contamination, resulting in costly remediation and significant ecological damage, without corresponding reductions in public health risks (Whicker et al., 2004). Public health risks typically increase as a result of unnecessary remediation due to negative impacts to local air and water quality and physical hazards to remedial workers.

Previous remediation in certain areas within restricted portions of the site have resulted in absent or very sparse vegetation (even with repeated reseeding efforts), exposing them to erosion by wind and water, a circumstance that requires monitoring and active or engineered mitigation measures. In lower-lying areas with greater available moisture, invader species such as ragweed

and Rabbitbrush, have become dominant.

Restoring areas of major soil disturbance back to original natural conditions is extremely difficult and perhaps even impossible to achieve in this semidesert environment. Other local sites that have been "reclaimed" for decades, such as the historic landfill at Ecology Park, are only sparsely vegetated with reseeded grasses and remain devoid of natural local vegetation.

A potential solution to this problem is to focus on well-established regulatory cleanup criteria for uranium mill sites, such as the dose-based decommissioning rule (25 mrem/yr), the concentration-based 5/15 rule, and the Criterion 6(6) benchmark dose approach for addressing radionuclides other than Ra-226, all of which are considered by most agencies and health physics organizations to be protective of public health and the environment. All of these criteria are consistent with RML termination, RAP, and Consent Decree specifications.

Designation as a CERCLA site does not mean greater health risks versus other sites with similar types and levels of contamination. The March 30, 2011 Soil Remediation Plan provides a strong technical and regulatory basis for radiological soil cleanup criteria that are protective of human health, are realistically achievable, and would not require collateral environmental damage to undisturbed natural areas outside of the restricted zone and OU-1.

As demonstrated in the Soil Volume Study (Tetra Tech, 2006), cleaning up soils to a proposed gamma screening level of 23 μR/hr would provide a 95% probability that soil Ra-226 concentrations across the site are less than 5 pCi/g above background, yet the *average* outcome would be about 3.2 pCi/g (*inclusive* of background). This expected average result is lower than the soil cleanup criterion established by the EPA in the ROD as being protective and acceptable for removal from the NPL.

In addition, in accordance with ALARA requirements, the Soil Remediation Plan commits to additional cleanup of soils until gamma screening levels approach 20 μR/hr, close to the upper range of background measured in the proposed background reference area. This would further reduce soil Ra-226 in areas of the site where true contamination exists, but it should not be applied to areas east of the restricted area that are known to have naturally occurring gamma levels in excess of 20 μR/hr.

Another potential remedy is to implement deed restrictions, zoning provisions, or other institutional mechanisms that would limit future uses of the restricted zone (and perhaps all of OU-1) to industrial or commercial activities. This would allow application of a less stringent soil Ra-226 cleanup criterion (11.7 pCi/g) that would still meet the 15 mrem/yr dose standard under CERCLA (and the minimally acceptable risk standard since the EPA considers 3×10^{-4} to be acceptably close to 1×10^{-4}).

In buffer zone areas, the future land uses could possibly be designated as recreational/open space or forestry-agricultural with residences prohibited, and corresponding dose assessments could be performed to establish soil cleanup criteria that are appropriate for such land uses. A similar remedy was selected by the EPA and the State of Colorado for Rocky Flats. There, the buffer zone was designated as a wildlife refuge and the receptor exposure scenario for determining soil cleanup criteria was for a wildlife refuge worker. This decision saved millions in remedial costs as well as valuable prairie habitat which is rapidly disappearing along the Front Range of Colorado (Whicker et al., 2004).

Finally, Cotter agrees with the Department that the Soil Remediation Plan should be revised to provide discussion of non-radiological constituents, both in terms of identifying potential COCs and developing a strategy to characterize and address them during the cleanup and final status survey. Characterization efforts to evaluate potential TCE in soils in the vicinity of the 1979 mill are currently under way, and Cotter plans to screen for other potential organic compounds, as well as inorganic COCs, such as molybdenum, during radionuclide-driven cleanup of soils. This is considered a reasonable, timely, and cost-effective approach.

In areas where knowledge of historical process and/or mill facilities suggests the potential for any type of soil contamination to reside at depths that could be missed by broad-scale excavations working downwards from the surface, test pits will be excavated and sampled to assure that any constituents that could impact groundwater in the future are successfully remediated.

Summary and Conclusions

The CDPHE, EPA, Consent Decree and RAP have all previously specified soil cleanup criteria for the CCMF and surrounding buffer zone that are codified in 40 CFR 192 (the 5/15 rule). Colorado regulations further require application of the Criterion 6(6) radium benchmark dose approach to develop soil cleanup criteria for radionuclides other than Ra-226.

The only non-radiological COC specified in the RAP for soils is molybdenum. In developing the RAP, the CDPHE and EPA concluded that soil cleanup for Ra-226, Th-230 and molybdenum would reduce any other COCs to acceptable levels. This is consistent with the soil cleanup strategy outlined in the March 30, 2011 Soil Remediation Plan, though non-radiological constituents were not discussed. The Soil Remediation Plan will be revised to address non-radiological constituents.

The CDPHE and EPA required more restrictive soil cleanup criteria for soils in Lincoln Park and other offsite locations (a soil Ra-226 concentration of 4 pCi/g, inclusive of background) and

indicated in the ROD that these criteria are appropriate for use as RAGs for the CCMF and adjacent areas. The ROD was issued in 2002, qualifying soils in Lincoln Park (OU-2) for delisting from the NPL.

Future land uses for the CCMF and surrounding areas on Cotter property are critical for developing soil cleanup criteria according to the Criterion 6(6) radium benchmark dose approach. Section 16, in which much of the restricted area at the CCMF is situated, is currently zoned as industrial. Areas of Cotter property beyond Section 16 are currently zoned as agricultural-forestry. Other future land uses on Cotter property such as residential development are not anticipated in the Cañon City Fringe Area Land Use Plan. The ROD and the TQEM report anticipated industrial future land uses for all areas within the restricted zone and OU-1, and a buffer zone in adjacent areas that would be limited to grazing and pasture lands.

Radiological COCs for the site are well characterized, but the discovery of elevated levels of TCE in groundwater near the mill complex has led to questions about the adequacy of characterization for non-radiological COCs. Past studies have conducted comprehensive evaluations of COCs for radionuclides and inorganic constituents, but evaluations of organic constituents associated with mill processing are sparse. Some limited testing for organics in groundwater, including pcb's, was conducted in the RI, but none were found. In the mid 1990's, the EPA conducted an investigation of pcb and TCE related to an incident of pcb soil contamination in a limited area of the site, but the report is currently unavailable.

Various published analyses from the EPA indicate that a dose rate standard of 15 mrem/yr is protective and achievable at radiologically contaminated sites, and that the concentration-based soil Ra-226 criteria specified in 40 CFR 192 (the 5/15 rule) is sufficiently consistent with both the 15 mrem/yr dose standard and 1×10^{-4} cancer risk standard to be considered protective. This indicates that the 5/15 rule could be used for soil cleanup at the CCMF and still satisfy CERCLA criteria for delisting from the NPL.

However, the CDPHE has indicated that the Criterion 6(6) analysis provided in the Soil Remediation Plan is unacceptable because the calculated radium benchmark dose (25.8 mrem/yr) exceeds the EPA's dose standard for soil cleanup at CERCLA sites. The reason for this result is due to the size of the area modeled, which was intended to be inclusive of the majority of impacted areas at the site (310 acres) and to be reasonably consistent with land use requirements for a resident farmer in this semidesert environment. The EPA's generic analysis of the 5/15 rule was limited to a 100 m^2 area of contamination which is not applicable for such a scenario.

Issues of land use and the size of the area being modeled for a corresponding exposure scenario are crucial to resolve in terms of determining acceptable and reasonably achievable soil cleanup criteria. Depending on site-specific area/dose relationships (e.g. Figure 2), the size of the area

modeled can have direct implications with respect to the size of the survey units to be used during final status surveys. For an impacted area as large as that at the CCMF, practicality is important in terms of selecting a survey unit size that will not require thousands of survey units and tens of thousands of soil samples to demonstrate compliance. Assessment in the Soil Remediation Plan concluded that a 10-acre survey unit is the smallest practical area for conducting final status surveys across the CCMF.

As recommended in OSWER Directive 9200.4-35P, calculation of soil Ra-226 cleanup criteria based on a *reverse* application of Criterion 6(6) to ensure that the radium benchmark does not exceed 15 mrem/yr, resulted in cleanup criteria that raise serious environmental concerns, particularly if gamma screening levels that demonstrate a 95% probability of compliance are to be employed. Use of such criteria would require excavation of background level soils across virtually all of Cotter property as well as all or most of the golf course.

Even gamma screening criteria at the 50% probability of compliance could cause considerable environmental and ecological damages to natural areas with no real reduction in human health risks under any plausible future land use scenario. Overall health risks could actually increase due to negative impacts to local air and surface water quality, along with physical risks to workers performing the remediation. Negative impacts to local air and water quality along with accelerated soil erosion could encroach onto lands surrounding Cotter property and cause additional environmental degradation.

Potential strategies that could simultaneously protect both human health and the local environment include the following:

1. Accept well-established regulatory cleanup criteria for uranium mills including the 5/15 rule and Criterion 6(6) as developed in the March 30, 2011 Soil Remediation Plan. Radiological soil cleanup criteria determined in the Soil Remediation Plan are consistent with RML termination requirements, the RAP, and the Consent Decree. These criteria, along with the additional ALARA proposal to further reduce gamma levels close to the upper range of background, are achievable, protective of human health, and would not require unnecessary remediation and ecological degradation in undisturbed natural areas.

2. Limit future land uses as appropriate for different areas of the site through deed restrictions, zoning provisions, or other institutional controls. Appropriate land use specifications could include industrial/commercial for the restricted area and OU-1, and recreational/open space or forestry-agricultural (without residences) for all other areas of Cotter property. Calculate separate soil cleanup criteria for each land use designation based on CERCLA dose and risk standards. This approach would also be protective of human health yet avoid destruction of valuable natural areas.

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