# Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico

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## Definitions

**Background** – Radiation levels generally representative of pre-mining conditions from cosmic sources, naturally occurring radioactive material including radon (except as a decay product of source or special nuclear material), and global fallout as it exists in the environment from the testing of nuclear explosive devices or from nuclear accidents like Chernobyl which contribute to background radiation.

**Becquerel (Bq)** – The International System (SI) unit of activity equal to one nuclear transformation (disintegration) per second. 1 Bq = $2.7 \times 10^{-11}$ Curies (Ci) = 27.03 picocuries (pCi).

**CFR** – Code of Federal Regulations.

**Curie (Ci)** – A quantitative measure of radioactivity. One curie equals $2.22 \times 10^{12}$ disintegrations per minute (dpm). Fractions of a curie, e.g. picocuries (pCi) or $10^{-12}$ Ci and microcurie (µCi) or $10^{-6}$ Ci, are levels typically encountered in radiation measurements of naturally occurring radioactive material or technically enhanced naturally occurring radioactive material.

**Effective Dose Equivalent (EDE)** – A unit of measure developed by the International Commission on Radiological Protection to normalize radiation doses by considering the adverse effects on a total body basis for the purpose of regulation of occupation exposure. EDE takes into account the sum of all internal and external doses of radiation which takes into account the somatic and hereditary cancer sensitivities of all organs and tissues of the body.

**Exposure** – The amount of external gamma radiation received from the surface of a proposed or new mine site, soil pile, waste rock pile, stockpile, ore pile, or similar feature.

**Gamma Radiation** – A true ray of energy, in contrast to beta and alpha radiation which are particulate. The properties of gamma rays are similar to X-rays and other electromagnetic waves. Gamma radiation is highly penetrating, but relatively low in ionizing potential.

**µR/hr** – microRoentgens per hour.

**pCi/g –** picocuries per gram.

**Post-Reclamation Radiation Level (PRRL) –** The amount of radiation emanating from a mine site after reclamation has been completed. In order to demonstrate adequate radiation reclamation under this guidance document, the PRRL must be equal to or less than the site-specific value of gamma radiation that has been correlated to an activity level for Ra-226 soil of 5 pCi/g + background at the 95$^{th}$ percentile confidence level for the complete site wide radiation data set.



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**Reclamation –** Employment of measures during and after a mining operation designed to mitigate the disturbance of affected areas and permit areas and to the extent practicable, provide for the stabilization of a permit area following closure that will minimize future impact to the environment from the mining operation and protect air and water resources.

**Roentgen Equivalent Man (rem)** – The amount of ionizing radiation that when absorbed by a person is equivalent to one roentgen of X-ray or gamma radiation.

**Roentgen (R)** – A primary unit of radiation exposure. Technically, is defined as the quantity of X-ray or gamma radiation that produces one electrostatic unit of electrical discharge per 0.001293 gram of air.

**Seivert (Sv)** – An SI unit (International System of Units) equivalent to 100 rem.

**Site –** Any mine or extraction facility installation, or discrete, physically separate parcel of land or lands disturbed by mining or uranium extraction, or any building or structure or portion thereof.

**Survey –** A systematic evaluation and documentation of radiological measurements with a correctly calibrated instrument or instruments that meet the sensitivity required by the objective of the evaluation.

**TENORM** – Technically Enhanced Naturally Occurring Radiological Material. Naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing.

**Working Level ("WL") –** A special unit of radon exposure defined as any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of $1.3 \times 10^5$ megaelectron volt ("MeV") of potential alpha energy. 1 WL = 3.7 Bq/L or 100 pCi/L of Radon-222.



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# Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico

The New Mexico Mining and Minerals Division ("MMD") and New Mexico Environment Department ("NMED") are providing this guidance to assist mine site responsible parties in addressing soil radiation at existing uranium mines as part of reclamation activities. Surface reclamation of mine sites falls under the jurisdiction of the New Mexico Mining Act ("NMMA" e.g., 69-36 New Mexico Statues Annotated) for surface conditions and is administered by the New Mexico Energy, Minerals and Natural Resources Department ("EMNRD"). The NMMA is administered under the New Mexico Mining Commission ("NMMC") regulations (e.g., 19.10 New Mexico Administrative Code ["NMAC"]). The NMMC regulations apply to all currently-operating mines as well as to mines that operated for a minimum of two years between January 1, 1970 and June 18, 1993, which is the effective date of the NMMA.

The NMMA and NMCC Regulations contemplate returning an area affected by mining activity to pre-mining conditions. Both define "reclamation" as the employment of measures to mitigate disturbance and stabilize the permit area so as to "minimize future impact" on the environment and to protect air and water quality [Section 69-36-3(K); 19.10.1.7(R)(1)]. Section 69-36-7.H.2 of the NMMA requires the "protection of human health and safety, the environment, wildlife and domestic animals." Also, sections 19.10.3.304.D.7.b, 19.10.5.507.B(2), 19.10.5.508.B and 19.10.6.603.C NMAC of the NMMC regulations have similar requirements. Section 69-36-7(H)(4) of the NMMA requires that a new site be reclaimed to a self-sustaining ecosystem, and Section 69-36-11(B)(3) requires that existing sites be reclaimed so as to re-establish a self-sustaining ecosystem.

Surface and subsurface mine reclamation of mine sites also falls under the jurisdiction of the New Mexico Water Quality Act ("NMWQA" e.g., 74-6-1 through 74-6-17 New Mexico Statutes Annotated). The NMWQA is implemented through the New Mexico Water Quality Control Commission ("WQCC") regulations (e.g., 20.6 NMAC).

In establishing this guidance, MMD and NMED have reviewed standards and guidance documents developed by the United States Environmental Protection Agency ("EPA"), the United States Nuclear Regulatory Commission ("NRC"), the United States Department of Energy ("DOE"), and other state and federal agencies for establishing criteria for cleanup and reclamation of existing uranium mine sites. These are general guidelines, since each mining and reclamation project will have unique characteristics and physical properties. As such, proposed reclamation designs will be reviewed on a case-by-case basis.

## 1.0 Review of Existing Regulations and Radiation Cleanup Standards

Numerous regulations and standards have been promulgated to address radiation cleanup standards at various types of sites that utilize or are impacted by radiological contamination. However, none of



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the federal or state regulations specifically apply to existing uranium mining operations or specify a radiation cleanup standard for reclamation of uranium mines. This section provides a synopsis of the existing federal and state standards and regulations related to uranium and radiation.

## 1.1 Nuclear Regulatory Commission Regulations

NRC regulations that relate specifically to protection of the general public from radiation are promulgated in 10 CFR 20: "Standards for protection against radiation," 10 CFR 40: "Domestic licensing of source material," and 10 CFR 61: "Licensing requirements for land disposal of radioactive waste." It is important to note that these regulations apply to TENORM that is comprised of mill tailings and do not apply to soil and sediment contaminated with uranium ore and waste rock because these materials were not beneficiated or processed for mineral extraction at a uranium mill.

### *1.1.1 Standards for Protection from Radiation Exposure*

10 CFR 20.1402 establishes 25 millirem per year ("mrem/yr") (=0.25 milliSieverts ["mSv/yr"]) as the maximum Total Effective Dose Equivalent ("TEDE") that a member of the public could receive from unrestricted site use following decommissioning of an NRC-licensed facility. 10 CFR 20.1404 provides an alternative criteria for NRC-regulated processing facilities' license termination if the operator can show "that the [radiation] dose from all man-made sources combined, other than medical, would … [unlikely to be] more than…1 mSv/year (100 mrem/year)," with assurance of continued protection of public health and safety.

### *1.1.2 Domestic Licensing of Source Material*

Radioactivity standards for operating uranium mills are promulgated in 10 CFR 40 Appendix A, Criterion 6, and include the following:

- The design of a byproduct waste disposal impoundment cover shall "limit releases of Radon-222…from uranium byproduct materials, and Radon-220…from thorium byproduct materials…so as not to exceed an average release rate of 20 picocuries per square meter per second (pCi/m$^2$/s) to the extent practicable…Direct gamma exposure from the tailings or wastes should be reduced to background levels" [paragraph (1)].

- "Near surface cover materials (i.e., within the top three meters) may not include waste or rock that contains elevated levels of radium; soils used for near surface cover must be essentially the same, as far as radioactivity is concerned, as that of surrounding surface soils" [paragraph (5)].

- Maximum Radium-226 ("Ra-226") and/or Radium-228 ("Ra-228") concentrations in soils must achieve 5 pCi/g over background averaged over areas of 100 square meters ("m$^2$") and the first 15 centimeters ("cm") of depth, and 15 pCi/g over background averaged over successive



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15-cm thick layers more than 15 cm below the surface [paragraph (6); herein referenced as the "5/15 standard"].

- "Byproduct material containing concentrations of radionuclides other than radium…must not result in a total effective dose equivalent…exceeding the dose from cleanup of radium contaminated soil to the [5/15 standard]" [paragraph (6)].

### *1.1.3 Licensing Requirements for Land Disposal of Radioactive Waste*

10 CFR 61.41 comprises the performance objective for the protection of the general population from releases of radioactivity that potentially may originate from land disposal of radioactive waste from uranium mill operations: "Concentrations of radioactive materials which may be released to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable."

## 1.2 Environmental Protection Agency Regulations

### *1.2.1 Standards for Uranium and Thorium Mill Tailings*

EPA regulations that apply to soil concentrations of radioactive elements are promulgated in 40 CFR 192, entitled, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings." Waste rock piles or ore stock piles at abandoned or active uranium mines are not subject to these regulations, since these materials have not been milled. These standards are predicated on a "residential use scenario," meaning that they are meant to ensure safe conditions for residential areas. 40 CFR 192.12(a) specifies that the concentration of Ra-226 in land averaged over an area of 100 square meters shall not exceed background (i.e., native concentrations of radioactivity or radioactive materials in the area prior to disturbance) by more than:

1. 5 pCi/g averaged over the first 15 cm of soil below the surface, and
2. 15 pCi/g averaged over 15 cm-thick layers of soil more than 15 cm below the surface.

40 CFR 192.12(b) further stipulates that in any occupied or habitable building:

1. The objective of any remedial action, within reasonable means, should be to achieve an annual average (or equivalent) radon product concentration (including background) not to exceed 0.02 working level ("WL"), and that in any case 0.03 WL should not be exceeded; and
2. Gamma radiation levels should not exceed 20 microroentgens per hour (μR/hr) above background.

### *1.2.2 Uranium Fuel Cycle & Standards for Normal Operations*

"Uranium fuel cycle" is defined in 40 CFR 190.02.(b) as uranium ore milling operations, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, and reprocessing of spent uranium fuel to the extent that these directly support the production of electrical power for public use utilizing nuclear energy. Uranium fuel cycle excludes mining operations, operations at waste disposal sites, transportation of any radioactive material in support of these operations, and the reuse of recovered non-uranium special nuclear and by-product materials from the cycle. 40 CFR 190.10.(a) states "operations covered by this subpart shall be conducted in such a manner as to provide reasonable assurance that:

> The annual dose equivalent does not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations."

For cover material performance on inactive uranium and thorium millsites, 40 CFR 192.32(a)(4) establishes the standard for Radon-222 flux at 20 $pCi/m^2/s$. Additionally implemented control measures must remain effective for up to one thousand years to the extent reasonably achievable, and in any case, for at least 200 years [40 CFR 192.32(b)(1)(i)].

### *1.2.3 Cleanup Under CERCLA (Superfund)*

The Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"; otherwise known as Superfund) may apply to abandoned uranium mines whenever there has been an uncontrolled release or suspected release of hazardous substances. Oftentimes the lack of viable human health exposure pathways precludes the inclusion of existing mine sites on the National Priority List ("NPL"). If a uranium mine is on the NPL, the CERCLA process must be followed. However, similar to the EPA regulations described above in Sections 1.2.1 and 1.2.2 above, the CERCLA process does not specifically apply to existing uranium mining operations that are not listed on the NPL.

The goal of the investigation and remedy selection process under CERCLA is to select remedies that are protective of both human health and the environment, that maintain protection over time, and that minimize untreated waste. The investigation and evaluation of remedies is described in 40 CFR 300.430 – Remedial Investigation / Feasibility Study and Selection of Remedy. Under CERCLA, remediation goals, which establish acceptable contaminant exposure levels that will be protective both of the environment and of human health under consideration of all potential exposure pathways, are developed by considering applicable or relevant and appropriate requirements ("ARARs") under federal environmental or state environmental or facility siting laws, if available, as well as the following factors:



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For systemic toxicants, acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety.

For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between $1 \times 10^{-4}$ and $1 \times 10^{-6}$ using information on the relationship between dose and response. The $1 \times 10^{-6}$ risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure.

## 1.3 International Commission on Radiological Protection

The 1990 recommendations of the International Commission on Radiological Protection ("ICRP") state: "The Commission recommends that the limit for public exposure should be expressed as an effective dose equivalent of 1 mSv in a year" (1 mSv/yr = 100 mR/yr).

This radiological protection standard applies to public radiation exposure, not to existing uranium mining operations or reclamation of uranium mines.

## 1.4 Multi-Agency Radiation Survey and Site Investigation Manual

The Multi-Agency Radiation Survey and Site Investigation Manual ("MARSSIM") provides a multi-agency approach to conducting radiation surveys and investigations at potentially contaminated sites, with a focus on contaminated surface soil and building surfaces. The purpose of MARSSIM is to provide a standardized approach to demonstrating compliance with a dose- or risk-based regulation. MARSSIM does not address existing uranium mining operations, nor does it establish radiation cleanup criteria for reclamation of uranium mines.

This manual states that the EPA, NRC, Department of Homeland Security ("DHS") and Department of Energy ("DOE") regulations and policies support 15 mrem/yr and/or 25 mrem/yr dose based safety standards.

## 1.5 Bureau of Land Management Guidance

The U.S. Bureau of Land Management ("BLM") has been using a radiation guidance since the late 1970s for the reclamation of uranium mines on BLM and Indian Lands in New Mexico. The guidance utilizes the NRC standard of 0.1 rem/yr above background for access to "unrestricted areas [of mill tailings] to individual members of the public" (10 CFR 20.1301), which BLM has calculated to be equivalent to 12 μR/hr above background.

For radon, in 1993 EPA established an action limit of 4.0 pCi/L above background. BLM uses 3.0 pCi/L above background as its criteria to ensure that the reclamation efforts do not exceed the EPA action limit. For a uranium mine site to be considered remediated using the BLM guidance, the site must emit less than 12 μR/hr gamma radiation above background and less than 3.0 pCi/L of radon above background.

BLM reportedly utilized these criteria for the reclamation of the Jackpile Mine in Cibola County, New Mexico, and the Church Rock Mine in McKinley County, New Mexico. These criteria were also reported to have been used by EPA to reclaim abandoned uranium mines on Navajo Allotted Lands. While potentially useful for comparison purposes, these criteria comprise an internal BLM guidance standard, not a federal regulation.

## 1.6 Texas Department of State Health, Decommissioning Standards

The relevant section of regulation is 25 Texas Administrative Code ("TAC") §289.202 – Standards for Protection Against Radiation from Radioactive Materials. For facilities licensed to utilize radioactive materials that are undergoing decommissioning in the state of Texas, a site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE value for an average member of the critical population group that does not exceed 25 mrem (=0.25 mSv) per year. Alternatively, the agency may terminate a license if the licensee provides assurance that public health and safety would continue to be protected, and that it is unlikely that the dose from all man-made sources combined, other than medical, would be more than the 1 mSv/yr (=100 mrem/yr) limit.

No licensee shall cause the concentration of Ra-226 or Ra-228 in soil, averaged over any 100 $m^2$ to exceed the background level by more than:

- 5 pCi/g (=0.185 Becquerel per gram [Bq/g]), averaged over the first 15 cm of soil below the surface; and
- 15 pCi/g (=0.555 Bq/g), averaged over 15 cm thick layers of soil more than 15 cm below the surface.

Additionally, no licensee shall cause the concentration of natural uranium with no daughters present, based on dry weight and averaged over any 100 $m^2$ of area, to exceed the following limits:

- 30 pCi/g (=1.11 Bq/g), averaged over the top 15 cm of soil below the surface; and
- 150 pCi/g (=5.55 Bq/g), average concentration at depths greater than 15 cm below the surface so that no individual member of the public will receive an EDE in excess of 100 mrem (1 mSv) per year.



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Again, these regulations pertain to licensed facilities undergoing decommissioning, and not to either active uranium mines or reclamation of uranium mines. The EDE standard of 100 mrem/yr to members of the public is the same standard promulgated by the NRC.

## 1.7 Summary of Federal Regulations and Radiation Standards

Table 1 summarizes the existing federal and state standards and guidance for radiation exposure, as well as existing standards related to concentrations of radioactive material in soil. As demonstrated by Table 1 and the information provided in Section 1 of this document, it is apparent that there is a regulatory gap related to active uranium mines and reclamation of uranium mines, for which no federal standard exists. While other states (e.g., Texas) have promulgated exposure and soil concentration standards, the state of New Mexico has no such standards.

**Table 1: Summary of Regulations and Standards and Guidelines**

| Agency | Regulation Description and Reference | Exposure Standard | Soil Concentration Standard |
|---|---|---|---|
| NRC | General public exposure (10 CFR 20) | 100 mrem/yr | -- |
| | Facility decommissioning (10 CFR 20) | 25 or 100 or 500 mrem/yr | -- |
| | High-level radioactive waste operations (10 CFR 60) | 100 mrem/yr | -- |
| | Low-level radioactive waste (10 CFR 61) | 25 or 75 mrem/yr | -- |
| EPA | Uranium Mill Tailing Radiation Control Act (40 CFR 192 & 10 CFR 40, Appx. A) | -- | 5 or 15 pCi/g Radium-226 above background based on depth; 20 pCi/m$^2$/sec radon above background |
| | Uranium Fuel Cycle (40 CFR 190) | 25 or 75 mrem/yr | -- |
| | National Emission Standards for Hazardous Air Pollution (40 CFR 61, B) | 10 mrem/yr to nearest off-site receptor | -- |
| | Superfund (CERCLA) cleanup (40 CFR 300) | Cumulative acceptable level of risk is $1x10^{-4}$ to $1x10^{-6}$ 15 mrem/yr = $3x10^{-4}$ risk level | |
| | Spent nuclear fuel and high-level transuranic waste (40 CFR Part 191) | 15 mrem/yr | -- |
| **Agency** | **Regulation Description and Reference** | **Exposure Standard** | **Soil Concentration Standard** |
| Mine Safety & Health Administration (MSHA) | Maximum permissible concentration of radon daughters in active workings (30 CFR 57.5039) | 1.0 WL | -- |



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| | | | |
|---|---|---|---|
| | Annual exposure limit (30 CFR 57.5038) | 4 Working Level Months (WLM)/yr | -- |
| OSHA, NRC, DOE | Occupational standards (20 CFR 1910, 10 CFR 20, 10 CFR 835) | 5,000 mrem/yr | -- |
| ICRP | Recommendation only; not a federal regulation | 1 mSv/yr (100 mR/yr) | -- |
| EPA, NRC, DHS & DOE | Jointly prepared MARSSIM guidance document; not a federal regulation | 15 or 25 mrem/yr | -- |
| Bureau of Land Management | Not a federal regulation; utilized by BLM in New Mexico | 0.1 rem/yr (12 µR/hour) & < 3.0 pCi/L radon above background | -- |
| Texas Department of Health | State of Texas regulation; not a federal regulation | 25 or 100 mrem/yr | 5 or 15 pCi/g Radium-226 above background based on depth; maximum of 30 or 150 pCi/g total uranium based on depth |

## 2.0 State of New Mexico Radiation Cleanup Criteria

The goal of mitigating mine site radiation levels will be reclamation to radiation levels that are compliant with 40 CFR 192.12, 40 CFR 192.32 and 10 CFR 40 ("5/15 standard"), such that remedial actions shall provide reasonable assurance that:

(1) The concentration of Ra-226 in land averaged over any area of 100 square meters ("$m^2$") shall not exceed the background level by more than—

(a) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and

(b) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

(2) Site post-reclamation radiation level ("PRRL") for gamma radiation should not exceed the site-specific value of gamma radiation that correlates to 5 pCi/g Ra-226 above background at the 95$^{th}$ percentile value. For example, at an existing mine site the value of gamma radiation that correlates to a maximum Ra-226 activity of 5 pCi/g above background in soil may be determined to be 20 µR/hr above background, which would then be designated as the site-specific PRRL.

(3) For sites at which contaminated material exceeding the target radium activity level discussed above is emplaced in an on-site repository, cover material for the repository must achieve radon flux equal or less than 20 pCi/$m^2$/s.

## 3.0 Cleanup Methodology

### 3.1 Preferred Methodology

The preferred reclamation method is physical removal of all radiologically-contaminated materials above background value from the site, with disposal of this material to a monitored disposal facility. This preferred methodology likely provides a final site reclamation solution to the responsible party for unrestricted public use to the site. However, the Agencies recognize that attainment of this standard could require the removal of a significant volume of materials that probably would include a considerable amount of soils comprising natural background. Such removal activity to an appropriate and monitored repository potentially could incur high reclamation costs, adverse environmental impacts, and unacceptable safety threat to on-site reclamation workers.

### 3.2 Alternative Methodology

Under certain circumstances, reclamation plans could include disposal of unprocessed ore or contaminated waste materials into an abandoned underground mine, particularly in mines where unsaturated conditions are likely to persist. Alternatively, the responsible party may provide a plan to construct an on-site, incised disposal repository using an appropriately-engineered cover with shallow slopes. Reclamation using this alternative methodology should employ a modified store-and-release cover (also called an evapotranspiration cover).

Any engineered elements of the reclamation plan (e.g., site or waste impoundment cover system, site drainage channels, etc.) should provide long-term protectiveness while minimizing maintenance requirements. The durability of engineered solutions should be documented by an engineering analysis that incorporates site and regionally-appropriate values for relevant climatic factors (e.g., precipitation and wind speed distribution).

## 4.0 Reclamation Considerations

The type, quality, and thickness of cover system material chosen will be a critical component of successful reclamation. The thickness of the material chosen will also be a critical component. Because of the long half-life of radioactive materials that may be found at the site, reclamation must take into account Best Management Practices to address erosion and stability. Cover material must be of sufficient thickness and texture to remain in place, and not allow for the re-exposure of buried TENORM material.

While the use of rock armoring has very good anti-erosion characteristics, the extreme coarseness of the material does not allow sufficient vegetative growth for the creation of a self-sustaining ecosystem. Similarly, clays may be added to the cover design to help in the suppression of gamma activity and radon gas emissions. However excessive clay is generally not suitable as a vegetative growth media. To address the need to limit erosion over long periods of time, the Agencies advocate

establishing incised repositories onsite for deposal of TENORM materials, and capping the repositories with shallow sloping rock/soil covers. Reclamation should be performed using a modified store-and-release cover (also called an evapotranspiration cover) using an overall coarser soil for erosional resistance combined with additional use of rock armoring in areas that may be more susceptible to erosion. Re-establishment of various vegetation such as native grasses and forbs on the cover will also reduce erosion over time. Post-reclamation hydrology must be addressed during reclamation in a way that supports positive drainage away from contaminated areas, minimizes erosion and prevents re-exposure of buried materials. Another option in addressing contaminated material may be to place unprocessed ore or waste material back into the underground mine, where the workings are dry. Various materials can be applied as an erosion control cap to prevent loss of cover from rain and wind erosion.

Since each mining and reclamation project will have unique characteristics and physical properties, reclamation designs will have to be evaluated on a case-by-case basis.

## 5.0 Generalized Mine Site Reclamation Implementation Guidance

### 5.1 Characterization Work Plan

Adequate site characterization must be performed prior to initiation of cleanup and reclamation activities to identify target areas of excessive radioactivity. In addition to sampling impacted soils for suitability and selected metals, the mine site responsible party should develop and submit a work plan for approval to characterize background radiological conditions. The evaluation should focus on the extent of surface soil contamination above background levels with both field instruments and appropriate geochemical laboratory analyses.

The characterization work plan should incorporate direct observation, field measurement, and laboratory analysis in order to provide a high-confidence determination of the extent and concentrations of the radioactive material that has been released. The scope of the characterization work plan should allow for discrimination among areas impacted by mining operations, unimpacted areas reflecting background conditions and areas proposed for acquiring suitable cover or borrow materials. Site surveying methodologies that should be specified in the characterization work plan may include random sampling, systematic/grid sampling or other accepted surveying/sampling methodologies.

### 5.2 Establishing Site Specific Radiation Levels

The site radiological surveying methodology employed by the operator should be specifically described in the Closeout Plan (CP), and may include random sampling, systematic/grid sampling, or other accepted surveying/sampling methodologies. At an existing mine site, vertical sampling should be performed as necessary to establish the vertical radium activity profile within the soil.

Existing mine site baseline radiation levels should be established, as well as associated background radiation levels.

Where feasible, the operator should use an undisturbed reference area to determine natural background radium activity in the soil profile. Mine sites with permit boundaries that occur in multiple radiological zones may consider application of stratified sampling or the use of multiple reference areas to adequately represent the variability of the proposed mine site. Reference areas proposed by the operator should be in close proximity to, and have similar geologic, topographic, soil and vegetation characteristics relative to the mine site. The operator must be able to ensure that MMD and NMED have access to any proposed reference areas.

The CP should also include an assessment of any soil materials that are proposed for use as cover during reclamation. Components of the CP related to the radiological survey may include:

- Gamma radiation emission survey
    - 1 meter above ground surface (Ludlum µR/hour meter or equivalent; dose measurement)
    - At ground surface – shielded (dose measurement with lead shielded probe)
    - At ground surface – unshielded (dose measurement)

  Evaluation of gamma radiation using disintegration counts is also acceptable, if desired by the operator. Consistency of approach between the pre-mining survey and the post-reclamation survey is a key component.

- Soil sampling – horizontal and vertical profiling (pCi/g)
    - Radium-226 (at a minimum)
    - Total Thorium
    - Uranium
    - Gross Alpha

- Radon gas flux sampling – pCi/m2/s

## 5.3 Characterization Summary Report

All results and conclusions from the implementation of the characterization work plan should be compiled into a comprehensive characterization report. The characterization report should include calculation of a statistical correlation (linear regression analysis) between the baseline/background gamma radiation readings and the site-specific Ra-226 soil activity, so that a conversion factor between the two readings can be applied to future site-specific data, if needed. The characterization report should also include the location of each sampling point using global positioning system data so that these points can be revisited in the future, if necessary.



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## 5.4 Reclamation Work Plan

Following the submittal of the characterization report, a site reclamation work plan should be prepared and should propose a cleanup methodology pursuant to Sections 2 and 3 of this guidance document. If the responsible party proposes to implement the preferred cleanup methodology, the work plan should specify the proposed final location of the excavated material. If the responsible party proposes to implement an alternative cleanup methodology, the composition of proposed cover materials should achieve the specified reclamation radiation performance criterion. The design should also incorporate features such that the cover will both be resistant to erosion and degradation without maintenance for the long-term and reduce infiltration of precipitation to the maximum extent practicable. Proposed activities under the reclamation work plan also should include establishment of permanent markers to delineate the boundaries of the reclaimed mine site area. Finally, the reclamation work plan also should include a post-reclamation radiation assessment and sampling program to document attainment of reclamation goals.

The reclamation work plan should also include a site management plan that provides an anticipated maintenance schedule or inspection schedule for the site. Because institutional controls on land usage are not legally enforceable in New Mexico, the site management plan should also include reporting of known or reasonably foreseeable changes in land use at the reclaimed site.

## 5.5 Reclamation Summary Report

A final reclamation report should compile a record of all post-reclamation data, engineering calculations, engineering drawings, and activities that were conducted during reclamation, and include a tabulation of the permanent marker locations that delineate the reclaimed mine site area. As appropriate, this report should be provided to the surface landowner and recorded with the appropriate county jurisdiction to establish a permanent record.



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