US Department of Energy Office of Legacy Management Abandoned Uranium Mines Report to Congress - 14132

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ABSTRACT

The National Defense Authorization Act for Fiscal Year 2013, signed into law on January 2, 2013, mandates that the US DOE prepare a Report to Congress on abandoned uranium mines (AUMs) that provided uranium ore for atomic energy defense activities of the United States.

The US DOE Office of Legacy Management (LM) was selected to develop the Abandoned Uranium Mines Report to Congress. LM was established in 2003 to manage post-closure activities at former US DOE defense and uranium ore mill sites. LM is responsible for administering the US DOE Uranium Leasing Program and its 31 uranium lease tracts, including reclamation activities.

LM is required to submit the Report to Congress by July 2014. The report will describe and analyze the following:

- The location and status of abandoned uranium mines
- An assessment of the impacts and risks to public health and the environment
- The potential cost and feasibility of reclamation and remediation
- A priority ranking for the reclamation and remediation of abandoned uranium mines

Database

LM developed a database of over 4,000 AUMs, primarily based on production records from the US Atomic Energy Commission. These records tie the mines to defense-related activities from 1947 to 1970. Federal agencies involved in AUM reclamation have not reached a consensus on the definition of an AUM, but LM developed a definition for the Report to Congress.

The database also incorporates relevant information from several other federal, state, and tribal databases, reports, and subject matter experts. Sources include the US EPA's Uranium Location Database, US EPA Region 9 Navajo Nation AUM Screening Reports, Bureau of Land Management Abandoned Mine Sites Cleanup Module, and the US Geological Survey Mineral Resources Data System. These databases were primarily used to identify the location of individual AUMs. Some of the databases, such as the US EPA Screening Reports, provided additional information such as gamma exposure measurements, distances to population centers, and features of the mine (e.g., portals, waste rock piles, structures).

Ore production amounts were used to categorize the potential AUMs into different size categories to assist in analyzing the data and evaluating the risks and costs. Six size categories were established for the amount of uranium ore produced, ranging from Small (up to 91 metric tons [100 tons]) to Very Large (more than 453,592 metric tons [500,000 tons]). Using the database and geographic information system data, mines can be plotted by location to demonstrate where they would have the most impact. The number of locations per state varies widely, ranging from states (e.g., Alaska, New Jersey) with just one AUM, to Colorado, which has over 1,500.

Risks

Available information is insufficient to develop an individualized risk model for most AUMs, so a generic conceptual site model was developed to assess potential exposure to receptors. The conceptual site model takes into account current land use and plausible current and future receptors and scenarios. The majority of AUMs are located on government land, with nearly 50 percent of the AUMs located on US Bureau of Land Management land, where the primary potential receptors will be hikers and campers. Since approximately 10 percent of the AUMs are on tribal lands, a residential scenario was also considered. Results and preliminary consultations are examined.

Costs

Cost data are based on reclamation performed by other federal and state agencies, along with US DOE's past experience reclaiming former mines on the uranium lease tracts. US DOE prepared a range of costs for performing both reclamation and remediation. Reclamation typically addresses mitigating the physical hazards and recontouring and covering the waste rock pile, which reduces erosion while reducing some radiological exposure. Remediation addresses the radiological and heavy metal risks, and typically involves removing radiologically contaminated soils to some cleanup level (e.g., 5 pCi/g [0.18 Bq/g] for Ra-226 above background). When appropriate, the remediation scenario assumes that one disposal cell will be built to accommodate waste from multiple AUMs located close to each other.

Priority System

Most federal agencies, states, and tribes use variations of the proximity of AUMs to structures, schools, or campgrounds as a criterion for prioritization of mine reclamation. Some agencies view radiological hazards as a high priority, while others may focus on environmental impacts to surface waters. Availability of funds also affects the prioritization, with some agencies looking to leverage limited funds by partnering with other agencies. Existing prioritization approaches are summarized, with consideration given to future prioritization. LM considered both the physical and radiological hazards in mine site prioritization. Individual mines will not be prioritized in the 2014 Report to Congress.

Public Outreach

Consistent with the 2013 legislation, LM has consulted with representatives from other federal agencies, affected states and tribes, and the interested public. LM is primarily using existing conferences and forums, such as the 2014 WM Symposia Conference, to solicit feedback.

INTRODUCTION

More than 150,000 abandoned or inactive hardrock mines exist in the western United States, not including Alaska. Most of these mines were established under the General Mining Law of 1872, and reclamation was not required. Many mines are so old that owners cannot be traced, so potentially responsible parties cannot be identified. Abandoned uranium mines (AUMs) are a small subset of the large number of abandoned hardrock mines. Limited funds are available to government agencies to address these abandoned mines. As the population grows in the west, more people live near the AUMs, and recreational activities such as hiking, bike riding, and off-road-vehicle riding occur more frequently near the mines. AUMs have the same physical hazards as most other hardrock mines plus the added risk of radiological exposure.

The National Defense Authorization Act for Fiscal Year 2013, signed into law on January 2, 2013, mandates that US DOE prepare a Report to Congress on AUMs that provided uranium ore for atomic energy defense activities of the United States.

The US DOE Office of Legacy Management (LM) was selected to develop the Abandoned Uranium Mines Report to Congress. LM was established in 2003 to manage post-closure activities at former US DOE defense and uranium ore mill sites. LM is responsible for administering the US DOE Uranium Leasing Program and its 31 uranium lease tracts, including reclamation activities.

LM is required to submit the Report to Congress by July 2014. The Report will describe and analyze the following:

- The location and status of abandoned uranium mines on federal, state, tribal, and private lands
- The extent to which abandoned uranium mines (1) pose a significant radiation hazard or other public health and safety threat and (2) cause, or have caused, water or other environmental degradation
- The potential cost and feasibility of reclamation and remediation in accordance with federal law
- A priority ranking for the reclamation and remediation of abandoned uranium mines

LM's Definition of Abandoned Uranium Mine

LM defines an AUM as a mine or complex developed to extract uranium ore for atomic energy defense-related activities of the United States from 1947 to 1970, as verified by purchase of ore by the US Atomic Energy Commission (AEC) or other means [1]. After 1970, uranium ore was produced for commercial nuclear power purposes.

An AUM may be a single feature such as a surface or underground excavation, or it may include an area containing a complex of multiple, interrelated excavations. An AUM may include associated mining-related features, such as mine adits and portals, surface pits and trenches, highwalls, overburden or spoils piles, mine-waste rock dumps, structures, ventilation shafts, ore stockpiles and stockpile pads, mine-water retention basins or treatment ponds, close-spaced development drill holes, trash and debris piles, and onsite roads.

LM's definition of an AUM does not include offsite impacts or features such as ore-buying stations, ore transfer stations, or ore used in structures, roads, and general fill. LM recognizes that offsite uses may result in an unacceptable risk to the public or environment, but LM is adhering to the congressional direction of addressing only AUMs as defined above.

LM recognizes that if the majority of mines in an area are defense-related, and if there was no active uranium mill in that area after 1970, then, subject to any other data, all uranium mines in that area would be considered "defense-related," whether or not a particular mine is included in the AEC records. There are many such areas, including Cameron, Arizona. This was confirmed by field visits in which mines that had the same characteristics of the AEC-era mine(s) were discovered in the immediate area of AEC mines.

Also, since the primary basis of the LM AUM database is the AEC production records, an AUM is generally associated with a patented or unpatented mining claim (established under the General Mining Law of 1872) or a lease of federal, state, tribal, or private lands. By this definition, these mines may not be abandoned (i.e., some have existing permits), and some mines have been reclaimed or remediated. Mines in any of these categories are still included in the set of legacy mines that were considered for evaluation as part of the congressional request for this report. Figure 1 illustrates some common physical and radiological hazards associated with uranium mines.

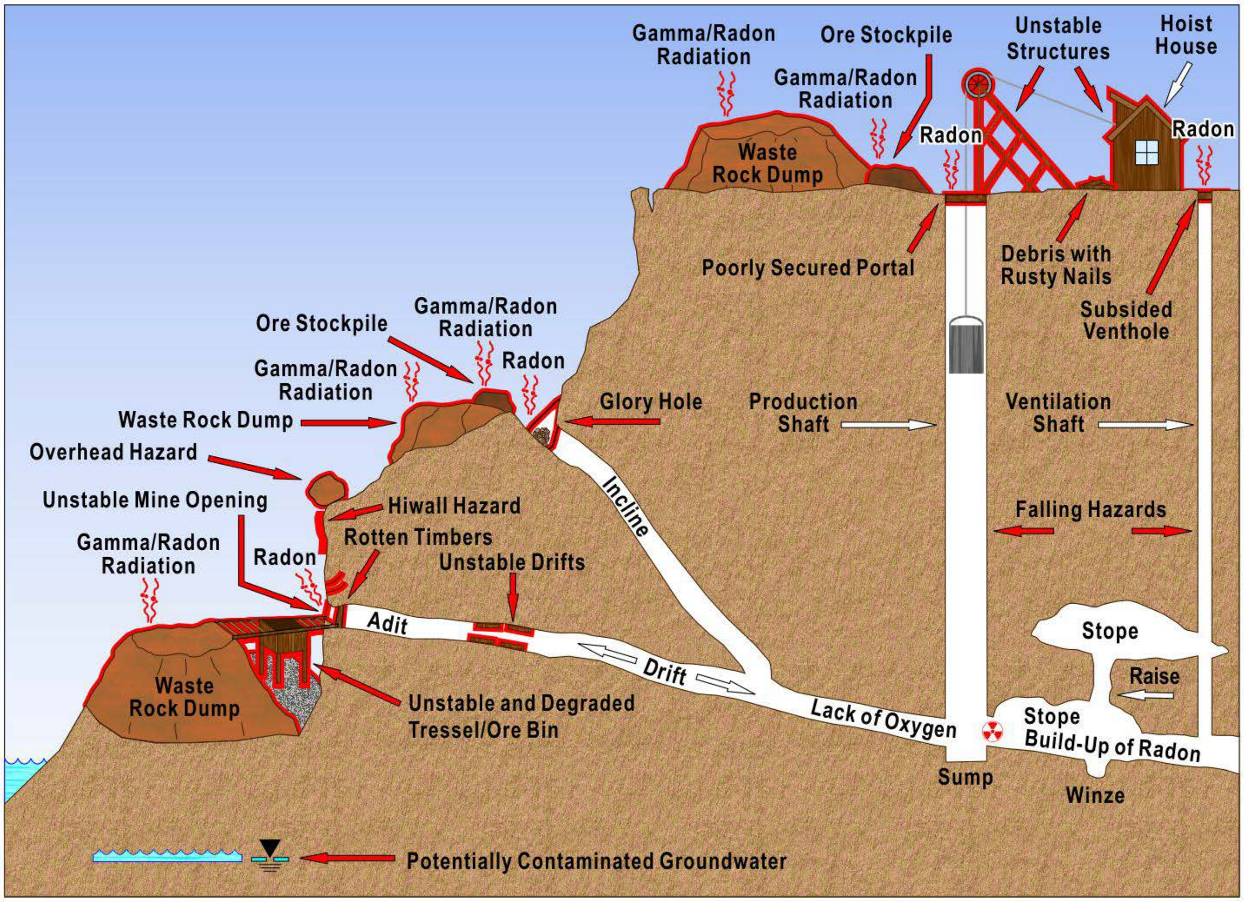

Fig. 1. This diagram illustrates common physical hazards and pathways for radiation exposure in uranium mines.

Abandoned Uranium Mines

AUMs are a subset of abandoned mine lands (AMLs) that have been and are being addressed by various state and federal agencies (US Bureau of Land Management [BLM], US Forest Service [USFS], US EPA, National Park Service [NPS], tribal and state-specific AML offices, and state offices with oversight of mining activities). A US Government Accountability Office (GAO) report notes that more than 150,000 abandoned hard-rock mines are in the western United States [2]. US EPA has documented several investigations specific to AUMs [3, 4]. The 2006 report focused on technologically-enhanced naturally-occurring radioactive material (TENORM). ("Technologically-enhanced" describes situations where human activity has concentrated the radioactivity or increased the likelihood of exposure by making the radioactive material more accessible to human contact. This includes any manmade action, whether intentional or not, that results in an accumulation greater than what was naturally occurring.) That 2006 report was part of US EPA's efforts to characterize risk from TENORM sources and to identify locations of TENORM concerns. US EPA's report identified approximately 15,000 locations associated with uranium in its database and noted that more than 4,000 mines had documented uranium production. More than 20 sources were used to create US EPA's uranium location database, including several national databases (e.g., the US Geological Survey [USGS] Minerals Availability System/Mineral Industry

Location System, the USGS Mineral Resources Data System, and databases or data tables from BLM, USFS, and state AML programs). Figure 2 provides an overview of the location of uranium mines in the United States in relation to the main mining districts.

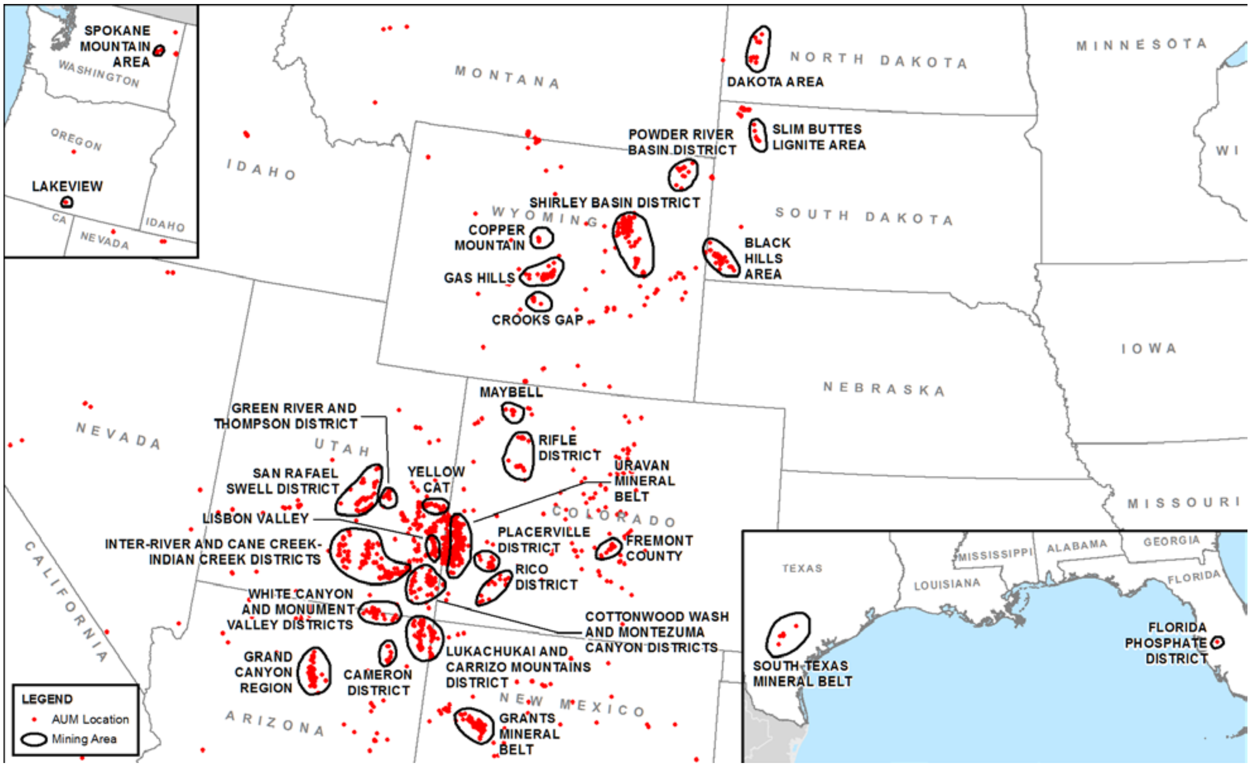

Fig. 2. This map shows the location of AUMs in the US in relation to the main mining districts.

Research of Existing and Available Databases

With a limited amount of time to accomplish objectives requested by Congress, LM researched and reviewed existing and available databases of AML and AUM sites to create an LM AUM database. AEC records served as the starting point and were enhanced with 37 sources of other data provided by US EPA, BLM, USGS, USFS, Navajo Nation, and several state agencies. The majority of the data were used to establish location coordinates for the AUMs. Where other data existed that served the purpose of the LM task, such as cost information or reclamation status, those data were also captured in the LM AUM database.

The LM AUM database was developed in an incremental fashion based on the data that were obtained. The AEC records listed only the mine name, uranium production, and the state and county for location. Some of the additional sources were limited to similar location data, while other additional-source databases included numerous data fields that could be of potential use. A review of the other databases, their available data fields, and data deemed necessary to support the risk evaluation and cost development led to an expansion of the list of data fields included in the LM AUM database.

After all readily available information for the fields was collected and entered into the LM AUM database, the data tables listed in Table I were created to categorize data. The data fields were chosen to support development of the requested topics in the congressional bill.

TABLE I. LM Abandoned Uranium Mines Data Tables

Table No.	Name	Description
T01	Location	Includes state, county, and latitude/longitude information
T02	Owner/Operator	Includes owner, operator, or permittee where available
T03	Production	Total tons of ore, pounds of U_3O_8, grade %, year
T04	Mine Status	Mine closure status
T05	Mine Features	Number of pits, adits, shafts, and structures
T06	Land Ownership	Private, state, federal, or tribal
T07	Costs	Source of data, year, and description
T08	RAD Gamma Data	Source measured, average and maximum, background
T09	RAD Soil Data	Range measured, units used, background values
T10	RAD Radon Data	Range, average, background, source
T11	Surface Water Data	Data availability and source of data
T12	Groundwater Data	Data availability and source of data
T13	Comments	Name of organization, person, date received
T14	Visual Checks	Are features visible on aerial or topography mapping
T15	Documents	Document name, source, and description
T16	Data Sources	Source name, type, comments, and description

The LM AUM database was constructed in several stages. The first stage established the number of mines and their location. The second stage reconciled known mines with locations identified in US EPA's uranium location database and other sources. The third stage determined the data fields and then populated data tables with available information. Concurrently with the third stage, a link was provided in the database to the original source data in case verification of specific data fields was needed (and also as a reference for additional data that might not be included in the selected data fields). The fourth stage was a combination of matching mine names and other source database attributes with the AEC base records. The final stages included developing a process to evaluate the data, conducting data validation, identifying data gaps and other issues, and selecting production-size categories.

Validation of Data and Data Gaps

Having assembled the LM AUM database, LM conducted a review of the data to assess data gaps, validate the data, and perform other QA/QC checks prior to creating data tables and queries for the cost and risk evaluations.

After the AUM records were matched to known databases, a significant number of mines (>1,000) remained with an "unknown location" (i.e., no latitude and longitude values). Using the available information, these "unknown location" sites were sorted by production size. Various state agencies were contacted, and other documentation was reviewed in an effort to produce better location information for the unknown-location records. This research focused first on larger production-size records and then worked down to the smaller production-size records. After this investigation effort, only 578 (or about 14 percent) of the mines in the LM AUM database still had unknown location coordinates, and nearly all the unknown-location mines were in the Small and Small/Medium production-size categories.

Table II and Table III show the number of unknown-location AUM records by state and by production-size category. Mines are categorized by the total amount (tons) of ore produced, as shown in Table III. Table II shows that approximately 69 percent of AUMs are located in Colorado and Utah, with another 23 percent present in Arizona, Wyoming, and New Mexico. In terms of total tons of uranium ore produced for defense-related purposes (68.7 million metric tons [75.8 million tons]), the top-producing state is New Mexico with over 31.8 million metric tons (35 million tons), followed by Wyoming, Colorado, and Utah with just over 10 million metric tons (11 million tons) each. The combined production from New Mexico, Wyoming, Colorado, and Utah represents 79 percent of defense-related ore production.

Table II. LM AUM Database Records Sorted by State, Including Unknown-Location Numbers

State	Total	Known Location	Unknown Location
Colorado	1518	1421	97
Utah	1380	1012	368
Arizona	413	409	4
Wyoming	319	291	28
New Mexico	247	240	7
South Dakota	155	133	22
Texas	29	20	9
California	26	20	6
Nevada	24	22	2
North Dakota	21	21	0
Montana	19	16	3
Washington	17	12	5
Idaho	7	6	1
Oregon	4	4	0
Oklahoma	2	2	0
Alaska	1	1	0
Florida	1	1	0
New Jersey	1	1	0
Pennsylvania	1	1	0
Unknown	26	0	26
Total	4211	3633	578

As shown in Table III, all of the AUMs in the Large and Very Large categories were in known locations. In addition, only six of the Medium and one of the Medium/Large categories have an unknown location, but this represents less than 1 percent of the total for those categories. The fieldwork conducted by LM confirmed that where groups of mines occurred in the same area, some of the small mines were not always captured in the database.

TABLE III. LM AUM Database by Size Category

Size Category	Total Ore Produced (tons)	Number of Mines	Known Location	Unknown Location
Small	0–100	1931	1445	486
Small/Medium	100–1,000	933	848	85
Medium	1,000–10,000	783	777	6
Medium/Large	10,000–100,000	397	396	1
Large	100,000–500,000	82	82	0
Very Large	>500,000	37	37	0

Unknown Size		48	48	0
Total		4211	3633	578

Mine Status

An important element in preparing the Report to Congress is an understanding of the status of any mine reclamation or remediation. Understanding that status will help determine the future scope of the remaining cleanup needs and assist in identifying a range of costs to mitigate potential safety and environmental hazards. Federal, state, and tribal records and personal contacts were used to capture the status of cleanup activities.

In researching mine status, it became clear that there is no national standard or approach for mine reclamation or remediation. There are differences in reclamation and remediation approaches for mines because of the disparity between missions by different agencies. Cleanup could range from simply closing a portal, to full remediation of contaminants from land and water and placing the contaminated material in a disposal cell. Because there is not just one standard for cleanup goals, the status depends on the intent of the organization performing the cleanup. In practice, different objectives are implied by reclamation versus remediation of mines.

Many mines sites have been partly reclaimed to address a safety hazard, such as closing open adits and shafts, but these sites are not considered fully reclaimed. To provide consistency for mine status, the following terminology is used:

- Reclaimed—elimination or mitigation of physical hazards by closing portals, adits, and vent holes; low-grade ore stockpiles have been addressed by placing them below grade as part of the portal-closure or recontouring activities; waste rock piles have been recontoured to a stable condition that minimizes the potential for future erosion and blends in with the original site topography; and the site has been covered with enough topsoil to enhance revegetation efforts.
- Remediated—performance of all of the scope in reclamation, plus the agency involved typically follows the CERCLA process and targets radiation risk to humans and the environment (uranium, radium, gamma); site is typically remediated to a soil or gamma cleanup standard, and material is placed in an onsite disposal cell or legally disposed of offsite.
- In-Process—an agency has started the CERCLA process; there is a current owner of property, current mineral claim, or permitted mining operation; entity holds a reclamation bond.
- Partially Reclaimed—typically, some physical hazards have been addressed; the reclamation or remediation is phased and not all phases are complete.
- Closed—portals, vents, adits, and other openings have been blocked or backfilled to prevent future entry by humans (could include bat gates).
- Permitted—operator has a reclamation bond with a regulatory agency; privately owned, and owner is responsible for reclamation/remediation.
- Not Reclaimed (or Unknown)—no work has been performed to reclaim, remediate, or mitigate physical and environmental hazards.

Table IV provides a summary of the seven categories of mine status along with a breakdown of the count by production size. As shown in the table, 3,621 (86 percent) of the AUMs are not reclaimed or their status is unknown. There are 131 AUMs (about 3 percent) that are closed and 423 (approximately 10 percent) that have been or are in some stage of reclamation.

TABLE IV. Number of Mines by Mine Status and Production-Size Category

		Production-Size Categories (Number of Mines)						
Mine Status	**Total Count**	**Small (0–100)**	**Small/Medium (100–1,000)**	**Medium (1,000–10,000)**	**Medium/Large (10,000–100,000)**	**Large (100,000–500,000)**	**Very Large (500,000+)**	**Unknown Size**
Remediated	3	0	1	2	0	0	0	0
Reclaimed	371	73	80	106	59	16	24	13
In-process	14	6	1	3	2	0	2	0
Partially Reclaimed	35	7	8	8	8	2	2	0
Closed	131	28	31	42	27	3	0	0
Permitted	36	12	5	3	10	3	3	0
Not Reclaimed (or Unknown)	3621	1805	807	619	291	58	6	35
Total[a]	4211	1931	933	783	397	82	37	35

[a] The total numbers do not include 46 unknown mines.

Cleanup Standards

There are no national standards for the cleanup of AUMs. Approaches used by the different federal agencies vary from generic qualitative guidelines that emphasize removal of physical hazards and surface stabilization, to site-specific numerical goals established for each contaminant of concern.

Cleanup standards primarily affect the remediation scenario but can also affect reclamation, although reclamation's primary focus is on mitigating the physical hazards and stabilizing the waste rock pile. Stabilizing the waste rock pile typically includes excavating the highest radioactivity materials (i.e., ore), placing the material on the waste rock pile, and regrading and shaping the pile into flatter slopes. A minimum of 6 inches of topsoil, when available, is spread on top of the waste rock to promote vegetation while reducing gamma exposure and radon flux. The thickness of topsoil and dirt in the cover affects how much the gamma exposure and radon flux are mitigated. Cleanup standards could dictate allowable gamma exposure, radon flux, and design life (e.g., 100 years, 200 years), which would impact the thickness of soil and rock to mitigate erosion

CERCLA specifies that remediation goals be established to meet a 10^{-4} to 10^{-6} incremental lifetime cancer risk. The CERCLA risk-based approach tries to achieve unrestricted use, typically using a residential use scenario; however, since most public lands do not allow residential use, recreational scenarios (e.g., BLM allows 2 weeks for a camper to stay in one place) [5] are used, resulting in higher levels of cleanup. Past CERCLA AUM projects have used cleanup levels of 1.2 to 50 pCi/g (0.04 to 1.85 Bq/g) for Ra-226 depending on the risk scenarios used. Ra-226 is commonly targeted because the soil concentration level can be detected by field instruments (e.g., scintillometers, sometimes referred to as Geiger counters), which correlate gamma activity to a Ra-226 soil concentration. Also, since the Ra-226 is commingled with other radioactive isotopes and heavy metals, it is assumed that if Ra-226 is cleaned up, then other metals and radioactive contaminants, such as uranium, are also cleaned up. Draft BLM guidance uses the US EPA Title 40 *Code of Federal Regulations* Part 192 standards for Ra-226 of 5 pCi/g (0.18 Bq/g) above background in the top 15 cm of soil, and 15 pCi/g (0.56 Bq/g) in any subsequent 15 cm layer [6].

The relevant cleanup standards have an impact on costs, scope, and risk reduction. Rather than pick a cleanup standard to base costs on, assumptions were made on how much waste rock and contaminated soils were typically remediated for each mine size category.

Field Data

Because limited data existed for individual mines, field verification was conducted to fill in data gaps, collect additional radiological data, and validate assumptions. Eight mining regions in six different states were visited. Trip reports were written for each of the 84 AUMs visited. Information collected included radon and gamma measurements, distance to nearby streams or population centers, number of features on the site, and numerous pictures documenting existing conditions. Preliminary site-specific gamma and radon data collected can be summarized as follows:

Range of Gamma Exposure Rates (microroentgen per hour)
- Minimum: 7–34
- Maximum: 17–730
- Average: 16–125
- Background: 7–30 (one outlier of 70)

Range of Radon Readings (Working Levels)
- Background: 0–0.01 (one outlier of 0.02)
- Range: 0–118 (high reading near a collapsed portal)

On individual sites where measurements were taken, approximately 70 percent of the sites that were not reclaimed had an average gamma activity of at least two times background, while 70 percent of the sites that were reclaimed had an average gamma activity less than twice background. Because it is not a large set of data, we did not intend to come to any conclusion other than some gamma reduction is achieved by reclaiming waste rock piles.

Many of the sites still had concrete pads, trash, and timber structures; one site had rail, a small locomotive engine, and four ore cars; and another site had a gunpowder magazine. Most of the large open pits visited in Wyoming and Colorado still had highwalls that would be considered a physical hazard; however, several of the pits in Wyoming appeared to be reclaimed.

Priority System

Multiple government entities have conducted reclamation/remediation of uranium mines under a variety of regulatory authorities. The approach to address site hazards and set priorities is partly dictated by the goals of the regulatory programs. Under the Surface Mining Control and Reclamation Act, physical site hazards are considered the highest priority and are generally addressed before any environmental concerns (e.g., contaminant releases to surface water bodies). Conversely, for sites being remediated under CERCLA, releases of hazardous substances are of greatest concern and highest priority. Surface water quality is of greatest concern for sites being addressed under the Clean Water Act.

Prioritization methods generally include a consideration of the severity of hazards associated with a site—physical and environmental—and the likelihood that receptors will encounter the hazards. Sites that are close to populated areas (e.g., towns, schools) or attractive features (e.g., recreation areas, historic sites) are generally considered to be higher priorities than sites at remote locations. Prioritization methodologies range from simple single-parameter rankings, to “high,” “medium,” and “low” categories, and finally to complicated multi-parameter numerical scoring systems. The ability to form joint agency partnerships with multiple funding sources is commonly a consideration in prioritizing cleanups.

Most organizations have prioritized mines for reclamation or remediation based on criteria that are most relevant to their programs.

Radiological Human Health Risk

For a majority of the AUM sites, there are no actual site-specific data to use for the estimation of potential human health risks. Therefore, LM has developed generic conceptual site models (CSMs) to explain potential exposure to receptors. The CSMs take into account land uses and plausible current and potential future receptors and scenarios (such as a recreational visitor or camper on BLM-managed lands, or a resident on tribal lands). Additionally, available risk information has been reviewed from LM's Uranium Leasing Program Programmatic Environmental Impact Statement, US EPA's TENORM report, and from CERCLA cleanups at individual AUMs.

Potential sources of contamination considered included waste rock piles, potential ground surface contamination, and mine openings. The receptors evaluated included an onsite resident, an offsite resident (at various distances), a recreational visitor, reclamation workers, and an occasional visitor. Potential pathways included inhalation of radon and particulates, external gamma radiation, incidental ingestion of soil, and ingestion of plants, meat, and milk, depending on the scenario. Risk calculations used US EPA's recommended methodology and exposure parameter values.

Generally, the risk estimates show that residential use of a mine site could result in radiological exposures exceeding US EPA's acceptable risk range. Inhalation of radon is the primary contributor to the potential risk for residential use of AUMs. Frequent use of a mine site by a recreational user (e.g., a camper) or repeated visits to mine openings can also result in risks exceeding US EPA's acceptable risk range. External radiation from exposure to waste rock and inhalation of radon at mine openings were determined to be the primary contributors to the risk estimates for the recreational user. For the offsite resident, risk estimates for a distance of 100 meters to 10,000 meters away from an AUM are indicated to be within the US EPA's acceptable risk range and decreased with distance. Inhalation of radon would also be the primary pathway. Since the majority of AUMs are on federal land and are generally removed from population centers, the potential risk to offsite residents would be low.

Federal Agencies' Costs for Individual Sites and Features

Other agencies have published numerous reports that deal with hardrock mines on the public lands they manage. Most of the reports discuss the nature and hazards of abandoned mines and future costs to mitigate the hazards. The reports analyzed were published primarily by GAO, US EPA, BLM, US DOE, and NPS. Except for the GAO reports, the other agencies' reports refer to all abandoned hardrock mines, which include uranium mines. Generally, BLM and NPS, as land management agencies, address the physical hazards as the highest priority. US EPA, using CERCLA, addresses the environmental and human health risks.

The general approach used to develop the range of costs for reclamation and remediation included collecting and reviewing historical data from other agencies. A cost for each of the six size categories was developed in lieu of individual mines. Using data from past reclamation projects, LM developed the number of features (e.g., portals, structures) for each size category. This was validated by visiting 84 mines in different regions and measuring the size and number of attributes.

GAO listed examples of cleanup activities at AUM sites [7]. Total costs and a brief description of the work were provided for 18 AUM sites. Cost information is summarized as follows:

- Closure of adits/portals—average cost of $2K, ranging from $1K to $4K
- Physical hazards—cost estimate for each size category — average cost of $14K per site, ranging from $2K to $33K

- Surface reclamation for small sites—average cost of $11K, ranging from $3 to $17K
- Surface reclamation for medium sites—average cost of $69K, ranging from $31K to 98K
- Remediation ranged from $203K for the Pryor Mountain mine, Montana, to $193M for the Midnite mine, Washington (Two-thirds of the projects cited were estimates, since cleanup had not been started or completed yet.)

GAO reported that BLM and NPS have primarily focused on physical safety hazards to date. (This is supported by other publications.) One BLM official informed the GAO that future costs to address sites with physical safety hazards could be higher because BLM had generally addressed safety hazards that were the least costly due to limited available funding.

The data in the AUM database from the various federal agencies cover a wide range of scopes and a diverse group of features. The data cover a simple adit closure with no identified environmental or human health risks, up to and including a major mine and mill remediation with significant groundwater/surface water impacts. Generally, as shown in Table V, mine features (waste rock piles, adits, shafts, load-outs) can be reclaimed for $2K to $49K per feature with an average cost of $17K. The table shows how variable reclamation costs are.

TABLE V. Agency's Typical Costs for Reclaiming Physical Hazards

Agency	Average Cost ($K, rounded)	Range of Costs ($K, rounded)
GAO	14	2 to 33
BLM	17	7 to 49
NPS	19	15 to 34
Summary	**17**	**2 to 49**

Summary of Reclamation and Remediation Costs

The range of costs for performing reclamation and remediation are presented in Table VI. All values are rounded to the nearest thousand. The range was developed by varying factors such as distance to mobilize a subcontractor, distance to haul topsoil, distance from the mine to the disposal cell (which affected the haul costs), and the type of cover over the disposal cell (e.g., from simple to complex). Costs were not estimated for the 37 Very Large AUMs because they are all in some form of reclamation or remediation or are permitted with reclamation bonds. In addition, because of the wide range of remediation costs and wide range of the sizes of the Very Large AUMs (500,416 to 7,241,382 tons of ore produced), an average cost did not seem representative of that size category.

TABLE VI. Range of Reclamation and Remediation Costs ($K)

Tons	Mine Size	Reclamation	Remediation
0–100	Small	10–70	10–80
100–1,000	Small/Medium	10–80	20–100
1,000–10,000	Medium	50–250	110–840
10,000–100,000	Medium/Large	270–730	2,500–6,500
100,000–500,000	Large	560–1,400	4,900–15,400
500,000+	Very Large	Not Estimated	Not Estimated

Public Outreach

Consistent with the 2013 legislation, LM has consulted with representatives from other federal agencies, affected states and tribes, and the interested public. LM is primarily using existing conferences and forums, such as the 2014 WM Symposia Conference, to solicit feedback. During 2013, LM presented an overview of the AUM Project at five major conferences, the Federal Mining Dialogue Group, and several federal and tribal agencies. Participation in the forums was extremely valuable in developing relationships with pertinent contacts and gaining direct information during the meetings. In addition, LM will hold two webinars to present a summary of the four topic papers to interested agencies and the public.

CONCLUSIONS

Extensive outreach to other federal agencies, states, tribes, and public groups has identified significant variability in the definitions, level of detail, quality, and completeness of data sets. Given the time and resources, it is impossible to physically verify most of the data, much less assess the risks or calculate the costs associated with individual mines. Risks for mine categories can be estimated using conceptual site models. Costs associated with categories of mines for both reclamation and remediation can also be estimated; however, actual risks and costs will vary considerably. There are no national standards for either mine reclamation or mine remediation. This creates uncertainty for mining companies, agencies conducting reclamation and remediation, and regulators. LM will provide factors to be used for prioritization of mines. However, LM cannot accurately prioritize the mines, given the data sets and difference in approaches. Prioritization needs to consider risks and hazards at legacy mines other than uranium.

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