U.S. Department of Energy Office of Legacy Management Legacy Uranium Mine Site Reclamation — Lessons Learned - 12384

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ABSTRACT

The U.S. Department of Energy (DOE) Office of Legacy Management is responsible for administering the DOE Uranium Leasing Program (ULP) and its 31 uranium lease tracts located in the Uravan Mineral Belt of southwestern Colorado (see Figure 1). In addition to administering the ULP for the last six decades, DOE has also undertaken the significant task of reclaiming a large number of abandoned uranium (legacy) mine sites and associated features located throughout the Uravan Mineral Belt. In 1995, DOE initiated a 3-year reconnaissance program to locate and delineate (through extensive on-the-ground mapping) the legacy mine sites and associated features contained within the historically defined boundaries of its uranium lease tracts.

During that same time frame, DOE recognized the lack of regulations pertaining to the reclamation of legacy mine sites and contacted the U.S. Bureau of Land Management (BLM) concerning the reclamation of legacy mine sites. In November 1995, The BLM Colorado State Office formally issued the *United States Department of the Interior, Colorado Bureau of Land Management, Closure/Reclamation Guidelines, Abandoned Uranium Mine Sites* as a supplement to its *Solid Minerals Reclamation Handbook* (H−3042−1).

Over the next five-and-one-half years, DOE reclaimed the 161 legacy mine sites that had been identified on DOE withdrawn lands. By the late 1990s, the various BLM field offices in southwestern Colorado began to recognize DOE's experience and expertise in reclaiming legacy mine sites. During the ensuing 8 years, BLM funded DOE (through a series of task orders) to perform reclamation activities at 182 BLM mine sites. To date, DOE has reclaimed 372 separate and distinct legacy mine sites. During this process, DOE has learned many lessons and is willing to share those lessons with others in the reclamation industry because there are still many legacy mine sites not yet reclaimed.

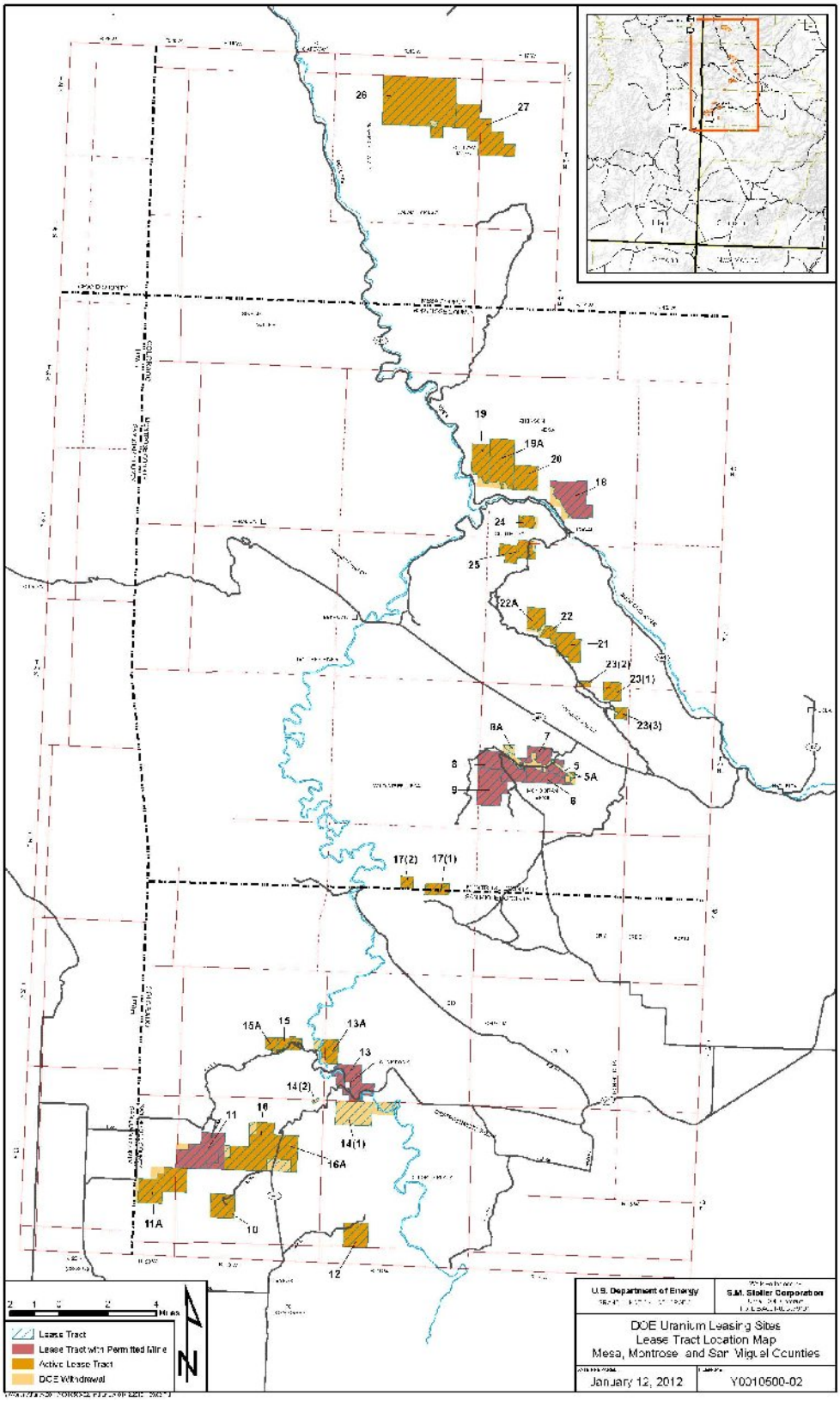

Figure 1. DOE Office of Legacy Management lease tract location map.

INTRODUCTION

The U.S. Department of Energy (DOE) Office of Legacy Management is responsible for administering the DOE Uranium Leasing Program (ULP) and its 31 uranium lease tracts located in the Uravan Mineral Belt of southwestern Colorado. The ULP began in 1948 when Congress authorized the U.S. Atomic Energy Commission (AEC), a predecessor agency of DOE, to withdraw lands from the public domain for the sole purpose of exploring for, developing, and mining uranium ore bodies. Through a series of public land orders, AEC took control of approximately 202,343 hectares (ha) of land in Colorado, New Mexico, Utah, and Wyoming. The U.S. Geological Survey assisted AEC in implementing a massive exploration program to identify lands that contained the most favorable geologic formations for uranium. Subsequently, AEC retained only lands (approximately 10,117 ha) that met the most favorable criteria. Those lands were the basis for the AEC's initial mineral leasing program from 1948 through 1962. A second leasing period was initiated in the early 1970s and continued through 1994. A third leasing period was initiated in 1996 and continued through April 2008, and the fourth leasing period was initiated in April 2008; however, leasing activities have been stayed by a court order and DOE is conducting additional environmental evaluations under the National Environmental Policy Act and other environment statutes.

DEFINING THE PROBLEM

In addition to administering the ULP for the last six decades, DOE also undertook the significant task of reclaiming a vast number of abandoned (legacy) uranium mine sites and associated features throughout the Uravan Mineral Belt. These legacy mine sites were typically operated during the 1940s, 1950s, and 1960s, when no regulations required operators to reclaim their mine sites once mining activities were suspended. Although the DOE lease tracts were withdrawn from the public domain, they remain totally accessible to the general public for a variety of uses, including oil and gas exploration, development, and extraction; other mineral development and extraction; recreation; livestock grazing; timber harvesting; and wood cutting.

Many of these legacy mine sites pose an attractive nuisance and therefore may be a safety hazard. A large percentage of abandoned uranium mine sites in the Uravan Mineral Belt are located in remote areas, once thought to be relatively inaccessible to the public. However, as backcountry recreation (e.g., camping, hunting, fishing, hiking, mountain biking, and four-wheeling with four-wheel drive automobiles and all-terrain vehicles) becomes more popular, these once-remote areas have become easily accessible to the general public during weekend adventures. The public has a natural curiosity about mines and mine sites that lures them into potentially dangerous situations. Unfortunately, the general public often does not recognize all the hazards. Besides the obvious hazards of various mine openings (adits, declines, and shafts), pits, and trenches, there may be conditions that are just as dangerous but less recognizable. These conditions include unstable geological structures, oxygen-deficient atmospheres, and the presence of mine gases such as radon. The mine sites pose

similar hazards to livestock and wildlife that inhabit the areas. Accordingly, these hazards needed to be mitigated to protect the public, livestock, and wildlife.

DOE adopted a policy that would reclaim the adverse environmental conditions resulting from its historical leasing activities. DOE developed a fourfold reclamation strategy:

- Eliminating physical safety hazards that have resulted from previous mining activities, including mine openings, portals, and surface depressions that contain severe vertical drop-offs of greater than 0.9 m;
- Recontouring the areas of disturbance to blend in with the natural, undisturbed topography surrounding the site, while at the same time allowing as much vegetation regrowth to survive as possible;
- Redirecting storm water away from the immediate areas where mine openings have been closed to eliminate the possibility of water flow and erosion into the mine workings and to collect, contain, and control storm water that contacts the site; and
- Decreasing the potential for the general public's exposure to radiological materials.

In 1995, DOE initiated a 3-year reconnaissance program to locate and delineate (through extensive on-the-ground mapping) the legacy mine sites and associated features contained within the historically defined boundaries of DOE's uranium lease tracts. That program ultimately identified 161 separate and distinct mine sites that required some form of site reclamation. In 2007, that number grew to nearly 200 sites as DOE incorporated numerous unpatented mining claims (and the associated legacy mine sites) into its existing lease tracts. Those claims became invalid in the late 1990s and the early 2000s as the U.S. Bureau of Land Management's (BLM's) claim regulations were revised and implemented. Once the claims became invalid, the lands associated with them automatically reverted to the AEC/DOE withdrawals.

Also in 1995, DOE recognized the lack of regulations pertaining to the reclamation of legacy mine sites. DOE contacted BLM and established a dialogue with the various field offices in southwestern Colorado (Grand Junction, Montrose, and Durango) concerning the reclamation of legacy mine sites. Ultimately, DOE collaborated with BLM to develop reclamation criteria specifically tailored to abandoned uranium mine sites. In November 1995, the BLM Colorado State Office formally issued the *United States Department of the Interior, Colorado Bureau of Land Management, Closure/Reclamation Guidelines, Abandoned Uranium Mine Sites* as a supplement to its *Solid Minerals Reclamation Handbook* (H−3042−1).

DOE, over the course of the next five and one-half years (through May 2001) and in accordance with the aforementioned BLM guidance document, systematically reclaimed the 161 legacy mine sites that had been identified on the DOE withdrawn lands. By the late 1990s, the various BLM field offices in southwestern Colorado began to recognize DOE's experience and expertise in reclaiming legacy mine sites. In 2000, BLM executed an interagency agreement with DOE, requesting DOE's assistance in

performing mine closures and reclamation at legacy mine sites located on BLM-administered lands throughout the Uravan Mineral Belt. During the ensuing 8 years, BLM funded DOE (through a series of task orders) to perform similar reclamation activities at 182 legacy mine sites located on BLM-administered lands.

THE RECLAMATION PROCESS

During reclamation activities, DOE pays special attention to the protection of threatened, endangered, or sensitive plant and animal species; wildlife habitat in general; and archaeological or historical resources. Typically, reclamation activities are restricted to the original, previously disturbed areas.

Concurrent with the closure and recontouring activities, cursory radiological scans of the mine site are conducted to identify those areas containing bulk, residual radioactive materials. These materials are used in the initial backfilling of the existing mine openings and portals so that the radioactive materials are placed at depth below ground back into the original mine. Trash and debris associated with the site is collected and either (1) burned and/or buried on site, as appropriate, during backfilling activities or (2) removed from the site for offsite disposal.

Mine openings are permanently secured by the construction and phased installation of bat-gate closures as directed by BLM, the Colorado Division of Wildlife, and the U.S. Fish and Wildlife Service, man-made bulkheads, or conventional closures with available materials, including mine-waste-rock, to backfill the openings. For conventional closures, materials are selectively placed according to size to enhance slope stability and preclude future sloughing and subsiding of the backfill materials after closure is completed. After closure, depressions surrounding or immediately adjacent to the mine openings and portals are backfilled with additional materials and then slightly mounded to provide positive drainage away from the entrance area to preclude future subsidence.

After the mine openings have been permanently secured, disturbed areas are recontoured, as practicable, to provide an undulating surface that closely resembles and blends in with the natural topography of the site. This task includes (1) removing mine-waste-rock materials from existing, natural drainages, as practicable, and eliminating the potential for these materials to re-enter the drainages in the future and (2) reducing the slopes of mine-waste-rock materials, as practicable, to a ratio that is typically less than 3 horizontal to 1 vertical.

During recontouring and reclamation, surface-soil material previously stockpiled or immediately available for use is redistributed across the disturbed areas to promote revegetation. If such material is not readily available within the disturbed area or within a reasonable hauling distance, other soil amendments are added. Large rock and boulders and dead trees and other slash are then placed out across the reclaimed landscape to “break-up” the contours and appear more natural.

Following surface-soil redistribution, most slopes are "pocked" to provide a multitude of mini-catch basins that will act as individual collection points (microcosms) for seeds, soil, and storm water, thereby enhancing revegetation efforts. These pocks are constructed large enough to retain the rainfall from a significant storm event (from several gallons up to tens-of-gallons of water). Additionally, they are constructed so that any storm water leaving one pock immediately enters an adjacent pock, thus greatly reducing the potential for down-slope erosion or rills. Next, major drainage features leading onto the mine site are diverted or controlled, as practicable, around the mine site and/or stabilized in place to reduce the overall effects that major storm water events could have on reclamation efforts and the site in general.

Areas of disturbance that have naturally and successfully reclaimed themselves during the past several decades are avoided unless physical hazards exist that must be addressed. In either case, as much of the existing vegetation regrowth is left as practicable during the reclamation efforts. Disturbed areas are reseeded with a BLM-approved mixture of native grasses, forbs, and shrubs developed for the specific climatic conditions. Silt fences or other suitable devices are installed, as necessary, in or across drainages located immediately below or adjacent to the mine sites to preclude migration of sediments downstream.

INNOVATIVE TECHNIQUES

Since the initial phase of reclamation activities in 1994, DOE has experimented with several innovative closure and reclamation techniques. These techniques include:

- Pocking surfaces to collect, contain, and control storm water.
- The use of polyurethane foam (PUF) to close small-diameter ventilation holes and exploration drill holes.
- The use of weather balloons as closure-support forms in medium-dimension ventilation shafts where PUF plugs are installed.
- The use of weather balloons as temporary radon barriers in adits where bat gates or bulkheads are installed. The balloons can be placed in the mine drift and then inflated to reduce the levels of radon potentially present at the portal area where the work is being done. As the work is completed, the balloon can be deflated and removed.
- The negotiated use (through the applicable surface-management agency) of stock pond sediments, as available, as a source of surface-soil material.
- The use of high-intensity cattle grazing to enhance revegetation efforts where site surface materials lack adequate nutrients and/or where site access is limited or otherwise restricted in a way that precludes the use of conventional tillage equipment.
- The use of culverts in some bat-gate installations, as dictated by site-specific conditions.
- The use of various site features to collect and retain storm water runoff to support livestock and wildlife.

SUMMARY OF RECLAMATION ACTIVITIES

To date, DOE has reclaimed 372 separate and distinct legacy mine sites located throughout the Uravan Mineral Belt. In summary, DOE has:

- Permanently closed 413 mine portal openings;
- Installed 127 bat-gate structures to conserve the associated mine workings for bat habitat;
- Backfilled numerous shallow surface pits and trenches with 148,266 m^3 of mine-waste-rock and other available surface material;
- Recontoured numerous mine-waste-rock dumps (221,125 m^3 of material) to blend in with the surrounding, natural topography;
- Backfilled numerous ventilation shafts with 4,090 m^3 of mine-waste-rock and other available surface material;
- Backfilled and permanently sealed 186 bored ventilation holes with available surface material and polyurethane foam;
- Permanently sealed and closed 402 exploration drill holes with polyurethane foam;
- Demolished and disposed of 26 structures in various states of disrepair;
- Collected and properly disposed of mine-related trash and debris from 297 sites; and
- Reseeded approximately 149 ha of disturbed ground with an approved native-species seed mixture.

Figure 2 shows DOE reclamation before and after pictures of the Uintah Mines complex on DOE Lease Tract C–SR–10.

LESSONS LEARNED

The reclamation efforts undertaken by DOE during the last 17 years have not always led to complete success, but the successes far outnumber the failures. Many of the reclamation techniques applied during the process have been adapted and revised to improve their usefulness. Accordingly, much has been learned through the process. DOE would like to highlight these few thoughts:

- Plan the reclamation project well in advance so that there is adequate time to (1) perform threatened and endangered species (including bats and potential bat habitat), raptor, or cultural resource surveys that may be required; and (2) prepare site documents required, including National Environmental Policy Act documentation, statements of work, and job safety analyses. The better the planning process is, the smoother the project will proceed from start to completion.

Figure 2. Uintah Mines complex before (top) and after (bottom) DOE reclamation.

- An experienced reclamation staff is the key to an efficient, cost-effective reclamation project. The reclamation staff need to be visionaries who can look at the abandoned mine site and envision what it needs to look like when the reclamation is complete. Unless mandated, stay away from contracts that use engineering estimates for the amount of materials to be moved. Any discrepancy in these numbers will cost the project dearly. Instead, let the reclamation staff determine what needs to be done, what pieces of equipment (type and size) are required to complete the project, what personnel (equipment operators and laborers) are required to complete the project, and the scheduled duration of the project. Then procure a contractor to provide the necessary equipment and personnel for the required duration based on the project schedule. This allows the reclamation staff to remain flexible during the project so they can determine when each phase of the project is successfully completed. In concert with this technique, basic ordering agreements (BOAs) that establish price quotes for the equipment and personnel can be negotiated with qualified contractors well in advance of the actual reclamation projects. Subsequently, when a reclamation project comes along, simply refer to the approved list of BOA contractors and select the one that's right and available for the job.
- If the mine site is in an area where the surface-soil material is more than a meter deep, consider digging a large trench around the entire mine-waste-rock dump (if possible) with a large trackhoe excavator. The trench should be excavated to the base of the soil layer and should be 2–4 m wide. The soil material removed should be stockpiled on the outside of the trench. The mine-waste-rock should then be "dozed" into the trench to lower the overall profile of the mine-waste-rock dump. Once the trench is full, the soil material should be folded back over the top of the entire mine-waste-rock dump area. This technique should substantially lower the overall profile of the dump area.
- Leave the final surface of the reclaimed site rough, and the rougher the better. Smooth surfaces will not retain water, and water (limited rainfall) is the key to revegetation success. Contour the site in an undulating fashion to blend in with the surrounding topography. Then, roughen the surface (using "pocking" or other similar techniques), so that any moisture that falls on the site stays where it falls. Less runoff means less erosion.
- Cover the reclaimed site with any surface soil materials available, without disturbing more ground. Even a thin veneer of soil is very helpful in getting things to grow, so spread the material that's available around, especially if the source is limited. Use sediments from nearby stock ponds if they are available and are determined to be free of noxious weeds. That's potentially a win-win situation for the project and the area livestock and wildlife.
- Do not expect too much revegetation success during the first 3 post-reclamation years. Most arid environments in the southwestern region of the United States are delicate and difficult to duplicate. Accordingly, the success of a revegetation project shouldn't really be assessed until after the third growing season. Patience is required when it comes to the revegetation of abandoned mine sites. Contractor performance and lease provisions should reflect this as well.

- Substantial vegetation (especially shrubs and trees) that have grown within the project site prior to the reclamation activities should not be disturbed unless it's absolutely necessary. Furthermore, spring moisture can be the greatest ally for site dust control.
- Use your imagination. It is the seed from which the next innovative reclamation techniques will blossom.

CONCLUSION

DOE currently administers 31 lease tracts (11,017 ha) that collectively contain over 220 legacy (abandoned) uranium mine sites. This contrasts to the millions of hectares administered by the BLM, the U.S. Forest Service, and other federal, tribal, and state agencies that contain thousands of such sites. DOE believes that the processes it has used provide a practical and cost-effective approach to abandoned uranium mine-site reclamation. Although the Federal Acquisition Regulations preclude DOE from competing with private industry, DOE is available to assist other governmental and tribal agencies in their reclamation efforts.