In Partnership with Amentum and TFE

United for the Legacy Management Mission

LMS/DRM/41156-0.5

Defense-Related Uranium Mines Verification and Validation Work Plan Campaign 2: Navajo Nation

October 2024

Work performed under DOE contract number 89303020DLM000001
for the U.S. Department of Energy Office of Legacy Management.

This document has been designed for online viewing.

Contents

Figures

Tables

Appendixes

Abbreviations

ACSR	after-calibration source response
AEC	U.S. Atomic Energy Commission
ALARA	as low as reasonably achievable
AUM	abandoned uranium mine
BLM	U.S. Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
cm^2	square centimeters
COC	chain-of-custody
COI	constituent of interest
CPM	counts per minute
DI	deionized
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQO	data quality objective
DRUM	Defense-Related Uranium Mines
DSP	DRUM Safety Plan
EC	Environmental Compliance
EFT	electronic file transfer
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
ERF	*Environmental Review Form*
ERG	Environmental Restoration Group, Inc.
ESA	Endangered Species Act
FOP	Field Operations Plan
ft	feet
ft^2	square feet
g	grams
GIS	geographic information system
GNSS	global navigation satellite system
IDW	investigation-derived waste

IPaC	Information for Planning and Consultation
keV	kiloelectronvolts
LM	Office of Legacy Management
LMFSC	Legacy Management Field Support Center
LMS	Legacy Management Support
mg	milligrams
µR/hr	microroentgens per hour
mL	milliliters
mrem/yr	millirem per year
NAD 83	North American Datum of 1983
NAMLRD	Navajo Abandoned Mine Lands Reclamation Department
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NNEPA	Navajo Nation Environmental Protection Agency
ONE	operations not evident
PDOP	Position Dilution of Precision
PGIS-2-1	portable ground information system
POC	point of contact
QA	quality assurance
QAM	Quality Assurance Manual
QAPP	Quality Assurance Program Plan
QC	quality control
QGIS	Quantum Geographic Information System
RCT	radiological control technician
RSA	risk scoring assessment
URP	Uranium Related Programs
USC	*United States Code*
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
UTV	utility task vehicle
V&V	verification and validation

Forms Referenced in This Manual

LMS forms are accessible on the **Document Management** homepage > **LMS Forms**.

After-Calibration Source Response Checks Data Sheet	LMS 1974
Daily Instrument Response	LMS 1974a
DRUM Verification and Validation Work Plan Process (QA/QC)	LMS 4501 DRUM
Plan of the Day/Plan of the Week	LMS 2130
Pre-job Brief/Safety Meeting Attendance Record	LMS 1554
Radiological Survey Map	LMS 1553
Shipping Request	LMS 1051
Supplemental Emergency Response Information (SERI)	LMS 1415
Water Sampling Field Data	LMS 1805

LM forms and templates are accessible at
LM Portal > **Services** > **Controlled Documents** > **LM-Federal Controlled Documents**.

Environmental Review Form	LM-Form-4-20.3-4.0

Glossary

adit. A mine opening greater than 10 feet (ft) deep driven horizontally for the purpose of providing access to a mineral deposit.

attractive nuisance. A potentially hazardous object or feature that arouses curiosity to the point of enticing an individual into a potentially hazardous situation for the purpose of investigating the object or feature; features may include buildings and structures, adits or shafts, equipment, nearby springs or bodies of water shown on maps, or other attractions that could encourage an individual to spend time on a mine property.

closed. The egress condition of a single mine feature such as an adit or shaft with a barrier which prevents human access to the mine.

decline. A sloping, three-sided (two sides and a floor) excavation trending from ground surface elevation to a subgrade mine entrance.

disturbed area. The portion of the ground surface that is impacted by mechanical mining-related activities. The area includes mine entries, rim cuts, open pits, waste rock piles, topsoil, and overburden stockpiles. Roads providing access to mines and natural features such as ephemeral drainages are excluded from the disturbed area. Features associated with a mine, but which are separated from the disturbed area by undisturbed lands will be mapped as disparate, isolated portions of the disturbed area for purposes of completing the risk scoring assessment. Examples of such features may include vents, buildings, and waste rock piles.

drainage. A large-scale natural erosional feature present at a mine but which existed before the mining disturbance (e.g., wash, ephemeral or perennial creek, canyon floor).

duplicate mine resolution. The resolution of duplicate mines is complete when two or more mines are reconciled into a single name and location. Irrelevant names and incorrect locations are removed from the Defense-Related Uranium Mines (DRUM) Program database. Merged duplicate records are documented using a certificate generated by the database titled the *Defense-Related Uranium Mines Program Verification and Validation Certificate of Completion: Merged Duplicates*.

ecological unit. A plant community that is distinct in terms of dominant species and successional stage from proximate communities within the mine disturbed area and surrounding undisturbed areas.

endangered species. Any species that is in danger of extinction throughout all or a significant portion of its range and that is protected by federal, state, or tribal statute.

engineered closure. A mine safety closure designed by a state or federal abandoned mine land program or equivalent. The closure may have been installed by an abandoned mine land program, a mining company, or other entities.

environmental sampling. A verification and validation (V&V) activity designed for the collection of soil, sediment, water, gamma radiation, or other environmental and ecological data at a mine.

environmental sampling completed. Environmental sampling at a mine is complete when the U.S. Department of Energy DRUM Program database is updated with field data collected by the Legacy Management Support contractor or obtained from an approved third party. V&V completion is documented when the database includes the date that field sampling occurred.

erosional feature. Small-scale erosion resulting in sediment transport of mined waste or disturbed soil from wind, water, or slope failure (e.g., rill, gully, unstable slope, soil piping, or sheet wash).

Field Operations Plan (FOP). A plan written to ensure that field teams are ready to perform their work as described in the *Defense-Related Uranium Mines Verification and Validation Work Plan Campaign 2: Navajo Nation* (DOE 2024b) (V&V Work Plan) before initiating field activities. FOPs are used to coordinate fieldwork and document that the necessary sampling and inventory preparations have been completed before deploying to the field. The FOP describes any deviation from the V&V Work Plan to the extent that such are anticipated before initiating environmental sampling work, lists the mines to be evaluated, describes the division of work tasks, identifies the inventory and environmental sampling responsibilities, and lists partner agency contacts and emergency response contact information.

habitat. A specific set of physical and biotic factors to which an individual, a species, or an ecological community is adapted.

hazard. A threat to physical safety of humans, the environment, or animals posed by conditions at a mine; something that can cause harm.

human use. Observable evidence of past and present human activity: Current activity might include mine inhabitation, recent campfire rings showing evidence of burning, or vehicle tracks, and past activity might include weathered foot or vehicle tracks, vegetative growth invading use areas, or relics such as weathered, discarded cans or trash. It is used in the context of the risk scoring assessment to partially describe degrees of mine occupancy.

inventory. A V&V activity designed primarily for the collection of observational data, such as the location of specific points or features at a mine. These geographic points may include the perimeter of the disturbed area, the crest and toe of a waste rock pile, or the location of a mine entry.

mine entry. A point at which people, wildlife, or materials can enter or leave an underground mine. Mine entries include adits and shafts but are not the same as ventilation raises meant for the intake or exhaust of mine air.

mine site location. A point at or immediately adjacent to a defense-related uranium mine from which most, if not all, mine features are visible.

mine size. Determined by the U.S. Atomic Energy Commission-documented quantity (tons) of uranium ore produced (DOE 1997). Mine sizes by production are as follows:

small mine = 0–100 tons of ore

small/medium mine = 100–1000 tons of ore

medium mine = 1000–10,000 tons of ore

medium/large mine = 10,000–100,000 tons of ore

large mine = 100,000–500,000 tons of ore

very large mine >500,000 tons of ore

needs maintenance. Status of a mine feature indicating that engineered abatement of physical hazards has been breached or otherwise damaged, and the engineering controls require maintenance to remain protective.

not addressed. Status indicating that no work has been conducted to reclaim or remediate the mine.

notifiable feature. A mining-related hazard that could pose a significant and immediate threat to a visitor who encounters such. Notifiable features may include subsidence areas, shafts, explosives, chemicals, or severely compromised structures.

open. The egress condition of a single mine feature such as an adit or shaft either without a barrier to human access or where underground mine workings may be observed from outside of the mine without a safety closure being present.

operations not evident (ONE). Status of a reconciled mine location where no evidence of mining operations is apparent during completion of V&V activities.

physical feature. An excavation created for the purpose of exploring for, extracting, or developing an orebody and consequent openings in the ground surface which result from such activities. Examples of physical features include trenches, prospects, pits, shafts, adits, vents, and subsidences.

portal. A surface entrance to an adit.

potential wetland. An area with a vegetation type that is ecologically distinct from surrounding vegetation types because of surface water or shallow subsurface water. Potential wetlands are generally lusher and contain at least one wetland plant species (a plant classified as an obligate or facultative wetland species in the Arid West Region on the U.S. Army Corps of Engineers National Wetland Plant List).

prospect. A mine opening or excavation related to mining activities with a depth between 4 and 10 ft.

reclaimed. Mine description indicating that, in actions not performed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), waste rock or other portions of the mine, such as roads or ponds, have been recontoured or graded to a stable condition. The primary purpose of these actions is to minimize the potential for future erosion and make items blend with the original site topography. This may include covering the site with enough topsoil to enhance revegetation. Unless otherwise noted in a FOP, complete V&V activities as described herein are conducted at reclaimed mines.

reconciliation. The process of evaluating mine location data, U.S. Atomic Energy Commission production records, and other pertinent information for the purpose of correlating a specific mine with a specific geographic location.

remediated. Mine description indicating that, in CERCLA actions, response actions have been taken, or Action Memoranda signed to mitigate the release or potential release of a CERCLA hazardous substance. The primary purpose of these actions is to mitigate potential risks to human health and the environment. Such actions include, but are not limited to, consolidation areas or repositories.

rim cut. A mining technique in which uranium ore is removed by relatively shallow underground extraction methods. Mining follows the trend of the ore-bearing formation parallel with the outcrop and generally occurs at or near the top of a cliff or slope.

risk. Potential exposure to health or environmental hazards posed by conditions at a mine.

safeguard. An engineered barricade constructed for the purpose of preventing site visitors from approaching or accessing a mine or mine feature. Some state and federal abandoned mine lands agencies refer to safeguards as “mine safety closures.”

sediment shed. Earthen material transported from a disturbed area by aeolian or fluvial processes and subsequently deposited outside of the disturbed area of a mine.

shaft. A vertical excavation that provides access to an orebody, sometimes equipped with a hoist at the top that lowered and raised a conveyance for workers and materials at a mine.

shallow excavation. A horizontal or vertical excavation less than 4 ft deep which is associated with mining or exploration activities.

special-status species. Species listed as threatened or endangered or proposed for listing under the Endangered Species Act and species designated for special protection by states, tribes, and other agencies including the U.S. Bureau of Land Management and U.S. Forest Service.

structure. A building or building remnant originally constructed for the purpose of facilitating mining operations. Examples include former offices, ore bins and loadouts, stand-alone powder magazines, workshops, and equipment storage facilities.

subsidence. Downward deflection of the earth’s surface as a result of a roof (back) failure in an underlying mine. The result of subsidence may be a shallow trench, a vertical hole, or a broad downward deflection on the ground surface. The subsidence feature might or might not be open to the underground mine workings.

threatened species. Any plant or animal species likely to become endangered within the foreseeable future throughout all or a significant portion of its range and also protected by federal, state, or tribal statute.

trench. An excavation created for the purpose of exploring a potential ore-bearing formation. They are generally longer than wide and sometimes open at both ends.

utility task vehicle (UTV). Vehicle type that also includes off-highway vehicles and all-terrain vehicles that may engage in cross-country travel along roads not suitable for four-wheel-drive vehicles.

verification and validation (V&V). The DRUM Program process of verifying historic records and validating current mine conditions. Collectively, V&V work is the process of reconciling mine data, inventorying mine features, performing environmental sampling, and documenting results in a database and report that provides a risk scoring assessment to federal land management agencies.

waste rock. Materials associated with an orebody of interest which, due to their subeconomic value, are disposed of onsite. Waste rock may contain constituents of interest and may exhibit elevated gamma radiation and thus is a focus of the DRUM Program.

waste rock crest. The area of topographic transition of a waste rock pile from a relatively flat surface to a downward trending slope. Generally, the crest is at or near the top of the waste rock pile and is accessible for environmental sampling.

waste rock toe. The area of topographic transition of a waste rock pile from a downward trending slope to a relatively flat surface below the crest. Generally, the toe of a waste rock pile is at or near the base of the pile.

1.0 Introduction

This verification and validation (V&V) work plan (V&V Work Plan) provides structure and guidance for successful coordination between field personnel and partnering agencies regarding preparation for and performance of V&V activities on the Navajo Nation. In addition, the V&V Work Plan documents the rationale and develops consistency in procedures and methodologies to achieve the Defense-Related Uranium Mines (DRUM) Program's objectives. Ultimately the data gathered will be used to evaluate the risks at each mine according to a combination of multiple lines of evidence and risk screening approaches.

1.1 Background

The *Defense-Related Uranium Mines Report to Congress* (DOE 2014b) (Report to Congress) found that U.S. Atomic Energy Commission (AEC) records were frequently inaccurate regarding the locations and descriptions of mines from which uranium ore was extracted for defense-related atomic energy activities from 1947 to 1970. In addition, information about the status of these mines was largely unknown or not well documented. To develop a record of the locations and current conditions of these legacy uranium mines, the DRUM Program was created within the U.S. Department of Energy (DOE) Office of Legacy Management (LM). The DRUM Program, through its V&V work, will determine the location, status, and current environmental, human health, and safety conditions of legacy uranium mines throughout the country. In addition, the DRUM Program has established a screening level evaluation and risk ranking system for physical hazards, accessibility, and potential risk to human health and the environment at these mines.

In this document, the word "mine" refers to a mine included in the DRUM Program. LM defines a mine as a feature or complex that is generally associated with a patented or unpatented mining claim (established under the General Mining Law of 1872, as amended) or a lease of federal, state, or tribal/Native nation lands or private property from which some or all of the extracted uranium ore was sold to AEC (DOE 2014b). A mine may be a feature such as a surface or underground excavation, or it may comprise an area containing a complex of multiple, interrelated excavations. Associated mining-related features typically include adits and portals, surface pits and trenches, highwalls, overburden piles, waste rock piles, structures, shafts for ventilation or other purposes, stockpile pads, water retention basins or treatment ponds, close-spaced development drill holes, and trash and debris piles.

In the Report to Congress, DOE reviewed information obtained from AEC records, various federal and state agency databases, tribal abandoned mine lands programs, private company and public input, maps, and other documents, and estimated that 4225 mines across the United States provided uranium ore to AEC from 1947 to 1970. DOE revised this estimate to 3472 mines following completion of the DRUM Program reconciliation process in 2021 (see Section 4.2). It was further determined that approximately 2500 of these mines may exist on public land managed by the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) (DOE 2014a). Mines in the DRUM Program fall under various land ownership scenarios that influence V&V strategies and the overall program organization. Mines existing on various types of lands have been grouped into the following three campaigns: Campaign 1 includes mines on public lands, Campaign 2 includes mines on tribal nations, and Campaign 3 includes mines on private property. Mines on the Navajo Nation are generally associated with mining leases or mining permits. Some mines listed as abandoned may have been reclaimed or remediated, while others have current operating permits but may have abandoned mine features within the permitted areas that are not yet reclaimed or remediated. Mines in any of these categories could be included in this V&V Work Plan; inclusion will be determined by affected federal and state partner agencies.

1.2 Uranium Mining Legacy on the Navajo Nation

From 1944 to 1986, almost 30 million tons of uranium ore were extracted from Navajo lands under leases with the Navajo Nation. This mining had significant impacts on the Navajo people. Many Navajos worked in the mines and often lived near the mines with their families. Although this was not well understood at the time, uranium mining can cause significant long-term health impacts from the inhalation of radioactive materials, hazardous chemicals, and radon gas. Even though uranium mining no longer occurs on the Navajo Nation, its legacy continues to negatively impact the Navajo people.

1.2.1 Mitigation of Uranium Mining Impacts

Efforts were underway to better understand the impacts of uranium mining on the Navajo Nation before the last mine closed in 1986. The U.S. Environmental Protection Agency (EPA) has a long history of working with the Navajo Nation to address impacts of uranium mining. In 1978, EPA, the Navajo Nation Environmental Protection Agency (NNEPA), and the Navajo Abandoned Mine Lands Reclamation Department (NAMLRD) set out to identify and locate uranium mines on the Navajo Nation and to gather information about their potential impacts. Beginning in the 1980s, several remediation efforts were completed to mitigate the impact of mining-related materials on nearby communities. These efforts continue to today and have more recently been aided by settlement money from former operators of uranium mines on the Navajo Nation.

The major focus of the DRUM Program has been on the identification and ultimately the safeguarding of hazardous features at abandoned uranium mines (AUMs). The Navajo Nation has made considerable progress in addressing hazardous mine features. Since 1989, NAMLRD has been addressing physical safety hazards at AUMs. These actions have greatly decreased the potential for injuries from abandoned mine features (e.g., shafts, adits). However, conditions at these mines change over time, and the DRUM Program will add value to the Navajo Nation by evaluating current conditions at each mine, sharing this information with the Navajo Nation, and working together to mitigate the identified physical hazards.

1.2.2 DRUM Sites on the Navajo Nation

As mentioned above, the DRUM Program clearly defines which AUMs are included in the program, and not all AUMs on Navajo Nation land meet the program's criteria. In addition, LM does not have authority under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Title 42 *United States Code* Section 9601 et seq. [42 USC 9601 et seq.]) to conduct remediation at mines that are being investigated under CERCLA. The current remediation efforts underway by EPA and the Navajo Nation include many abandoned mines that would normally be addressed by the DRUM Program. However, the DRUM Program will not conduct V&V activities at these sites because remediation work is currently funded under CERCLA by EPA and the Navajo Nation. There are also mines on the

Navajo Nation recognized by EPA that do not meet the definition of a mine under the DRUM Program. These mines do not have historical ore production records, but because mining occurred before 1970 and the mines are not currently funded for remediation under CERCLA, they have been included for evaluation by the DRUM Program. For purposes of this V&V Work Plan, these mines are referred to as "orphan" mines. To help mitigate the hazards posed by the orphan mines, LM will conduct V&V activities at these sites. Table 1 summarizes the current information regarding uranium mines on the Navajo Nation. The estimates may change with the discovery of new information and the evolution of the program. Section A5.0 of Appendix A provides a crosswalk of the mines as defined by the various organizations. Figure 1 shows the 200 mines on the Navajo Nation that are currently scheduled for V&V activities under the DRUM Program.

Table 1. Summary of DRUM Sites on the Navajo Nation as of February 1, 2024

Mine Site Type	DRUM Program Action	Number
Total DRUM sites on Navajo Nation[a]		**386**
Funded DRUM sites (CERCLA mines)[b]	No V&V activities	186
Unfunded DRUM sites (non-CERCLA mines)	V&V activities	161
EPA "orphan" mines[c]	V&V activities	39
Total mines to verify and validate		**200**

Notes:

[a] These numbers are based on the method used by the DRUM Program to define a mine, which does not always agree with how EPA or the Navajo Nation define mines. These data are the most recent and may be slightly adjusted based on new information.

[b] The DRUM Program will not conduct V&V activities on sites that are currently funded under CERCLA and were or will be addressed by EPA and the Navajo Nation.

[c] These sites are currently not funded for CERCLA actions and do not meet the definition of what constitutes a mine under the DRUM Program. Nevertheless, to foster a "one-government" approach and to fulfill the mission of protecting human health and the environment, the DRUM Program will conduct V&V activities at these sites.

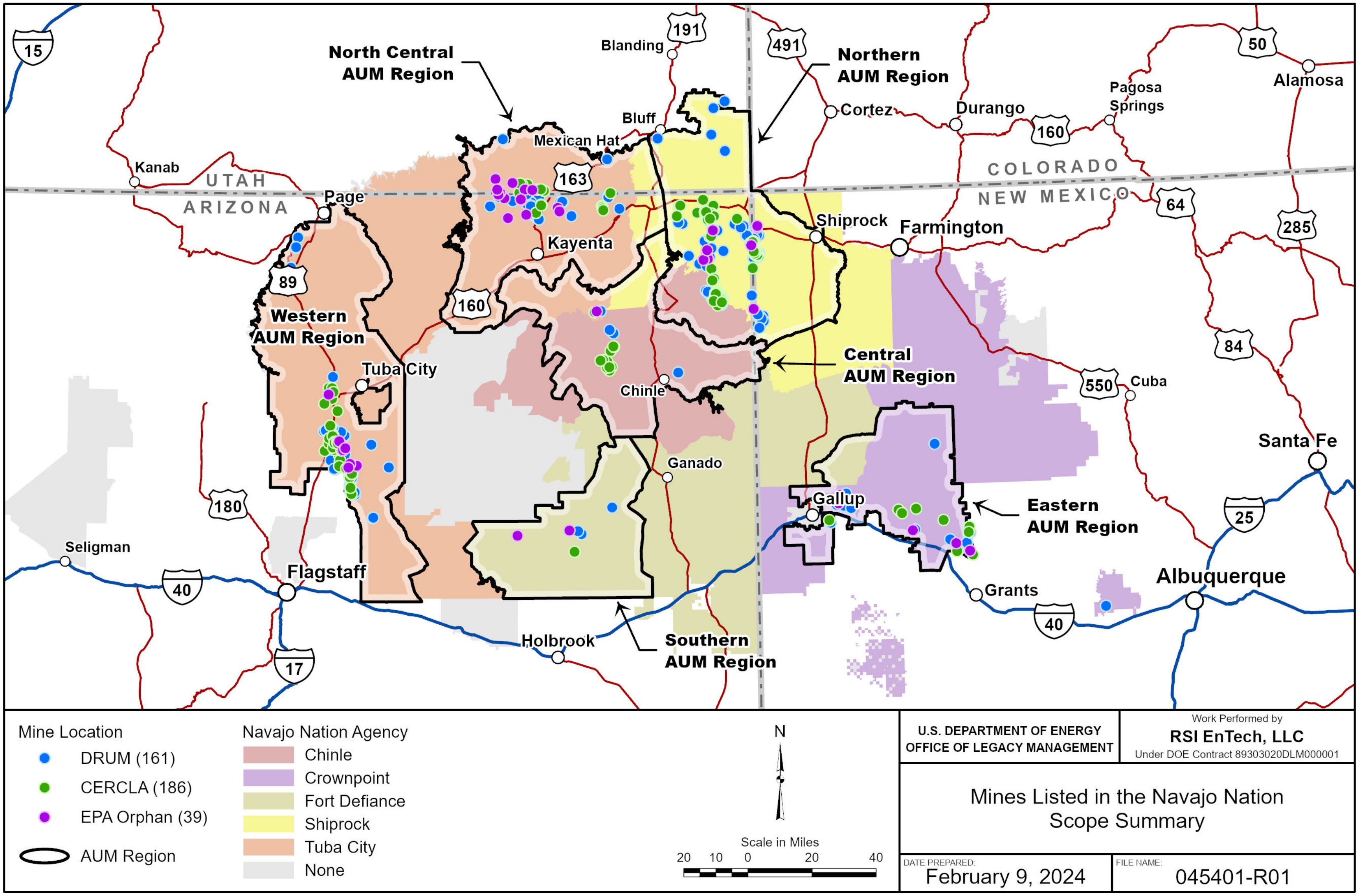


Figure 1. Uranium Mines on the Navajo Nation

2.0 Purpose and Objectives

2.1 Purpose of the V&V Work Plan

The purpose of the V&V Work Plan is to provide objectives, direction, and methodologies for how LM will collect, store, and report information during V&V activities at mines on the Navajo Nation. This work will be a collaborative effort with the Navajo Nation and EPA, which are considered partners in these endeavors.

2.2 Objectives

The primary objective of the DRUM Program is to verify the location, production records, and status of reclamation or remediation and to validate current site conditions of legacy uranium mines. The data gathered will be used to evaluate the mines' environmental risks and physical hazards using a combination of weight-of-evidence and risk screening approaches that will help land management agencies prioritize mines for possible future actions.

To accomplish these objectives, DOE is assessing various datasets and collecting new data to make mine-specific determinations and perform risk scoring assessments (RSAs) of these mines. Most of the data will be observational and descriptive in nature (e.g., the location, complexity, and general condition of mine features); however, some will be newly acquired analytical data. The objectives and data inputs for the observational and analytical data consist of the following:

1. Existing information garnered from AEC historical records, including mine location; historical production; partner agency records; status of permitted mines; and other resources (e.g., the U.S. Geological Survey [USGS] records and reports and U.S. Fish and Wildlife Service [USFWS] Information for Planning and Consultation [IPaC]) pertaining to special-status species, designated critical habitat, area geology, watersheds, and the presence of surface water. As described in Section 4.3 below, information gathered from existing sources will be evaluated during the reconciliation, inventory, and sampling processes.
2. Observational data will be collected during inventory efforts by partner agencies or by DOE's Legacy Management Support (LMS) contractor. Data will include the following: the mine location; physical hazard locations and photographs; evidence of human use or visitation; evaluation of the potential for human access; locations of significant mine features, including the footprint and volume of waste rock piles; and ecological information, including plant species presence and abundance and evidence of special-status species or their potential habitat.
3. Analytical data for metals and radiological activity are obtained through gamma radiation measurements, radiological screening, and soil and sediment shed sampling. These data are compared to benchmarks established by BLM and DOE and will be used to screen for potential human health risks.

The multiple lines of evidence screening approach (i.e., the RSA) is used to evaluate the potential risks posed by each mine, as described in Section 3.0 and Appendix E. The data quality objectives (DQOs) process (see Appendix A) provides a strategic planning approach to ensure that the analytical sample collection and subsequent results are adequate in quality and quantity to support determinations regarding potential risks to human health. Appendix A presents a detailed summary of the steps for planning for analytical sample and data collection. Although observational data are collected for physical hazards, these data are not considered relevant to the DQO process.

3.0 Risk Scoring Assessment

To meet the objectives described in Section 2.0, LM defined data needs and assembled an RSA approach based on the most likely conceptual site models that describe the potential physical hazards at a mine on the Navajo Nation. This information is then used to develop risk screening benchmarks to objectively evaluate observable physical hazards at each mine. V&V activities will establish multiple lines of observational evidence to generate risk scoring information regarding potential physical safety hazards and potential risks to human health.

In the case of Campaign 2, unlike Campaign 1, risk scores will not be developed for constituent of interest (COI) or gamma radiation data. COI information will, however, include tables and bar charts showing analytical results compared to screening benchmarks, which will be provided to Navajo Nation agencies and U.S. government agencies as part of the final reporting for each mine. This approach provides sufficient flexibility to allow other agencies to establish priorities based on their needs, requirements, and budgets.

3.1 Potential Exposure Scenarios

To assist in making risk-informed decisions on future potential actions, it is important to establish the most likely exposure scenarios on the Navajo Nation. Navajo Nation land could be the potential site of additional exposure scenarios beyond those that could occur on federal public lands, and these scenarios could result in longer-term exposures. Using additional risk screening exposure scenarios provides useful information for prioritizing possible future actions at the mines. These exposure scenarios and the associated screening levels focus on the most significant exposure pathways and contaminants. The following four exposure scenarios will be evaluated:

- Recreational (camping)
- Livestock rancher
- Residential
- Navajo Nation surrogate residential

Each of these scenarios is explained in more detail below, and summaries of the screening levels for gamma radiation and chemical constituents (including radium-226) are presented in Sections 3.1.1 through 3.1.4.

3.1.1 Recreational Scenario

The recreational screening scenario is the same scenario currently used for public lands and will help the comparison of data across the three DRUM campaigns. The potential human health risks at a given mine are compared to benchmarks associated with a recreational user (i.e., a person camping). For the chemical constituents, risk scoring is based on ratios comparing chemical constituent concentrations in waste rock samples to BLM screening levels (after subtracting background concentrations). The recreational screening level (BLM 2017) conservatively assumes an exposure duration of 14 days per year for 26 years (2 years as a child and 24 years as an adult). In addition, the recreational screening level assumes an equivalent hazard quotient of 1 for noncarcinogens and a threshold of 10^{-6} for carcinogens. The radium-226 results from waste rock samples are compared to benchmarks described in Brown (2017). The benchmark in Brown (2017) also assumes a recreational scenario for a 2-week per year exposure. Screening levels and laboratory detection limits are provided in Table 2.

Appendix B contains supporting documentation pertaining to the screening levels and methods of deriving these values. In developing these screening levels, BLM assumed an individual would be exposed to mine-related COIs as a result of soil ingestion, dermal contact with soil, and inhalation of airborne particulates.

3.1.2 Livestock Rancher Scenario

A viable exposure scenario for the Navajo Nation is that a livestock rancher could establish a camp on a waste rock pile for a longer period than a recreational camper. Unlike more established exposure scenarios, this scenario does not have a commonly used set of exposure assumptions; therefore, reasonable exposure assumptions must be developed. In this case, it is assumed that a livestock rancher establishes a camp directly on a waste rock pile for a 6-week period over 1 year. Aside from this change, the same assumptions described in BLM (2017) and Brown (2017) are used for this scenario (the livestock rancher returns to the same waste rock pile for 26 years and is exposed to the same COIs, assuming the same hazard quotient of 1 for noncarcinogens and 10^{-6} for carcinogens). In estimating risks, a change in the exposure duration (weeks of exposure per year) is proportional to the end result.

3.1.3 Residential Scenario

Although not likely, it is possible a residential structure could be constructed directly on a waste rock pile. EPA has developed regional screening levels as a unified and consistent way to screen chemical constituents at CERCLA sites; however, these levels are also useful screening tools for other types of sites. The COI screening levels for DRUM Program sites were extracted directly from the EPA regional screening level summary tables (EPA 2024a; EPA 2024b). In the residential scenario estimates, it is assumed that the receptor spends most of the day at home. The activities for this receptor involve typical household tasks and outdoor activities. The resident is assumed to be exposed to contaminants from incidental soil ingestion, dermal contact with soil, and fugitive dust inhalation. Adults and children exhibit different ingestion rates for soil, which was accounted for as follows: The child resident is assumed to ingest 200 milligrams (mg) of soil per day, while the adult resident is assumed to ingest 100 mg of soil per day. Age-adjusted intake equations were developed to account for receptor intake changes over time. The residential scenario ingestion rates additionally assume exposure to indoor dust. The receptor is assumed to be at the residence 350 days per year and live in the residence for 26 years (20 years as an adult and 6 years as a child). The residential scenario has the same assumptions as the recreational and livestock rancher screening scenarios of an equivalent hazard quotient of 1 for noncarcinogens and a threshold of 10^{-6} for carcinogens.

Table 2. Soil Screening Levels and Laboratory Detection Limits (mg/kg)

Analyte	Recreational Screening Level[a]	Livestock Rancher Screening Level[b]	Residential Screening Level[c]	Navajo Nation Surrogate Residential Screening Level[d]	Laboratory Detection Limit
Aluminum	>1,000,000	652,000	77,000	26,700	8
Antimony	782	261	31	11	0.4
Arsenic	30.6	10	0.68	0.24	0.7
Barium	390,000	130,000	15,000	5,200	0.1
Beryllium	3,910	1,303	160	56	0.02
Cadmium	1,780	593	7.1	2.5	0.02
Chromium	>1,000,000	978,000	120,000	42,000	0.2
Cobalt	586	195	23	8	0.01
Copper	78,200	26,066	3,100	1,100	0.3
Iron	>1,000,000	456,000	55,000	19,100	8
Lead	800[e]	267[e]	200[e]	69	0.1
Manganese	46,700	15,566	1,800	625	0.2
Mercury	271	90	11	3.8	0.004
Molybdenum	9,780	3,260	390	135	0.1
Nickel	39,000	13,000	1,400	485	0.1
Selenium	9,780	3,260	390	135	0.04
Silver	9,780	3,260	390	135	0.1
Thallium	19.6	6.5	0.78	0.27	0.1
Uranium	391	130	16	5.6	0.01
Vanadium	9,850	3,283	390	135	0.1
Zinc	587,000	195,700	23,000	8,000	0.4
Radionuclide Activity (pCi/g)					
^{226}Ra	147[f]	49[f]	18[f]	6.3[f]	0.1

Notes:

[a] Recreational screening levels (RSLs) for metals were determined by BLM (2017), and screening levels for ^{226}Ra were determined by Brown (2017). Primary exposure assumptions are 14 days per year for 26 years for adults and children.

[b] The livestock rancher screening scenario assumes camping occurs for 6 weeks per year for 26 years; levels are one third those for the recreational screening level determined by BLM (2017).

[c] The residential screening level is based on EPA's regional screening levels for residential exposures to soils (EPA 2024a; EPA 2024b), which assume a screening level for carcinogens (arsenic) of 1×10^{-6} and a hazard quotient of 1 for noncarcinogens. Exposure to soils may occur from ingestion, dermal contact, or inhalation. Primary exposure assumption is 350 days per year for 26 years in the same residential structure (20 years as an adult and 6 years as a child).

[d] The Navajo Nation surrogate screening level assumes a receptor lives in the same residence for 75 years. The surrogate screening levels were developed by the DRUM Program and are derived through linear extrapolations of the EPA 26-year regional screening level summary table values (EPA 2024a; EPA 2024b). The Navajo Nation surrogate COI screening levels assume a direct proportionality for exposure duration, and no contributions from other potential sources (e.g., livestock, cultural use plants) were added as an approximation of the potential Navajo Nation screening levels for comparison purposes.

[e] There are different approaches used to estimate screening levels for lead. The one commonly used by EPA is the Integrated Exposure Uptake Biokinetic model for lead in children. More conservative assumptions were used by BLM (2017) to estimate the lead recreational screening level.

[f] The screening levels of ^{226}Ra soil activity are based on the 100 mrem/yr exposure benchmark and vary by the exposure assumptions for each screening level as follows: 2 weeks per year for 26 years for the recreational scenario, 6 weeks per year for 26 years for the livestock rancher scenario, 350 days per year for 26 years for the residential scenario, and 350 days per year for 75 years for the Navajo Nation surrogate residential scenario (Brown 2017; Brown 2022).

Abbreviations: mg/kg = milligrams per kilogram, mrem/yr = millirem per year, pCi/g = picocuries per gram, ^{226}Ra = radium-226

3.1.4 Navajo Nation Surrogate Residential Scenario

EPA has developed a Navajo Nation residential exposure scenario which assumes a receptor lives in the same residence for 75 years. Unlike the EPA 26-year regional residential scenario described in Section 3.1.3 above, the EPA Navajo Nation residential scenario is developed on an investigation level basis. Also, unlike the 26-year residential scenario, regional screening level summary tables are not available for the 75-year Navajo Nation residential scenario.

For comparison purposes, the DRUM Program has developed a Navajo Nation surrogate residential scenario that assumes a 75-year residence for use only as a reference metric in bar graphs included in V&V reports. The individual COI benchmarks for the Navajo Nation surrogate residential scenario presented in Table 2 are derived through linear extrapolations of the EPA 26-year regional screening level summary table values (EPA 2024a; EPA 2024b). The Navajo Nation surrogate COI screening levels assume a direct proportionality for exposure duration and no contribution from other potential sources (e.g., livestock, cultural use plants); the COI screening levels were added as an approximation of the potential Navajo Nation screening levels for comparison purposes.

3.2 Observational Data Inputs

The following primary categories of observational lines of evidence related to mine conditions, along with the measurement endpoints and objectives supporting them, will be recorded during V&V work:

- **Physical hazards:** The number, type, and dimensions of physical features and associated structures
- **Access:** The ease of access to a mine, including the types of vehicles that can access it, difficulty of access by hiking, visibility of the mine from surrounding areas, and visibility of any attractive nuisance features
- **Suitability of use:** Signs of recent human use, including those associated with camping (e.g., fire rings, tent stakes) or more limited recreation (e.g., trash, tire tracks); any suitable areas for camping within the disturbed area are noted
- **Size and nature of waste rock piles:** The length, width, and volume of waste rock piles; the general surface condition of waste material (particle size, vegetative cover, etc.); and any visual evidence of significant mineralization, including the presence of sulfide minerals or other acid-generating compounds
- **Waste rock migration potential:** The steepness of slope, stability of waste rock pile materials, presence or development of erosional features, presence of sediment derived from waste rock piles, and proximity of the piles to arroyos and surface water
- **Ecological hazards:** The presence of the following: surface water within 0.25 mile of the mine; signs of intermittent ponding or flowing water and nearby potential wetlands; estimated foliar cover of vegetation on each waste rock pile and dominant, secondary, and trace plant species; signs of nesting, burrowing, foraging, and other evidence of wildlife activity on each waste rock pile; evidence of special-status species; and any mine-related features that present a potential hazard to migratory birds, special-status species, and large or small wildlife

3.3 Quantified Data Inputs

In addition to the observational data described above, a radiological survey and collection and analysis of metals content in soil and sediment were determined by LM to be necessary to screen for potential impacts on human health. Environmental data will be collected in accordance with the DQO process described in Appendix A to ensure that the sample collections, analytical laboratories, analytical methodologies, and quality assurance/quality control (QA/QC) methods used are valid and sufficient to produce reliable bar charts and RSAs.

3.3.1 Gamma Radiation Survey

The gamma radiation survey is the primary method used to screen for potential radiological risks to human health. Gamma radiation data collection activities are described in Section 5.3.6 and Appendix D. LM has established dose-based screening criteria for radiological data based on the four exposure scenarios described in Section 3.1.

The characteristics of exposure scenarios as they apply to abandoned mines like those in the DRUM Program are described in the technical memoranda *Screening Assessment Approaches for Metals in Soil at BLM HazMat/AML Sites* (BLM 2017), *Establishing Radiological Screening Levels for Defense-Related Uranium Mine Sites on BLM Land Using a Recreational Future Use Scenario* (Brown 2017), *Addendum – Establishing Radiological Screening Levels for DRUM Sites on BLM Land Using a Recreational Future Use Scenario* (Brown 2018), and *Establishing Radiological Soil Screening Levels (SSLs) for DRUM Sites on Tribal Land – Final* (Brown 2022). These documents are included in Appendix B.

Screening levels are and based on a dose of 100 millirem per year (mrem/yr) above background (i.e., total effective dose equivalent); Table 3 summarizes the gamma radiation screening levels determined in Brown (2022).

Table 3. Gamma Radiation Screening Levels

Exposure Scenario	Exposure Screening Level	^{226}Ra Concentration[a]
Residential screening	35 μR/hr	18 pCi/g
Navajo Nation surrogate residential screening	35 μR/hr	18 pCi/g
Livestock rancher screening[a]	85 μR/hr	49 pCi/g
Recreational screening	256 μR/hr	147 pCi/g

Notes:
This analysis is based on the 100 mrem/yr above background dose (i.e., total effective dose equivalent), which is the basic international consensus standard for public exposure from all sources (10 CFR 20; DOE Order 458.1 Chg H [LtdChg]; ICRP 2007).[a] According to Brown (2017; 2022).
[a] The livestock rancher screening scenario assumes camping occurs for 6 weeks; levels are one third those for the recreational screening level determined by BLM (2017).

Abbreviations:
CFR = *Code of Federal Regulations*
μR/hr = microroentgens per hour
pCi/g = picocuries per gram
^{226}Ra = radium-226

The two primary objectives of the gamma radiation survey are: (1) mapping the spatial distribution of elevated gamma radiation and the risks associated with materials left on mine sites and (2) evaluating the potential for those materials to migrate outside the disturbed area. Risks associated with exposure to gamma radiation at mine sites are focused only on gamma radiation levels within the disturbed area. Further, the criteria for ecological and environmental hazard evaluation establish that a gamma radiation signature greater than 85 microroentgens per hour (μR/hr) is indicative that radioactive and nonradioactive materials may have migrated offsite. Assuming the disturbed area is properly defined, assignment of an established background gamma radiation value has no impact on the risk ranking associated with the potential gamma radiation exposure when evaluating the potential for offsite ecological and environmental pathways. Therefore, a bounding gamma radiation value that is safely below these levels (to account for uncertainty and variability) addresses the objective of using background gamma radiation data while allowing for appropriate evaluations of risks to human health. The DRUM Program has established 20 μR/hr as a surrogate background gamma radiation value for the purpose of conducting gamma radiation surveys.

3.3.2 Chemical Survey

Mining-related features with elevated gamma radiation readings—primarily waste rock piles—will be sampled to screen for metal and radionuclide COIs associated with mining activities that may pose risks to human health. The COI screening levels for all four exposure scenarios are listed in Table 2 along with the screening levels for radium-226 based on data from Brown (2018; 2022) using a 100 mrem/yr above-background dose.

It is likely that when surface water is present at a mine it will occur as an adit discharge, spring, or seep or be contained in a seasonal livestock pond. Surface water samples will not be collected from ephemeral sources, such as recent storm event water. Care will be taken to collect nonephemeral surface water that has the potential to have been impacted by the mine; therefore, priority will be given to downgradient or onsite surface water resources, as described in Section 5.3.5.2. Additionally, discharge measurements will be made of surface water flowing from open adits or adits closed with backfill. Analytical results of surface water sampling and discharge rates, when recorded, will be reported for each mine where surface water is encountered. However, no screening or evaluation of water quality results will be performed, and results will not be incorporated into the risk score or ranking. In addition, the water quality data collected represent a "snapshot in time," which does not consider seasonal or annual variations.

Potential consumption of surface water is not considered in the screening criteria. The limited duration and seasonal nature of water availability, the variability of water quality in many uranium mining districts, and the generally unpalatable appearance of water discharging from hard-rock uranium mines drastically limit the potential for consumption of the water.

3.4 Risk Scoring and Ranking

After the physical hazard and potential human health risk data are collected at each mine, the information will be presented in individual V&V reports. Unlike the approach used on public lands in Campaign 1, the Campaign 2 approach will not include developing a risk score for the chemical data, radium-226 data, or gamma radiation data. Rather, these data will be compared to established benchmarks and presented as bar charts in the V&V reports. COI concentrations in waste rock samples (minus the background concentrations) will be compared to established screening level benchmarks to determine risk ratios for each of the four exposure scenarios (see Section 3.1). The risk ratios for individual analytes are summed to develop a cumulative risk ratio for all exposure scenarios. A cumulative risk ratio below 1 indicates that chemical or radiological factors for the feature sampled will not pose an unacceptable human health risk. Where COI concentrations are equal to or exceed a screening level, a potential human health risk may be present.

The RSA process for Campaign 2 includes evaluation criteria for physical hazards and modifying factors, including the ease of public access to a mine, complexity criteria, and ecological and environmental hazards, as described in Appendix E. These RSA criteria were established to individually evaluate specific groups of hazards at a mine. This system incorporates numeric evaluations with the broad risk ranking categories of "none," "low," "medium," or "high." Each evaluation criterion in the RSA may be considered independently.

3.5 Screening Process Limitations

The V&V process is designed as a screening protocol with the following inherent limitations to the datasets evaluated:

- **Snapshot in time:** V&V activities at each mine may be conducted during a single day. Thus, some factors, particularly weather and human activity, may alter mine conditions over time. For example, some plant species are only evident seasonally, and wildlife species may move in and out of the area.
- **Background gamma radiation variability:** Background gamma radiation surveys are conducted at a specific area to represent regional or mine-specific background gamma radiation levels. The measurements are typically made at undisturbed areas on native soil units. The soil may shield background gamma radiation from naturally occurring outcrops or formations that may be present at or near a mine.
- **Statistical uncertainties resulting from combining samples:** Compositing multiple samples into a single analytic unit is an acceptable screening tool. However, the compositing methodology has the potential to mask certain mine conditions, such as high COI concentrations in a small area or small volumes of radiologically elevated materials.
- **Unknown subsurface mine conditions:** Subsurface mine conditions, such as bat habitat and mine stability, are not accounted for during the evaluation process. As a result, physical hazards within the mine, subsidence potential, and species-specific habitat (though the ecologists may note species or habitat potential) are not evaluated. Subsurface physical hazards within an abandoned mine, including the potential for roof fall and flooding, are not documented.
- **Mine atmosphere:** Atmosphere discharging from subsurface mine entries, including radon and radon progeny, is not evaluated. Such exposure was determined to be a minimal factor in the recreational exposure scenario (Brown 2018) and is also expected to be minimal for the other exposure scenarios.
- **Subsurface waste rock and soil concentrations:** The composite sample only collects surficial material. Subsurface rock and soil are not sampled, and any variations in chemical concentrations are not known. This approach is consistent with the overall conceptual site

model, which assumes human exposure primarily, if not exclusively, to the surface material of a waste rock pile.

- **Safety considerations:** Worker safety protocols may limit access to some mine features, including steep slopes associated with waste rock and surface mining operations.

4.0 Preparations for V&V Field Activities

V&V work is essentially a four-step process designed to focus LM efforts on identifying mines, inventorying mining-related features, collecting environmental data, and reporting the findings. Figure 2 describes these tasks and the general progression of data collection and reporting activities. This section provides a description of the tasks required to prepare for V&V field activities (field preparation tasks are shaded in Figure 2). Preparation includes identifying project areas, creating agreements with partner agencies, reconciling mine location data, establishing work authorization, and developing Field Operations Plans (FOPs).

4.1 Establish Partner Agency Agreements

To ensure an efficient method of collecting prefield data and inventory data pertinent to the mission of the DRUM Program, LM develops agreements with partner agencies. For Campaign 2 the partner agencies include Navajo Nation agencies and U.S. government agencies. The Cooperative Agreement between LM and the Navajo Nation, *Program Support and Safeguarding of Defense-Related Uranium Mines* (DOE and NAMLRD 2022), funds the organizations to effectively share information, provide authority to access mine locations, efficiently screen identified mine locations, identify cultural and environmental concerns, and make informed future land management decisions.

LM will prepare a FOP for each project area or set of mines to be assessed. FOPs, which are described in Section 4.5, will be developed individually to facilitate field operations for specific AUM regions. The FOPs will be developed in consultation with partner agencies to identify unique needs for field activities.

4.2 Data Reconciliation

Initially, the estimated 4225 mines and their locations identified for the DRUM Program were compiled from historical AEC production records from 1947 through 1967 and from existing federal, tribal, and state databases. In many cases, the data associated with a mine were both incomplete and potentially inaccurate and thus required reconciliation of the various datasets to be useful. The need for increased integrity within the dataset was behind the reconciliation process, which was geared toward correlating all pertinent location data in an effort to assign a specific mine to a specific geographic point. Typical issues identified and subsequently resolved during the reconciliation process include inaccurate location information, duplicate records, the listing of multiple mines under one record, and missing records. To promote efficient task completion, the reconciliation process ensures that the most accurate location data are available to DRUM field teams before they mobilize to conduct V&V activities. Reconciliation work was completed in late 2021 with a final list of 3472 mines and their locations.

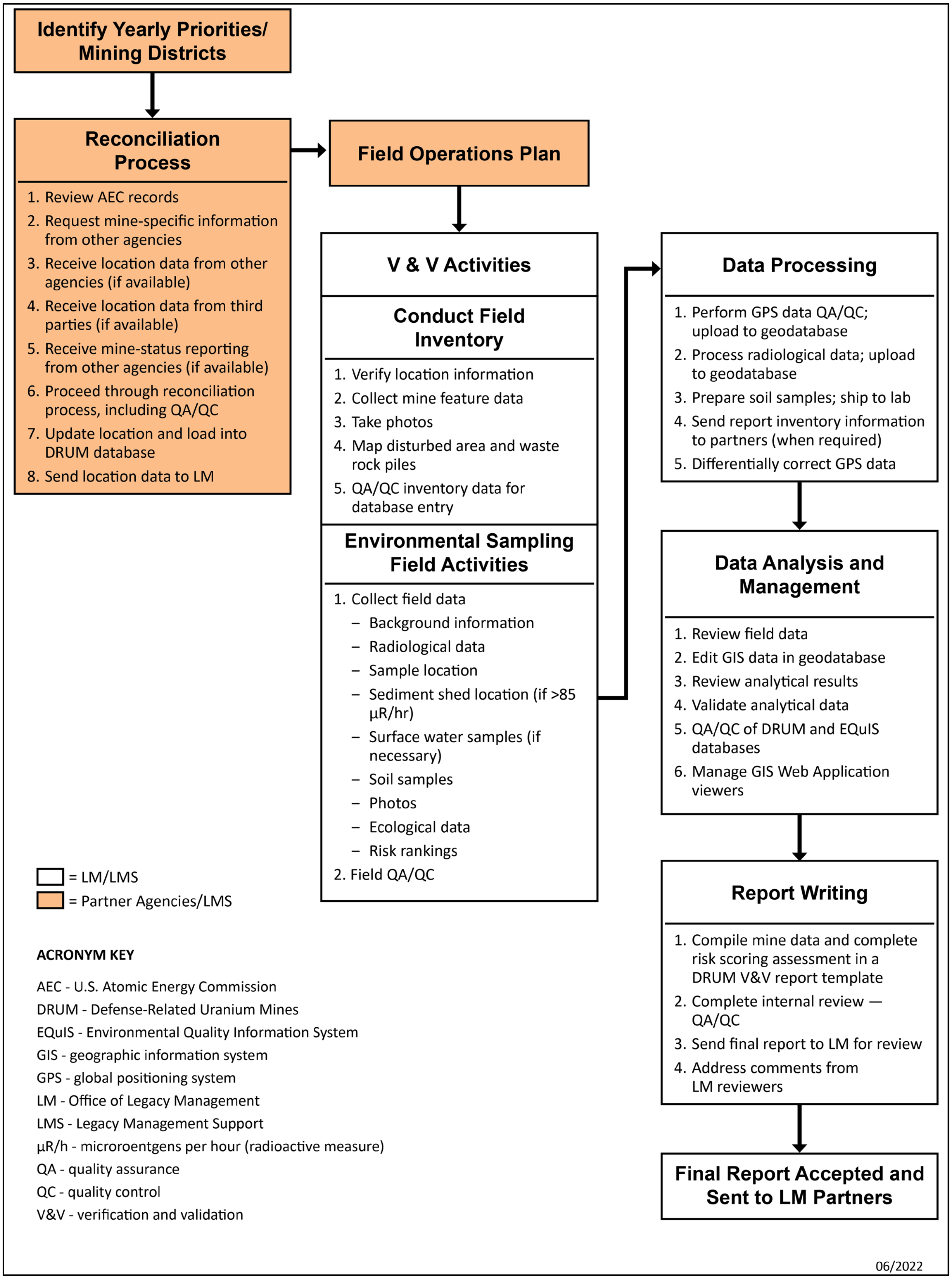


Figure 2. Flowchart of DRUM Program V&V Processes

During the reconciliation process, location and production data for each mine listed in AEC production records are individually evaluated and corrected as needed. The reconciliation team assesses mines within a predetermined geographic area or mining district by using multiple data sources and reference materials. The primary focus includes a determination of the mine name, the number of mine workings, detailed latitude and longitude coordinates, landownership status, the amount of ore produced, and the period of time in which it was produced. Permit status (if applicable), physical hazard safeguard status, and reclamation and remediation status are also determined from available information. Location data sources include AEC claim and area economic maps and other AEC publications; topographic and geologic maps and other publications from USGS, DOE, and state geological surveys; aerial imagery; state mining data; and other historical mining claim maps and documents. Correlation of several of these documents and maps is used to confirm the mine location and to further verify mine-specific data. Also, mine location data are collected from partner agencies and other stakeholders, including state abandoned mine lands programs that are involved with the DRUM Program. An example of partner agency contributions are the 39 EPA orphan mines scheduled for V&V activities under the DRUM Program. These mines are presented in Table 1 and Figure 1 of this document. All records and location data are recorded in the DRUM Program database during the reconciliation process. Duplicate records and missing records within the DRUM Program database are identified and addressed. Duplicate records are consolidated via the merging of existing records, and missing records are added to the database as needed. Merged duplicate, nonmine, and non-DRUM records are documented using a certificate generated by the DRUM Program database titled the *Defense-Related Uranium Mines Program Verification and Validation Certificate of Completion: Merged Duplicates*.

QA during the reconciliation process is completed as staff geologists check one another's work against available data sources. A reconciliation worksheet is used to ensure records and locations are documented consistently from all available references. A final location check using the reconciled coordinates in the DRUM Program geographic information system (GIS) is also completed. Upon completion of reconciliation, vetted records and mine locations are updated in the DRUM Program database and made available to the field teams and partner agencies.

4.3 Prefield Research

Most prefield research pertains to determining access routes to the mine and evaluation of existing ecological data resources, which are researched before field investigations begin to develop the framework for performing mine-specific ecological screening. These data are communicated to the field team before fieldwork begins. Data are collected from federal, state, or tribal agencies when available, and from publicly available resources and websites, including (1) the USFWS IPaC system, (2) state special-status species lists, (3) state natural heritage programs, (4) the U.S. Department of Agriculture Natural Resources Conservation Service Web Soil Survey, (5) the National Wetlands Inventory, (6) the USGS National Hydrography Dataset, and (7) applicable Navajo Nation agency-specific management plans.

Relevant data to be collected include the following, as appropriate and available:

- Lists of special-status species and their potential habitat
- Designated critical habitat for federally listed threatened and endangered species
- Habitat for big game species (when available)

- Surface water, potential wetlands, and riparian resources
- Soils information, including areas with sensitive soils when appropriate
- Areas of critical environmental concern
- Vegetation community types
- Noxious weed lists specific to mine localities
- Applicable mine-specific environmental compliance guidelines relevant to DRUM inventory and sampling activities (noted in the appropriate FOP)

Additional data may be added as information becomes available.

4.4 Work Authorization

The LMS *Integrated Work Control Process Manual* (DOE 2023d) details the process for initiating, authorizing, performing, and conducting work within the scope of the LMS contract. Line management, project leads, and other staff will be capable of understanding and applying the requirements of the *Integrated Work Control Process Manual*, as outlined in associated manuals specific to the planned work scope. All managers and field personnel are required to adhere to this process.

Following completion of the prefield tasks described above, an authorization to proceed with fieldwork is issued by the LMS Uranium Related Programs (URP) manager for activities implemented by the LMS contractor. The work authorization process requires completion of a *Plan of the Day/Plan of the Week* form (LMS 2130) before the start of work each week. The *Plan of the Day/Plan of the Week* form documents the URP manager's authorization of work activities to be performed in the field. The URP manager authorizes work activities only after verifying that the proposed work activities are within the contractually approved scope, that the work has been adequately defined and planned, that appropriate work controls have been established, and that qualified personnel and necessary equipment are available to perform the work safely. Furthermore, the URP manager will verify with LM that other interested Navajo Nation, state, and federal agencies have been notified of the planned work. The LMS contractor or subcontractor personnel will only perform work preauthorized by the URP manager.

4.5 Field Operations Plan

A FOP is prepared for each defined project area after reconciliation efforts are complete. Project FOP areas will correspond with NNEPA AUM regions, and FOPs will list the associated mining districts, specific regions, or other relevant, predetermined geographic areas. Partner agencies, LM, and the LMS contractor all provide information incorporated into the FOP. In turn, FOPs convey to LM, the LMS contractor, the Navajo Nation, and partner agencies information pertinent to the V&V activities being undertaken at the specified project area. Each FOP is unique to the requirements of the individual field investigations and is meant to supplement and expand upon the V&V Work Plan as circumstances require. FOPs will list pertinent information regarding field activities, including the mines targeted and their locations, specific access issues, known environmental compliance and conservation-related information, cultural sensitivity concerns, and logistical contact information. An important component of the FOP will be the reporting of any mines that are permitted or that were closed or reclaimed by partner land management agencies. A tabulation of permitted, closed, or reclaimed mines in the FOP will facilitate observation of closed and reclaimed mines by the field teams. The location and status of permitted and reclaimed mines is included in the FOP. The field teams will observe and record the current status of mine feature safeguards and previous reclamation efforts at affected mines.

The FOP will provide coordination instructions for the field teams so that fieldwork is conducted efficiently and with appropriate emergency response guidelines established. Each FOP will be accompanied by a *Supplemental Emergency Response Information (SERI)* form (LMS 1415), which will include appropriate emergency response guidelines. Any access or environmental restrictions for a field project will be described in the FOP and observed during field operations. The FOP will also address specific activities to be undertaken by inventory and environmental sampling crews to the extent that these activities are conducted separately. The FOP may define modifications to the inventory checklist; therefore, field teams will be familiar with the FOP to ensure that all necessary information is collected. The FOP will be developed in coordination with the appropriate partner and stakeholder agencies and will describe the roles and responsibilities of the field teams to ensure that all required data are collected. The FOP will be completed by LM and the LMS contractor and will be distributed to partner agencies for review before the start of V&V fieldwork.

4.6 Asset Management

The Asset Management group's purpose is to (1) establish a data-driven, risk-informed, performance-based approach to the life-cycle management of real property assets that aligns LM's real property portfolio with DOE mission needs; (2) acquire, manage, positively account for, and dispose of real property assets in a safe, secure, cost effective, and sustainable manner; and (3) ensure that LM's real property portfolio is appropriately sized, aligned, and in the proper condition to support efficient mission execution.

Asset Management is a keystone part of the DRUM Program. To maintain the safety of the field teams during the V&V process, Asset Management works with internal and external partners to ensure that requirements regarding both land rights and environmental compliance-related restrictions are properly observed when the field teams access land managed by public, private, and tribal landowners. It is necessary and required by DOE Order 430.1C Chg 2 (Admin Chg), *Real Property Asset Management*, to follow the policies and procedures of each land management agency. It is the responsibility of Asset Management to adhere to all regulations pertaining to elements of real property where DOE has a legal interest in or right to use such property.

Asset Management's responsibilities include the following, as they apply to each property type:

- Obtaining access agreements, permission to survey, or permits
- Notifying landowners, leaseholders, and permitholders about program activities
- Obtaining landowner information that may affect the planning of routes to mines
- Performing due diligence for landownership
- Contributing to the planning of field schedules

- Reviewing and establishing agreements with partner agencies and tribal land management organizations
- Coordinating with counterparts at various partner agencies and tribal organizations

5.0 Inventory and Environmental Sampling Field Activities

DRUM fieldwork consists of two primary components: inventorying mine features and environmental sampling. The primary focus of these activities is to locate the mine via GPS technology; identify the area impacted by mining operations, including offsite areas impacted by sediment shed; locate and sample waste rock materials; obtain gamma radiation measurements from the mine and adjacent areas; and document hazardous mine entries and unstable structures. Inventory and environmental sampling activities will be undertaken solely by LM.

NAMLRD estimates that 95% of the 200 DRUM sites on the Navajo Nation scheduled for V&V work have been reclaimed by NAMLRD. Reclamation activities may include safeguarding potentially hazardous mine openings, stabilizing waste rock piles (burying and capping with clean fill material), and returning the topography to premining condition. Because of the degree of NAMLRD reclamation work, additional information will be required to assist the field teams in locating reclaimed mine features and defining the extent of waste rock material for soil sampling. NAMLRD has agreed to share reclamation information with DOE according to the *Program Support and Safeguarding of Defense-Related Uranium Mines* (DOE and NAMLRD 2022).

This section introduces the V&V field team and describes the various components of the inventory and environmental sampling tasks. Figure 2 provides a graphic representation of how these activities are conducted.

5.1 V&V Field Team

Each field V&V team consists of a multidisciplinary team of scientists who are cross-trained to perform multiple field activities. At a minimum, each team will include the following personnel to perform specific tasks:

- **Field team lead:** The field team lead directs the field team, provides overall technical assistance, and ensures data collection is thorough and accurate and is completed safely and in accordance with the V&V Work Plan and the FOP. The field team lead is responsible for completing the field documentation portions of the *DRUM Verification and Validation Work Plan Process (QA/QC)* (LMS 4501 DRUM) (Process Form) attached to Appendix F, or an equivalent form stored in an online LMS database, composing a narrative describing mine conditions and other relevant observations, documenting sampling events including opportunistic sampling and variances from sampling protocols, and providing any other information that will facilitate reporting.
- **Radiological control technician (RCT)/safety specialist:** The RCT is responsible for implementing the personal dosimetry program for the field team, which could include setting up a supplemental dose rate instrument for the purpose of collecting dose information. The RCT will also use the gamma radiation scanning backpack unit to collect gamma radiation exposure rate data at DRUM sites.

- **Sample team (typically the team lead and geologist):** The sample team collects composite soil samples, sediment shed samples (when present), and surface water samples (when present); ensures that samples are representative of the mine; and ensures that chain-of-custody (COC) procedures are followed. The sample team also verifies that GIS data derived from inventory activities adequately represent all data points and collects additional GPS information as needed.
- **Ecologist:** The ecologist collects GPS data to designate and characterize vegetation on waste rock piles; documents ecological units on and surrounding the site; notes the presence of wildlife; and records evidence of any wildlife use, special-status species or their habitat, and wildlife hazards at or near the mine.

5.2 Inventory of Mines

Inventory tasks are intended to maximize the efficiency of the overall field effort by collecting information that documents current field conditions while optimizing planning and preparation for the environmental sampling effort. Unless otherwise directed by the LM project manager, DRUM field V&V teams will complete inventory at the 161 unfunded DRUM sites (i.e., non-CERCLA mines) and 39 EPA orphan mines listed in Table 1. Funded DRUM sites (i.e., CERCLA mines) will not be visited. Overall, the objectives of the inventory task are to ascertain a primary route to access the mine, verify that the mine visited is the intended target, preliminarily define the disturbed area, use a GPS unit to locate and record mine features, and photographically document site conditions. The field team will also record other measurements, such as mapping the crest and toe of each waste rock pile, estimating the thickness of each pile, and identifying those areas within a mine's disturbed area that may be suitable for camping or a possible residence.
A checklist of the information collected by the field team and an example of the Process Form are included in Appendix F. Because much of the inventory effort is based on observations of existing conditions, the checklist and the example Process Form included in Appendix F (or an equivalent form stored in an online LMS database) act as QA tools for the field teams to ensure that all required information has been accurately collected before leaving a mine.

5.2.1 Pre-Job Briefing

Upon arriving at the mine, the field team will conduct a pre-job briefing (documented on the *Pre-Job Brief/Safety Meeting Attendance Record* form [LMS 1554]) to review the work to be performed. This will include a briefing on the *Defense-Related Uranium Mines Safety Plan* (DOE 2023b) (DRUM Safety Plan [DSP]) as needed. Based on the DSP, the team will discuss potential hazards that may be encountered as they prepare to conduct sampling activities. The team will continue to analyze the mine conditions and, if unanticipated safety issues arise, communicate the hazard to the rest of the team. Other topics that potentially impact data collection efforts, including information and restrictions related to conserving natural resources and complying with species-related laws (as noted in the applicable FOP), will be discussed during the briefing.

5.2.2 Verifying the Mine Location

Verification of a mine location using the reconciled data presents specific challenges. Many of the mines, claims, and survey markers have changed names and locations over the years, thus making positive identification a tedious process in some circumstances. Claim corner markers with posted claim papers (although quite rare) are a good way to verify that the mine name is correct in the DRUM Program database, as is any information scribed or painted onto mine entries, ore bins, or other mine features. The location coordinates of the mine area will be collected by the field team using a handheld GPS unit with sub-meter accuracy. The mine location point will be at or adjacent to the mine so that most if not all mine features are visible. The mine location point is important because it represents the physical mine location in the DRUM Program database. The procedure is described in Appendix G. Field teams will utilize available NAMLRD reclamation documents and information to assist them in locating the extent of reclaimed mines.

In rare circumstances, field verification efforts for a particular mine location may reveal no observable mining-related disturbances, in which case the mine is labeled as an operations not evident (ONE) mine. In these instances, the field team will investigate adjacent areas to determine whether the mine can be located. If the mine cannot be located, the field team will navigate to the coordinates identified by the reconciliation team, log that location using a handheld GPS unit, and note that no evidence of mining-related activity was observed. Section 5.3.5 describes the environmental sampling efforts that will be completed when ONE mines are encountered.

5.2.3 Determination of Disturbed Area

The disturbed area is the portion of the ground surface associated with a mine that is impacted by mechanical mining-related activities. In some cases where the mechanical disturbance is not obvious, a determination of the disturbed area perimeter may be made through use of gamma radiation measurements. Such measurements and a final determination of the disturbed area boundary will be made by the field team. The field team will use a handheld GPS unit with sub-meter accuracy to record the location. Due to steep terrain or other obstacles, it might be unsafe or impossible for field teams to map the perimeter of the disturbed area. In such cases, the team lead will record this data gap, and the disturbed area perimeter will be delineated using GIS technology in the office.

Generally, the disturbed area includes mine entries, rim cuts, open pits, waste rock piles, topsoil and overburden stockpiles, and mine support facilities. Roads providing access to mines and natural features, such as ephemeral drainages, are excluded from the disturbed area. Features associated with a mine but separated from the disturbed area by undisturbed lands will be mapped as disparate features for purposes of completing the RSA. Examples of such features may include subsidences, vents, buildings, and waste rock piles. Some mines may have multiple unconnected disturbed areas that will be mapped as disparate, isolated features when they are separated by undisturbed land.

For reclaimed mines, the disturbed area directly impacted by mechanical mining-related activities may be difficult to determine. In these cases, the disturbed area will be synonymous with the reclaimed area. Field teams will utilize the ecological footprint associated with reclamation activities and NAMLRD reclamation documents in mapping disturbed areas.

5.2.4 Collecting Mine-Related Features

The field team will use a handheld GPS unit with sub-meter accuracy to record the location of all mine-related features (portals, adits, shafts, waste rock piles, headframes, vents, drainages, trash dumps, claim corners, etc.). Access roads will also be recorded with a GPS unit to delineate the most efficient route to the mine.

The field team will note whether mine entries are open and whether barriers to human access exist. Generally, shallow mine-related features such as prospects are considered to pose little inherent risk and will be documented as “low hazards.” Mine feature information, including inherent risk, dimensions, and other important observations will be captured in the geodatabase and included in the DRUM Program database and V&V report. The team lead narrative described in Appendix C summarizes the number of features identified at the mine, environmental sampling details, and other information unique to the mine.

When existing physical hazard safeguards are observed at a mine site, the field team will note whether they are constructed to be effective safeguards (e.g., intended to prohibit entry into the subsurface) and, if so, whether they function as designed or if maintenance is required. An existing engineered safeguard indicates the mine may be designated as “no hazard,” while evidence of an ineffective safeguard indicates that the mine may be designated as “hazards present” (nonengineered safeguards may have been installed at a mine by a private company without the safeguard being structurally competent).

Field teams will note and locate mine-related hazards that could pose a significant and immediate threat to a visitor at the mine location. These notifiable features may include subsidence areas, shafts, explosives, chemicals, or severely compromised structures. When notifiable features are identified, the field team lead will provide the mine name, LM ID number, coordinates, and a description of the feature to the appropriate land management agency and the LM project manager as soon as practicable.

5.2.5 Mapping Waste Rock Piles

The field team will use a handheld GPS unit with sub-meter accuracy to record polygons defining the extent of each waste rock pile to the level that is practicable without compromising worker safety. The field team will use the GPS unit to identify the location of the crest (top) and toe (base) of each waste rock pile. If the crest of the waste rock pile is not identifiable or cannot be located safely, that situation will be described in the inventory field notes. Similarly, if the toe of the waste rock pile cannot be mapped, circumstances and other pertinent information will be described in the inventory field notes and in the team lead narrative described in Appendix C. A visual estimate of waste pile thickness will be recorded. For reclaimed waste rock piles that have been capped with overburden or fill material, the extent of waste rock may not be able to be determined visually. In these circumstances, field teams will utilize gamma radiation data and NAMLRD reclamation documents in mapping and sampling waste rock piles.

Due to steep terrain or other obstacles, it might be unsafe or impossible for field teams to map the perimeter of a given waste rock pile. In such cases, the team lead will record this data gap, and the waste rock pile perimeter will be delineated using GIS technology in the office.

5.2.6 Photo Documentation

The field team will take photos of the mine and related features, including close-up, detailed photos of features as well as larger-scale photos of the entire area. Photographs must include an object or person for scale. Photos will help the field teams document staging areas, disturbed areas, ecological units, and physical hazards. Photo documentation will be evaluated in the field before the field team demobilizes from a mine to ensure that the photos include both overview images and specific features of interest, particularly those that are potentially hazardous or unstable. Digital photo filenames will include descriptions and be documented in field notes or by other suitable means, such as embedded metadata, that facilitate data transfer.

When using a device with geotagging capabilities and where the camera is able to access the GPS function, latitude and longitude will automatically be populated in the photo metadata. For digital cameras that cannot connect to the GPS function or are not GPS-enabled, the approximate location of the photo will be documented by other suitable means. An acceptable data format for digital photographs is a JPEG file that can be included in an electronic transfer of data. Specific data transfer information is included in Appendix F.

5.2.7 Postinventory Data Processing and Data Transfer

Observational data will be collected by a handheld GPS unit, as described above. Typically, data will be collected and transmitted in an Esri geodatabase-compatible format. Standard geospatial data formats include shapefile (.shp), file geodatabase (.gdb), and GeoPackage (.gpkg) files and will be transferred to LM using an assigned electronic file transfer (EFT) site for storage, postprocessing, and use.

5.2.8 Differential Correction of GPS Data

Field data are collected using rugged field tablets running industry standard GPS-enabled data collection software or equivalent devices. A real-time correction is automatically applied at the time data are collected using the satellite-based augmentation system.

The inventory information collected via GPS units will be transferred to the field team, for use in environmental sampling, as uncorrected data when it is collected by the LMS contractor, and as both corrected and uncorrected data when collected by partner agencies. By correcting the GPS information before transmittal to the LMS contractor, partner agency field teams complete a QA step to ensure the accuracy and validity of the data. By accumulating both the corrected and uncorrected data, the LMS contractor is able to compile an accurate record of all information collected at a mine and ensure that all information is corrected using identical methodologies to enhance data quality and consistency. Submittal of both corrected and uncorrected data also makes it possible to evaluate the accuracy of the information collected so that the most accurate location information is utilized in the DRUM Program database. Specific data transfer information is included in Appendix F.

Once the GPS data have been collected and transferred to the LMS contractor, a differential correction algorithm will be run against the uncorrected GPS data by the LMS contractor. Differential correction is a mathematical computation used to improve the accuracy of GPS data by comparing the coordinates collected in the field via GPS satellites to Continuously Operating

Reference Stations. These stations consist of survey-grade GPS receivers that transmit radio signals to GPS units in the field to correct the minor inaccuracies of GPS signals caused by atmospheric, solar, and terrestrial interference.

A comparison will be made between the differentially corrected data and the uncorrected files to select the most accurate information for export. This QC step is critical to ensuring that the most accurate data possible are used. It also supports the QA process by allowing all data to be assembled, corrected, and stored in the same manner, thus reducing potential errors. As a QC step, the data file exported from the GPS unit is never altered and is saved to the proper directory for future reference.

The selected data are exported to an Esri file geodatabase-compatible format. The exported geodatabase features are then loaded into the DRUM geodatabase.

5.2.9 GIS Upload

Upon completion of the data evaluation efforts, the corrected data and the information described in the inventory checklist in Appendix F will be stored by the LMS contractor for use by the field team. The data evaluation procedure described in Section 5.2.8 is a QA/QC step that ensures collected data are free of inherent errors created during the collection process. The corrected GPS data will be loaded into ArcGIS for use by the field team and in the final V&V report. The procedure for loading corrected GPS data into ArcGIS is described in Appendix G.

5.3 Environmental Sampling

This section describes environmental sampling field activities, including reviewing inventory data for completeness; determining background conditions; collecting soil, sediment, and surface water samples; and conducting gamma radiation surveys.

An environmental sampling checklist and the Process Form included in Appendix F act as QA tools for the field teams. The primary purpose of the checklist is twofold: to help ensure data completeness, particularly as information is exchanged between inventory and environmental sampling personnel, and to help ensure the completeness of information collected during environmental sampling. Teams will primarily rely upon the Process Form (or an equivalent form stored in an online LMS database), which will be uploaded to field computers, to ensure that all required information has been collected before they leave a mine. The FOP may require modifications to the environmental sampling data collected; therefore, field teams will be familiar with the applicable FOP so the appropriate information is collected.

5.3.1 Initial Fieldwork

Initial fieldwork consists of delivering the pre-job briefing, setting up the field operations base, and designating a sample preparation area.

5.3.2 Set Up Field Operations Base

A field operations base will be established outside the disturbed area on an as-needed basis. The field team lead, team ecologist, and the RCT will choose an area for the field team to park vehicles and set up the field operations base for the particular site being surveyed, or for the day, depending on the size and complexity of the mine. As low as reasonably achievable (ALARA) principles will be employed to determine a safe work area. The gamma radiation detector will be used to verify that the area chosen for the field operations base is at or near background levels for radiation and dose rate. The ecologist will look for evidence of special-status species in the proposed field operations base area when these resource concerns have been identified in the applicable FOP. If evidence is found, the base area will be set up in a different location. The field operations base may consist of a shade awning and tables and chairs and may be used as a makeshift field office and rest area as needed. No environmental samples shall be handled in or around the field operations base (see Section 5.2.4).

5.3.3 Designate Sample Preparation Area

The field team lead, ecologist, and RCT will determine a safe place to set up the sample preparation area where samples and sampling equipment will be handled on an as-needed basis. The gamma radiation survey instrument will be used to verify that the area is at or near background exposure rate levels. The ecologist will look for evidence of special-status species in the proposed sample preparation area when these resource concerns have been identified in the applicable FOP. If evidence is found, the proposed sample preparation area will be set up in a different location. The ecologist will also determine if liquids used for sample preparation have the potential to be discharged or spilled into surface water, potential wetlands, or sensitive ecological areas. If these resources are present and could be affected by the work, samples will be prepared in a different area. The sample preparation area may consist of a table, chairs, and sample collection and decontamination equipment and will be separate from the field operations base location to minimize contamination potential.

The following safety precautions will be taken while performing soil sampling and working in the sample preparation area:

- All personnel will wear proper personal protective equipment
- No eating or drinking will be allowed in or around the sample preparation area
- All personnel will practice ALARA principles while handling soil samples (the least number of people handling samples for the least amount of time)

5.3.4 Determination of Background

Background soil samples and gamma radiation measurements will be collected on a regional or mine-specific basis. This information will be used to document specific baseline conditions to which individual mine COIs and gamma radiation data may be compared.

In addition, the surrogate gamma radiation background value of 20 μR/hr is used to control the areal extent of the gamma radiation survey, as described in Appendix D.

Background data will be collected on a regional basis in cases where these measurements adequately represent conditions at specific mine locations within a region or mining district. A single background location will be chosen as a regional marker for multiple mines if the data point meets specific criteria. The criteria for a suitable background location require an undisturbed area with vegetative cover, soil, and geologic conditions similar to those of the mine in the same region or district as the mine or group of mines being investigated.

Circumstance may dictate that mine-specific background data need to be collected, for example, when mine conditions, geology, environment, or mining method, are not encompassed by demonstrable regional trends. In those cases, regional conditions are not representative of mine-specific circumstances. The decision to obtain mine-specific background measurements will be made by the field team lead in conjunction with appropriate team members (e.g., the team geologist and RCT) who can provide scientific guidance and insight.

Background soil sampling procedures are described in Appendix C, while Appendix D describes background gamma radiation collection processes. The background gamma radiation collection and background soil sample collection processes will be conducted at the same location. USGS developed a statistically based strategy for sampling the surficial material of mine waste rock piles, drainages, and background areas for use in screening historical abandoned mine lands (Smith et al. 2000). This procedure has been adapted for use during the environmental sampling process. If there is significant variability in mining conditions at mine locations encountered within a district, mine-specific background samples may be taken so adequate screening information is collected. If the applicable FOP identifies any potential special-status species (or their habitat) that may be encountered in the area, the ecologist will ensure that background data collection will not adversely impact these resources.

In the event that the Navajo Nation elects to use soil sample analytical data from an AUM regional background location instead of the DRUM background area, the following decision units will be implemented:

- If AUM regional background location and soil analytical data are available at the time of V&V activities, then the DRUM field team will not collect background soil samples, and the DRUM V&V report will incorporate the AUM regional background soil sample data. Gamma radiation data will be collected from the AUM regional background location using DRUM Program gamma radiation surveying equipment.
- If AUM regional background location and soil analytical data are not available at the time of the V&V activities, then DRUM Program personnel will determine a regional or local background location that meets the criteria specified in this section. Soil samples and gamma radiation data will be collected using procedures identical to those employed at other sample sites and described in Appendix C and Appendix D. The V&V report will incorporate DRUM soil sample analytical data unless the AUM regional background soil sample data become available at the time of the V&V report start date.

5.3.5 Sample Collection

Evaluation of potential human health risks at a mine involves the sampling and analysis of the materials encountered there. Three environmental elements to be analyzed are (1) chemical constituents in mining-impacted soil and sediment, (2) chemical constituents in surface water, and (3) gamma radiation. Soil and sediment analytic data and field-generated gamma radiation data are compared to established benchmarks to develop risk ratios for each exposure scenario screening level. A risk ratio below 1 indicates that chemical or radiological factors at the mine-related feature will not pose an unacceptable human health risk. Where concentrations of a COI equal or exceed a screening level, the potential for human health risk may be present assuming that the exposure scenario occurs. In addition to the soil samples typically collected from accessible areas of the waste rock piles, opportunistic samples and surface water samples will be collected as described in Sections 5.3.5.1 and 5.3.5.2 below. Analytical results of opportunistic samples are used to provide a snapshot in time of a specific small area of a mine. Risk ratios are not developed for opportunistic samples or surface water samples.

For ONE mines, team members will perform a reconnaissance of the immediate area in an effort to locate the mine or evidence of mining operations. The reconnaissance will be recorded using GPS technology to document the extent of the area evaluated. If no evidence of mining operations is found during reconnaissance, sampling will consist of a gamma radiation survey of a 0.25-acre area, where safely accessible (see Section 5.3.6.2 below and Appendix D). Ecological information will be collected as described in Section 5.4.2. If the reconciliation point is on a bench, the gamma radiation survey will be performed 200 feet (ft) on either side of the coordinates located by the field team. If the mean gamma radiation value recorded during the survey is greater than 85 µR/hr, an opportunistic sample (see Section 5.3.5.1 below and Appendix C) of the area of elevated gamma radiation will be collected.

5.3.5.1 Soil and Sediment Sampling

Soil sampling is primarily conducted at waste rock piles. Waste rock is a derivative product of mining operations and is the primary mine feature where chemical COIs would occur. Waste rock material, when graded into a level configuration, may be utilized by recreationists for camping and in these instances act as a pathway for exposure. Under this exposure scenario, samples are collected to quantify the COIs from each waste rock pile with more than 100 square feet (ft^2) of accessible area. Furthermore, offsite mine-derived sediment that exhibits a gamma radiation signature greater than 85 µR/hr is sampled to assess the migration of material that could be a source of gamma radiation.

Soil samples will be collected from waste rock piles as described in Appendix C. Sampleable areas are defined as the safely accessible portions of waste rock piles and are identified by visually assessing the perimeter of a waste rock pile, then evaluating the gamma radiation signature of the area to ensure that all necessary materials are considered in the sampling strategy. The area to be sampled is then mapped using a handheld GPS unit. Samples are collected from all piles except those with less than 100 ft^2 of accessible area. The Appendix C sampling procedure contains detailed instructions for collection of soil samples using a 30-point composite sample collection strategy. The procedure covers pretrip planning, the use of COC forms, QC, sample identification and handling, analytical program requirements, equipment decontamination, and documentation. Soil samples will be analyzed at a subcontracted analytical laboratory that is accredited in multiple states and through the U.S. Department of Defense Environmental Laboratory Accreditation Program.

In some circumstances, only the toe or crest of a waste rock pile may be accessible for sampling because of safety considerations. In these instances, deviations from the prescribed compositing sampling scheme (Table C1, Appendix C) will be required, which typically result in a reduction of prescribed sample nodes. When such deviations occur, these samples will still be utilized as waste rock samples, but a note regarding the sampling restrictions will be included in the V&V report. Nonetheless, field teams will collect an appropriate number of sampling nodes at waste rock piles where the recreational scenario (camping) may be fulfilled. Due to worker safety considerations and the fact that camping on steep, inaccessible waste rock pile side-slopes is not feasible, refraining from sampling these slopes is appropriate to achieve program objectives.

For reclaimed waste rock piles that have been capped with overburden or fill material, the field teams will map the extent of the cap and use gamma radiation measurements to define areas that will be sampled. Using the conservative residential screening scenario defined in Section 3.3.1, soil samples will be collected from the reclamation cap where gamma radiation values exceed 35 μR/hr. Areas of visible erosion of the reclamation cap will be mapped and documented. Soil samples will also be collected from areas of visible waste rock material within the disturbed area that are not capped with overburden or fill material, or that have been exposed by erosion of the cap. Waste rock material exposed by erosion of the cap and transported outside the disturbed area will be considered sediment shed and will be sampled as described below and in Appendix D.

In addition to soil samples collected at waste rock piles, sediment shed samples may be collected from other locations outside the disturbed area to quantify potential offsite releases. The field team will determine if sediment shed samples need to be collected from ephemeral drainages and downgradient areas by using gamma radiation signatures and visual evidence to determine if radiological material has migrated via erosional processes from the disturbed area, which will be of particular importance when the mine is close to private property. Sediment shed samples are collected using a sampling protocol identical to that used for soil samples obtained on waste rock piles, except that sediment sampling grids are generally established in the field.

If material is encountered in the field that differs from that typically encountered at a mine, the field team lead will determine whether an opportunistic sample (see Section C3.2.4 of Appendix C) will be obtained to identify mine features that may have unique COI characteristics (e.g., they might be collected from the base of a loadout or an ore stockpile).

Opportunistic samples may also be collected to provide additional information to land management agencies (e.g., to identify isolated areas where gamma radiation exceeds 256 μR/hr or to analyze visually identified sediment migration onto nearby private property, regardless of whether the gamma radiation of that sediment is below 85 μR/hr). Opportunistic samples of surface water may also be obtained when such sampling adds value to the information collected at a mine. Notations regarding the circumstances of opportunistic sampling and observations at opportunistic sample locations will be recorded by the field team lead and team geologist.

As described in Appendix D, gamma radiation survey data will establish the ephemeral drainages and other downgradient areas to be sampled. When gamma radiation data demonstrate that material with a dose rate greater than 85 μR/hr has been transported from the disturbed area, a GPS-located polygon will be built around the area of elevated gamma radiation, a sediment shed sample grid will be constructed, and a sample will be taken. The sediment shed area will be mapped to 30 ft beyond its 85 μR/hr limits or to the point where values of 20 μR/hr are recorded, whichever comes first. If additional large areas of downgradient waste rock erosion and deposition are present, the team lead may elect to perform additional gamma radiation survey work. If the gamma radiation signature of sediment transported outside the disturbed area is less than 85 μR/hr, no sediment shed sampling will be performed, unless the sediment shed area is adjacent to private property and an opportunistic sample is deemed necessary. All areas sampled as a result of elevated gamma radiation (greater than 85 μR/hr) will be mapped with corresponding sample locations noted. The threshold of 85 μR/hr is equivalent to the livestock rancher exposure scenario screening level discussed in Section 3.3.1.

5.3.5.2 Surface Water Sampling

The purpose of sampling surface water is to document the presence of water at a mine, provide discharge information if water is flowing, and provide a chemical analysis of that water while recognizing that the analysis provides a snapshot in time of the surface water quality. The observation of surface water is evaluated as a potential pathway hazard in the RSA; the chemical analyses and discharge information are provided in the final V&V report for information purposes only.

For sampling purposes, surface water is defined as water within the disturbed area, or within 300 ft of the disturbed area of a mine. Surface water samples are collected when site conditions suggest surface water could potentially be impacted by the mine. Water bodies could include stock ponds, perennial streams, water discharging from an adit, or water discharging from springs or seeps within or adjacent to the disturbed area. Water samples are not collected from ephemeral water bodies that form due to precipitation and are likely to persist for less than 2 weeks. Analytes and sampling procedures for surface water samples are listed in Appendix H. Surface water samples and discharge information will be collected by personnel trained to the specifications outlined in Appendix H.

Soil samples, sediment shed samples, and surface water samples will be sent to an accredited laboratory for analysis. Generally, shipment of environmental soil samples does not require special notices or placards as these materials are exempted from such requirements when the radioactivity concentration is unknown. Before shipping an environmental soil sample with an unknown radioactivity concentration to an analytical laboratory, the RCT will complete a contamination survey of the sample containers and measure the dose rate of the shipment packaging. This information will be enclosed in the shipment container as a courtesy to the lab.

5.3.6 Gamma Radiation Data Collection

Gamma radiation data are used to determine the radiation signature of a mine. This is appropriate because the uranium isotopes are present in their naturally occurring isotopic abundances and are assumed to be in secular equilibrium with all of their progeny. Several of the uranium progeny are relatively high-energy gamma radiation emitters and are readily measured in the field.

Two types of gamma radiation data collection may be employed at each mine: (1) handheld measurements and (2) gamma radiation surveys. Handheld measurements may be used for features where radiologic information is needed to facilitate other data collection efforts, as described in Section 5.3.6.1. Gamma radiation surveys are used to map the extent and magnitude of gamma radiation at each mine and associated sediment shed areas, as described in Section 5.3.6.2.

Both types of gamma radiation data will be collected from safely accessible portions of a mine. These areas may include the crest and toe of waste rock piles where the intervening slopes are inaccessible. Gamma radiation surveys will not be performed within disturbed areas that are inaccessible because of steep slopes, physical obstacles, or similar hazards. These limitations will be documented. Due to worker safety considerations and the fact that camping on steep, inaccessible waste rock pile side-slopes is not feasible, refraining from sampling these slopes is appropriate to achieve program objectives.

5.3.6.1 Handheld Radiation Dose Reading Measurements

Handheld radiation dose rate measurements may be performed during V&V activities to provide radiologic-specific information to the field team regarding gamma radiation emanating from a source measured in µR/hr. Once elevated radiation dose rates are identified, ALARA techniques can be implemented to minimize personnel radiation doses by avoiding higher-dose areas, such as ore stockpiles and storage pads, or by working as quickly and efficiently as possible in these areas.

Handheld radiation dose rate instruments usually consist of an integrated unit (the instrument) in which the radiation detector and associated electronics are built into a single instrument, or a separate detector interfaced with a rate meter. When using the gamma radiation survey instrument, the surveyor will document the range of readings observed around the source of radiation being surveyed. Measurements performed using a radiation dose rate instrument (e.g., Thermo Scientific FH 40 G Multi-Purpose Digital Survey Meter or equivalent) are conducted in accordance with Appendix D.

For consistency, the radiation dose rate instrument will be positioned approximately 3 ft above the ground surface or 3 ft from the feature being investigated. It is acceptable to perform radiation dose rate measurements at distances of less than 3 ft above the ground surface or feature when attempting to identify or delineate discrete points of radioactivity. When the instrument is used to obtain radiological-type characteristic information, those measurement results will generally not be recorded as the information is intended to guide further field investigation. However, if reportable information is captured with the handheld instrument, the data will be stored in an electronic form created for radiological surveys, and the measurement point will be recorded with the handheld GPS units.

5.3.6.2 Gamma Radiation Surveys

Gamma radiation surveys are performed to obtain radiological data that represent the magnitude and spatial distribution of gamma radiation across the mine. This information is used to understand the potential radiological risk to visitors and residents. Due to the natural mineralization surrounding most mines, spatial variability in soil radionuclides is expected to be high, potentially exhibiting order-of-magnitude changes in concentrations and associated exposure rates over distances of 20 or 50 ft. It has been the experience of the DRUM Program that 20 or 50 ft transect spacing conservatively and reliably documents site conditions for most mines surveyed and that greater spacings could be employed with the awareness that additional transects may be added after QA procedures have been completed to ensure adequate coverage and achievement of the objective. After delineating the total disturbed area, the field team lead and the RCT will decide what spacing, ranging from 20 to 50 ft, is most appropriate for a given mine. A survey that involves spacing above 50 ft will have additional requirements outlined in Appendix D. For larger mines where the disturbed area exceeds 10 acres, a modified transect spacing is appropriate to efficiently collect the screening level data to evaluate site conditions without jeopardizing the overall objective. For these larger mines, transect spacing may be increased to 100 ft if the field team lead, in consultation with the RCT, determines that an increased transect interval is appropriate. If gamma radiation readings are greater than 256 µR/hr, the area in question will be further delineated and surveyed with 20 or 30 ft transect spacing. A gamma radiation survey can identify these spatial variabilities and the resultant gamma radiation exposure rates when used in conjunction with location data collected with a GPS unit. The resulting map of the gamma radiation survey visually displays, in a color-coded isocontour fashion, the extent and magnitude of gamma radiation to identify potential onsite sources and offsite releases, and to understand the overall area of gamma radiation elevated above background. Observations of gamma radiation will be used to target sediment shed areas for sampling.

During its initial field season in 2017, the DRUM Program used local or regional background levels to delineate the mines and control the extent of the gamma radiation surveys. Although the concept is sound, this method proved to be inefficient and cumbersome for screening a high volume of mines. An analysis of the 2017 background gamma radiation dataset concluded that using 20 µR/hr as a surrogate exposure rate would be more efficient and equally as effective as using actual regional or local background data. Beginning in 2018, a surrogate background gamma radiation value of 20 µR/hr was incorporated for all V&V gamma radiation surveys.

Table 4 provides a summary of the updated background gamma radiation dataset, which as of May 2020 includes 255 gamma radiation background areas (n = 255). The statistics provided in Table 4 are based on the minimum (i.e., the lowest gamma radiation value measured at each background location), maximum, and mean gamma radiation values for each background location dataset. Mean gamma radiation values are calculated using gamma radiation data from within the disturbed area only.

Table 4. Summary of Background Gamma Radiation Dataset

Evaluation Criteria	Minimum	Maximum	Mean
Number of gamma radiation data points per location	10	1303	157
Mean gamma radiation values (µR/hr)	4.4	54.8	8.7
Standard deviation	2.7	8.2	4.4
95% UCL	7.8	11.7	9.3

Abbreviation:
UCL = upper confidence limit

Table 4 shows that the background gamma radiation values are somewhat variable for the locations sampled, but the 95% upper confidence limit for the maximum data values from each background location is well below 20 µR/hr. Moreover, only three of the 255 background locations had mean gamma radiation values greater than 20 µR/hr (these three values were 23.5, 26.6, and 54.8 µR/hr). This indicates that 20 µR/hr is a reasonable higher-end background estimate. It is also safely below the lower risk threshold of 35 µR/hr and well below the sediment shed threshold of 85 µR/hr to account for uncertainties associated with the instrumentation or impacts from surrounding geologic conditions. For these reasons and to continue to meet the objectives of the gamma radiation surveys, 20 µR/hr is used as a surrogate background gamma radiation value. Therefore, the gamma radiation survey transect endpoint value is 20 µR/hr, as described in Appendix D.

Surveys performed using the gamma radiation survey instrument (e.g., NUVIA Dynamics Inc. model portable ground information system [PGIS-2-1], Environmental Restoration Group, Inc. [ERG] RadScout, or equivalent) will be conducted as follows (and in accordance with Appendix D).

The gamma radiation survey system (instrument) consists of several primary components, as described in Table 5 below. The system, carried in a backpack or mounted on an all-terrain vehicle, is used to collect GPS and corresponding gamma radiation measurements over a wide area at a rate of approximately one measurement per second. The system records, compiles, and then stores the radiological survey and GPS location data via software on the user interface device.

Table 5. Gamma Radiation Survey Systems

System	User Interface	GPS Receiver	Radiation Detector	Radiation Signal Processor
PGIS-2-1	Smartphone with Android OS	Trimble Inc. R1 or equivalent	Sodium iodide crystal and processing electronics are fully integrated into the PGIS-2-1 unit	
RadScout	Tablet with Windows OS	Juniper Systems, Inc. Geode or equivalent	Ludlum Measurements, Inc. (Ludlum) Model 44-10 sodium iodide	Ludlum Model 3000 count rate meter

Abbreviation:
OS = operating system

The goal for survey coverage density is to collect data sufficient in degree of magnitude and spatial proximity to identify and map onsite sources and potential offsite releases of gamma radiation. The areas to be surveyed include the disturbed area; impacted sediment shed areas, if any; the safely accessible crest and toe of waste rock piles where the intervening slopes are inaccessible; and areas adjacent to the disturbed area margins that are safe to access. Adequate coverage will be achieved by walking transects of adequate spacing across the disturbed area until the surrogate gamma radiation level of 20 µR/hr outside the disturbed area is encountered, as described in Appendix D. Data will be reviewed in the field as described below to ensure that the gamma radiation survey adequately covers the area of interest.

When utility task vehicles (UTVs) are used in conjunction with gamma radiation surveys, UTV speeds shall keep within a range of 3 to 10 miles per hour.

The sufficiency of gamma radiation data collected at each mine will be evaluated in the field following completion of the gamma radiation survey by overlaying real-time gamma radiation data with an aerial image of the mine. The gamma radiation survey coverage and conditions relative to the value of 20 µR/hr at the termination of each transect will be reviewed to identify any data gaps and collect additional data as conditions allow before demobilization from the site. Examples of insufficient data include areas of possible offsite migration between transects and the delineation of onsite gamma radiation anomalies above 256 µR/hr.

Field QA steps frequently involve informal evaluation of real-time data generated by the gamma radiation instrumentation and the GPS units. These checks are made in the field as data are collected and again before demobilization. As noted in Section 5.0, many of the data collected are based upon observations of existing conditions.

The gamma radiation survey instrument's spatial accuracy can sometimes be disrupted by terrain and vegetative cover that reduce the GPS satellite signal quality. This reduction of accuracy is known as Position Dilution of Precision (PDOP) and causes the individual data points to appear skewed from their true location. In these instances, to ensure all appropriate gamma radiation points are included in the mean calculation, a polygon or "footprint" will be generated to include these points. The gamma radiation footprint feature will only be used to incorporate data points that were recorded within the disturbed area but appear outside it because of PDOP.

5.4 Assessment of Mine-Related Features and Ecology

The following section describes the data points collected in the field for the purpose of documenting conditions encountered at a mine at the time of the sampling event. Various QA points are incorporated into these processes to validate specific sampling activities and to verify measurements collected during inventory.

5.4.1 Mine-Related Features

Field data will be collected by trained staff using documented, repeatable methods with QA checkpoints to ensure that high-quality, accurate information is obtained. Field data are reviewed as they are collected to ensure that the information is complete and accurate and that any anomalies are accounted for.

Each mine may vary in the number and complexity of mine features. The purpose of the inventory task is to observe and record those features. Appendix F describes the features catalogued during inventory. To establish accurate correlations between the inventory data and environmental sampling points, the following five data validation points are completed as part of the sampling process: (1) verification of the disturbed area perimeter, (2) evaluation of mine entry status, (3) confirmation of waste rock pile locations and dimensions, (4) verification of mine accessibility observations, and (5) verification of observations of previous human use associated with the mine. These observations are field-confirmed by the field teams as a QC checkpoint and to facilitate environmental sampling and aid in the RSA process.

The disturbed area is mapped during inventory activities, as described in Section 5.2.3 above. However, to ensure the validity of the disturbed area determination, the field team lead, team geologist, and team RCT (while recording gamma radiation) will walk the disturbed area margins and either confirm their location or adjust as necessary to ensure that the most accurate representation of the disturbed area boundary is identified given observed conditions. Although the disturbed area boundary is defined as the margin of mechanical disturbance associated with a specific mine, there may be unique instances in which that margin is unclear. In these cases, relatively elevated gamma radiation measurements may be used to determine the disturbed area boundary. Any adjustments to the disturbed area boundary will be mapped with a GPS unit.

To aid in the sampling QA process, the checklist described in Appendix F will be utilized by field teams to determine the scope of the data that need to be collected and to ensure that appropriate information is observed and recorded given the extent to which the features are safely accessible. FOPs, however, may outline modifications to the checklist. The field team will use a GPS unit to map any mine-related features not recorded during the inventory.

Critical components of the QA process include use of the Process Form (attached to Appendix F) or an equivalent form stored in an online LMS database, data checks while in the field, and the best professional judgement exercised by field teams while relying on the authority of team leads to make field decisions. Visual observations of site conditions and sampling locations and procedures are undertaken by the team lead and complement the field QA process. The rationale for field decisions and any modifications to sampling or QA procedures will be documented by detailed field notes to ensure that an accurate record of work accomplished is preserved for final reporting.

5.4.2 Ecology Features

Ecological information relevant to each field activity area is collected in advance to direct field activities and address special-status species likely to be present. The FOPs contain information on the potential presence of special-status species and habitat along with related restrictions for preventing disturbance of these species and habitat. Before field visits, the field team ecologists create special-status species lists which include information about collecting evidence of these species; soils information when appropriate; and data related to surface water, potential wetlands, and other ecologically sensitive areas.

Data are collected to describe the ecology at each mine and evaluate potential hazards to ecological resources. Evidence of flora and fauna and their potential habitat on or near the mine is collected and evaluated in relation to mine features and sources of contamination. Appendix F contains checklists and additional information about the ecological features that will be recorded at each mine.

Ecologists will collect the following information and document it with a GPS unit and photographs:

- **Vegetation on waste rock piles:** Estimated foliar cover and dominant, secondary, and trace species present on each waste rock pile. Species are documented using their common and scientific name or Natural Resources Conservation Service standardized code. Although waste rock piles may not represent separate ecological units, they will be mapped separately from the rest of a mine so this information can be used in the ecological hazard evaluation. If vegetation is similar, several waste rock piles may be mapped as a single unit.
- **Ecological units:** The general location (normally recorded as a representative GPS location point) of distinct ecological units at and surrounding the mines. Descriptions will include dominant and secondary species. Trace species will be recorded as time allows, especially when they have special significance (e.g., if the species is a noxious weed or indicates that an area may have been reseeded).
- **Special-status species:** Evidence may include sightings, calls, or physical evidence, such as distinctive burrows, prints, bones, feathers, or plant parts.
- **Potential habitat for special-status species:** Evidence many include specific soil or ecosystem types, structural features that could provide nest or shelter habitat, primary food sources, or riparian areas.
- **Wildlife use:** Signs of animal presence (e.g., bones, scat, burrows, nests, roosting areas).

- **Wildlife hazards:** Any physical features that pose a threat of injury or death to wildlife will be recorded. Examples include open drill holes or vents (2–18 inches in diameter), wells or pipes, tangled barbed wire, subsidence features, and confining structures.

The Endangered Species Act (ESA), described in 16 USC 1531 et seq., requires all federal agencies to further the conservation of endangered and threatened species and their habitat and to consult with USFWS for all actions that have the potential to affect these species and their designated critical habitat. In support of this requirement and to support USFS, BLM, state, and other USFWS conservation efforts, field ecologists will notify managers if a federally listed endangered or threatened species is found at or near a mine, or if any special-status species is found outside its known range during the course of V&V work. Managers will contact DOE and request that the appropriate land management agency (USFWS, state, BLM, USFS, or tribe) be notified of the occurrence.

The Navajo Nation Division of Natural Resources Department of Fish and Wildlife protects tribally listed endangered species on Navajo Nation lands. Many of these species are also listed under the federal ESA. The field ecologists will be given the Navajo Endangered Species List and will ensure that any areas to be disturbed by vehicles, soil sampling, staging, or other work activities do not affect Navajo listed species or their habitat. If a species is sighted, it shall be handled under the same guidelines outlined above for federally listed species.

5.5 Approval of V&V Work Plan Deviations

Depending on field conditions observed during the inventory activities, specific environmental sampling procedures may be modified by the field team lead with approval from the URP manager. It is anticipated that V&V Work Plan deviations would only occur when site-specific circumstances do not allow for implementation of V&V Work Plan procedures. If deviations are necessary and approved by the URP manager, in consultation with LM if available, the changes shall be documented in field notes, saved electronically, and referenced in mine-specific V&V reports. If there is a need for substantive deviations from the procedure during project execution as determined by the URP manager, an addendum to this procedure will be prepared and implemented, and LM will be notified.

5.6 Postfield QC Evaluation

Postfield QA/QC evaluation of the environmental data collected during V&V activities is completed the week following the site visit. The purpose of the evaluation is to ensure that data were collected as specified in the V&V Work Plan. The data review, using the Process Form or an equivalent form stored in an online LMS database, includes an evaluation of the following: the accuracy of GPS data; the field assessment of the number, type, and condition of mine entries; the sufficiency of background and mine-specific gamma radiation data; and whether the number of waste rock piles, impacted drainages, and corresponding number of sample nodes were collected accurately.

6.0 Reporting

6.1 V&V Reports

A V&V report is prepared for each mine following compilation and examination of data collected during the field visit. The purpose of each mine-specific report is to summarize the results of V&V activities and to facilitate the transfer of information to help inform agency decisions regarding potential remnant hazards and risks to human health and the environment. The report also serves as documentation that DOE has completed DRUM Program objectives and has addressed discrepancies in historical records for mines identified in the Report to Congress (DOE 2014b). Each report will be a stand-alone document summarizing the findings for the mine it represents and will include the following:

- An introduction to the DRUM Program and V&V activities
- A description of reconciliation information and documentation
- Regional geologic information
- A mine inventory information table
- Figures showing mine location, topographical features, mine inventory features, gamma radiation survey results, derived radium-226 concentrations, and environmental sample locations
- Photos of mine-related and other relevant features
- Environmental sampling information including:
    - Gamma radiation survey information.
    - A table summarizing soil and surface water (if applicable) sampling activities and a table containing soil sample results with corresponding analytical data.
    - A risk scoring summary that ranks and describes hazards and risks presented by the mine.
    - Metals and radium-226 cumulative risk ratio bar charts for waste rock samples.
    - Appendixes with a glossary of terms, investigation methods, RSA criteria, RSA tables, and when applicable, mine merged duplicates forms, environmental sampling laboratory reports, and any other relevant documentation related to the mine.

Using the multiple lines of evidence from the field data collected, each report will focus on evaluating physical hazards and screening potential human health risks at a mine, as well as the modifying factors (potential ecological and environmental impacts, access and suitability, and complexity). Details on the RSA process can be found in Section 3.0 and Appendix E. A copy of the RSA table is included in Appendix E.

The report writing process begins with an initial evaluation of the data by the field teams and management to ensure data QA. Any conflicting or missing data are addressed by the field team members and resolved. Once data review is complete and the applicable lab analysis is validated (over the course of approximately 60 days), a V&V report is assembled. Individual reports are tracked through the writing and review process to ensure accuracy and timely completion. Reports and appendixes are formatted and edited to LMS and program-specific style standards.

To assure the validity of the dataset, QA/QC checks are performed before data evaluation and report development. QA/QC checks are completed via the data QA process described in Section 9.0 and during the qualitative and quantitative field data generation steps described in Sections 4.0 and 5.0.

V&V reports are subjected to multiple reviews to ensure completeness and accuracy. Reviews are conducted in accordance with the *Defense-Related Uranium Mines Quality Assurance Program Plan* (DOE 2024a), also called the Quality Assurance Program Plan (QAPP). The basic methodology for V&V report reviews involves several evaluations conducted by field team members, Document Management, a technical reviewer, and the report manager. This process is outlined in detail in *DRUM Report Writing Desktop Procedures* (DOE 2024c). These reviews evaluate the report using the following criteria:

- Adherence to the V&V Work Plan
- Accuracy of mine information
- Accuracy of figures
- Sample results
- RSA accuracy
- Spelling and grammar
- Consistent formatting
- Consistent use of terminology
- Incorporation of LM concerns and comments

V&V reports are submitted in PDF format to LM through the DRUM Program administrative assistant. LM reviews the report using a standard checklist created and approved by LM specifically to review V&V reports. Any comments are addressed, and the document is sent through an additional review process, revised accordingly, and resubmitted. Final reports are uploaded to the EFT site for partner agency access. Storage and version control of reports are managed locally by Records Operations and Document Management.

7.0 Safety and Health

Safety and health considerations for V&V activities at the mines are focused on physical and environmental hazards as well as limited potential radiological risks.

The *Worker Safety and Health Program (10 CFR 851)* (DOE 2023e) is the basis for how the LMS contractor safely performs work. The *Integrated Safety Management System Description for LMS in Support of DOE Legacy Management Sites* (DOE 2024f) defines how the LMS organization, in performing work, systematically integrates safety management and work practices at all levels. Both documents apply to all work conducted by LMS employees and subcontractors at any location.

The *Integrated Safety Management System Description for LMS in Support of DOE Legacy Management Sites* and the DSP ensure clear roles, responsibilities, and procedures are in place to achieve an integrated approach to ensuring worker safety and health consistently with Title 10 *Code of Federal Regulations* Section 851.11(a)(2)(ii) (10 CFR 851.11[a][2][ii]).

The DSP identifies hazards and defines health and safety policies and procedures for site workers (including subcontractors) who perform work for the DRUM Program; it also applies to vendors and visitors.

V&V work performed at the mines will also follow the requirements of the *External Dosimetry Procedure* (DOE 2024e). Specific requirements, limitations, goals, and actions associated with radiation protection for this project are defined in the DSP. Field workers will wear dosimeters to monitor their radiological exposure. If the dosimeters are not available, the DRUM Safety and Health coordinator will be contacted before the team mobilizes to a field location.

8.0 Environmental Requirements

8.1 Environmental Management System (EMS)

The joint LM/LMS EMS is a framework that includes environmental compliance and environmental sustainability, both of which are described below as they relate to the DRUM Program. The EMS is maintained by all DRUM Program employees with the assistance of the program's Environmental Compliance (EC) point of contact (POC).

8.1.1 Environmental Compliance

Environmental compliance consists of regulatory compliance and monitoring programs that implement federal, state, tribal, and local compliance requirements and obligations. Because work done under the DRUM Program is investigative in nature, it has a minor impact on the environment. This section describes areas of compliance most relevant to the program. Any special or unusual situations will be addressed in individual FOPs on a case-by-case basis.

8.1.2 Environmental Sustainability

The environmental sustainability aspect of the EMS, mandated by Executive Orders and DOE orders, integrates initiatives such as energy and natural resource conservation, waste minimization, and use of sustainable products and services in all phases of work. Sustainability programs applicable to the DRUM Program include EMS Sustainable Acquisition, Electronics Stewardship, and Vehicle and Fuel Use. Sustainable acquisition and electronics stewardship requirements are integrated into the LMS purchasing department processes; materials purchased for the DRUM Program outside the LMS purchasing department will also conform with these requirements. U.S. General Services Administration vehicle management is integrated with the vehicle and fuel use requirements. UTV fuel use is also subject to reporting requirements for the EMS Vehicle and Fuel Use Team. To support other goals of the EMS sustainability efforts, DRUM Program personnel will practice water conservation, waste minimization, pollution prevention, and recycling whenever possible.

8.2 Environmental Reviews and the National Environmental Policy Act (NEPA)

NEPA (42 USC 4321 et seq.) provides a process for federal agencies to evaluate the impacts of their actions on the environment. The LM *Environmental Review Form* (LM-Form-4-20.3-4.0) (ERF) is used to screen for potential human and environmental impacts of proposed actions and identifies the anticipated level of NEPA review and documentation to be completed. The ERF also identifies the need for environmental surveys, consultations, permits, and other regulatory considerations. An ERF and associated NEPA review are required for each project before undertaking activities. The Navajo Nation will be consulted during the environmental review process, and resulting concerns will be included in the ERF and NEPA review. Should any new scope develop outside of the typical DRUM Program work, it would be evaluated to determine the need for additional NEPA documentation.

8.3 Environmental Resources Potentially Present at V&V Sites

The following subsections identify requirements and restrictions regarding cultural and natural resources that apply to V&V fieldwork. This section does not include environmental laws or associated permits determined not to be applicable based on the noninvasive nature of V&V fieldwork (e.g., Clean Water Act, Sections 401 and 404).

8.3.1 Cultural Resources

Under the National Historic Preservation Act (NHPA) (54 USC 300101 et seq.), it is illegal to remove, pick up, or relocate items that have historical or cultural value without prior consultation with the appropriate State or Tribal Historic Preservation Officer. Artifacts and cultural resources are defined in Appendix F. Items with historic or cultural value may be difficult to distinguish from items without historic or cultural value. Therefore, if an item is not obviously recent, it is assumed to be protected under NHPA and will not be touched by the V&V team.

8.3.2 Natural Resources

The following subsections describe typical natural resource considerations as part of the DRUM Program.

8.3.2.1 Migratory Birds and Bald and Golden Eagles

Migratory birds are protected by the Migratory Bird Treaty Act (16 CFR 703–712), and bald and golden eagles are protected by the Bald and Golden Eagle Protection Act (16 USC 668). The acts prohibit harassment or destruction of birds, eggs, and nests, including removing bird parts, eggs, or nests from a site. To prevent disturbance or take of birds as defined by the acts, restrictions may apply to activities or UTV use in some areas or at times in a bird's life cycle. These restrictions will be provided by the EC POC and included in the FOP.

8.3.2.2 Threatened and Endangered Species

Threatened and endangered species and designated critical habitat are protected by the ESA and in some areas by other state, tribal, or local laws. This act requires all federal agencies to conserve threatened or endangered species and their habitat. It also requires all agencies to consult with USFWS regarding all actions that have the potential to affect these species or their designated critical habitat. In some areas and at certain times of year, DRUM inventory and environmental sampling activities have the potential to affect threatened or endangered species or designated critical habitat. Various species may experience different impacts from planned activities; therefore, the EC POC will provide the DRUM Program with guidelines specific to the ESA during FOP development to further compliance, enhance planning, and avoid confusion. The EC POC will assist LM in consulting with USFWS in cases where impacts on threatened or endangered species or designated critical habitat cannot be avoided.

8.3.2.3 Navajo Nation Listed Species

The Navajo Nation Division of Natural Resources Department of Fish and Wildlife protects tribally listed endangered species on Navajo Nation lands. The Navajo Nation will be consulted during preparation of the ERF before visiting mines on tribal lands to identify species of concern and related protection measures. The field team ecologists will ensure that any areas to be disturbed by work activities do not affect Navajo listed species. If a listed species is identified, it will not be pursued or harmed. The field ecologist will note its presence and report the information to the EC POC.

8.3.2.4 Motorized Vehicle Use Restrictions

Motorized vehicle use for the purpose of accessing mines is restricted to travel routes designated by the appropriate land management agency or tribal nation. Use of UTVs is usually permissible on waste rock piles, mine access roads, and previously disturbed portions of mines. UTV use is not permitted in designated critical habitat where activities have the potential to affect that habitat or in areas where activities have the potential to affect threatened or endangered species. The EC POC will determine whether activities could result in potentially harmful effects as individual FOPs are being developed.

The field team ecologist will determine if special-status species, migratory birds, or their habitat is present in areas considered for UTV use, and their presence will be identified in the FOP. The ecologist, in consultation with the field team lead, will develop a strategy to complete work in a manner that does not adversely impact these resources. Potential strategies include avoidance of resources by UTVs and completion of work without UTVs. In all instances and locations, care will be taken to ensure that ecological resources will not be adversely affected by UTV use.

8.4 Hazardous Materials and Wastes

The use, handling, and storage of limited hazardous materials and wastes are described in the following subsections.

8.4.1 Hazardous Material Transportation

Small quantities of hazardous materials (e.g., nitric and sulfuric acid) are used to preserve surface water samples and will be transported to field locations. The U.S. Department of Transportation (DOT) regulates the transport of hazardous materials (49 CFR 172; 49 CFR 173) and specifies allowable quantities, packaging, and training requirements. In accordance with these regulations, the acids used for sample preservation qualify as materials of trade because they are packaged as required, and drivers of all vehicles are trained to transport them safely.

8.4.2 Waste Management

Although unlikely, investigation-derived waste (IDW) may be generated in the process of investigating a potentially contaminated mine site and may include surface water sample material intended for disposal, used personal protective equipment, used decontamination solutions, and used sampling supplies and equipment. IDW may also be generated offsite, such as at an analytical laboratory. Uncontaminated IDW (including materials that have been decontaminated) may be bagged and disposed of as trash. Contaminated IDW will be characterized and managed in accordance with applicable environmental laws and regulations. In the case of samples and sample containers, disposal of contaminated IDW will normally be done by the analytical laboratory.

Samples sent for analysis will be managed by the receiving laboratory. Unaltered soil and water sample materials (e.g., unpreserved water samples) that are not submitted for analysis will be returned to their originating locations. Altered sample materials (e.g., preserved water samples) as well as other types of contaminated IDW will be evaluated to determine whether they are hazardous or radioactive before disposal. Such materials are subject to applicable laws and regulations as described in Section 4.0 of the *Environmental Instructions Manual* (DOE 2024d). Under the Resource Conservation and Recovery Act (42 USC 6901 et seq.), a solid waste exemption exists for uranium mining waste products. Radioactive waste is primarily addressed by the Atomic Energy Act (42 USC 2011 et seq.) in addition to multiple DOE orders.

8.4.3 Spills

Management of fuel, other petroleum products, and refueling operations will be conducted in accordance with the DSP. Spills may include fluid leaks from vehicles, spills from sample preservatives or calibration standards, or spills from other equipment. If a spill occurs, the approximate volume and concentrations of the spill will be recorded, and the EC POC will be notified as soon as possible. If the volume and concentrations of the spill require reporting, the EC POC will report it to LM and the Navajo Nation. If the spill involves hazardous or suspected hazardous materials, the EC POC will be contacted before the field team leaves the site to determine proper management, notification, and transport procedures. Spills involving hazardous materials are considered environmental releases and will be cleaned up immediately according to instructions on Safety Data Sheets described in the DSP.

Small spills are those involving less than 10 gallons (liquids) or 50 pounds (solids). Personnel will follow established protocols for preventing and responding to small spills as outlined in Section 11.0 of the *Environmental Instructions Manual*.

Dry, absorbent materials may be used to clean up small spills. Soil that contains the spilled material will be overexcavated about 3 inches on all sides and will be placed in a container labeled with identifying information, a contact name, and a phone number. If the material is known or suspected to be hazardous, then the term “Hazardous Pending Analysis” will also be included on the label.

If the spill is larger, field teams will follow protocols outlined in the *Environmental Instructions Manual*. Regardless of the size of the spill, field teams will contact the EC POC, who will give follow-up instruction and record the spill incident to track for the EMS program.

9.0 Quality Assurance

The LMS contractor aims for quality in all endeavors. The delivery of defect-free products and services on time and within approved budgets is integral to this goal. At the same time, these activities must be accomplished in a safe and environmentally protective fashion. To achieve quality in activities and products, the LMS contractor has implemented a formal QA program to ensure that the LMS contractor achieves quality standards throughout all technical, administrative, and operational functions.

The *Quality Assurance Manual* (DOE 2024g) (QAM) describes and establishes the LMS QA program. The QAM describes a QA management system that incorporates the requirements of DOE Order 226.1B Chg 1 (Admin Chg), *Implementation of Department of Energy Oversight Policy*, and DOE Order 414.1D Chg 2 (LtdChg), *Quality Assurance*, using International Organization for Standardization (ISO) 9001:2015, *Quality Management Systems—Requirements*, as the chosen national standard. The provisions of the QAM apply to all programs and projects managed by the LMS contractor that require the application of a QA program. The achievement of quality is the responsibility of those who manage and, most importantly, perform the work. All personnel are expected to work in accordance with the QA program procedures and requirements to ensure they display quality to themselves, their customers, and their suppliers.

For the DRUM Program, the QAPP was developed to be consistent with EPA's *Requirements for Quality Assurance Project Plans (EPA QA/R-5)* (EPA 2001). EPA's (2002) *Guidance for Quality Assurance Project Plans (EPA QA/G-5)* was used as a guide in preparing the QAPP. DQOs are discussed in the QAPP and presented in Appendix A. The QAPP identifies the training and qualification requirements for staff to ensure the highest degree of quality workmanship during V&V activities. All personnel performing V&V activities are knowledgeable and capable of performing the work and making appropriate field determinations.

The inventory and environmental sampling field protocols require inputs of qualitative observations and quantitative data into a handheld GPS unit with sub-meter accuracy. Field checklists are employed to ensure that the appropriate data are collected during each mine visit. An additional in-office evaluation of field data will include a review of the following:

- Type and status of mine entries
- Number and condition of structures
- Sufficiency of gamma radiation survey data
- Number of soil samples obtained
- Number of sediment shed samples obtained
- Sufficiency and accuracy of ecological data
- Sufficiency of photographic documentation

- Accuracy of hazard and risk assessment
- Accuracy of access and human use assessment

The Process Form, or an equivalent form stored in an online LMS database, defines a method to capture and document the completion of QA/QC checks as required in the QAPP and the V&V Work Plan.

In addition to observational and quantitative data collected in the field, analytic data from laboratory analyses of soil and surface water samples are evaluated by the Environmental Monitoring, Operations, and Sciences group. The reporting team will also evaluate quantitative and qualitative data to ensure that reconciliation documentation, inventory, and sampling activities are internally consistent and adhere to program protocols.

10.0 References

10 CFR 20. U.S. Nuclear Regulatory Commission, "Standards for Protection Against Radiation," *Code of Federal Regulations*.

10 CFR 851.11. U.S. Department of Energy, "Development and Approval of Worker Safety and Health Program," *Code of Federal Regulations*.

16 CFR 703–712. U.S. Fish and Wildlife Service, "Migratory Bird Treaty Act," *Code of Federal Regulations*.

49 CFR 172. U.S. Department of Transportation, "Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans," *Code of Federal Regulations*.

49 CFR 173. U.S. Department of Transportation, "Shippers – General Requirements for Shipments and Packagings," *Code of Federal Regulations*.

16 USC 668. "Bald and Golden Eagle Protection Act," *United States Code.*

16 USC 1531 et seq. "Endangered Species Act," *United States Code.*

42 USC 2011 et seq. "Atomic Energy Act," *United States Code*.

42 USC 4321 et seq. "National Environmental Policy Act," *United States Code*.

42 USC 6901 et seq. "Resource Conservation and Recovery Act," *United States Code*.

42 USC 9601 et seq. "Comprehensive Environmental Response, Compensation, and Liability," *United States Code*.

54 USC 300101 et seq. "National Historic Preservation Act," *United States Code*.

BLM (U.S. Bureau of Land Management), 2017. *Screening Assessment Approaches for Metals in Soil at BLM HazMat/AML Sites*, technical memorandum, September.

Brown, S.H., 2017. *Establishing Radiological Screening Levels for Defense-Related Uranium Mine Sites on BLM Land Using a Recreational Future Use Scenario*, report prepared by SHB Inc. for Navarro Research and Engineering, Inc., July 27.

Brown, S.H., 2018. *Addendum – Establishing Radiological Screening Levels for DRUM Sites on BLM Land Using a Recreational Future Use Scenario*, prepared for Navarro Research and Engineering, Inc., Grand Junction, Colorado, March.

Brown, S.H., 2022. *Establishing Radiological Soil Screening Levels (SSLs) for DRUM Sites on Tribal Land – Final*, report prepared by SHB Inc. for the LMS contractor, July 7.

DOE (U.S. Department of Energy), 1997. *Tabulation of Uranium Ore Production Under AEC Program, 1948–1970*, National Archives Record Group 434-00-287.

DOE (U.S. Department of Energy), 2014a. *Defense-Related Uranium Mines Location and Status Topic Report*, LMS/S10693, Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2014b. *Defense-Related Uranium Mines Report to Congress*, U.S. Department of Energy, August.

DOE (U.S. Department of Energy), 2021. *Records and Information Management*, LM-Policy-1-11-1.0-0.1, Office of Legacy Management, March.

DOE (U.S. Department of Energy), 2023a. *Defense-Related Uranium Mines Data Management Plan*, LMS/DRM/S19467-2.0, Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2023b. *Defense-Related Uranium Mines Safety Plan*, LMS/DRM/S15804-2.0, Office of Legacy Management, October.

DOE (U.S. Department of Energy), 2023c. *Environmental Restoration Group, Inc. RadScout Instrument Evaluation for Defense-Related Uranium Mines Program Gamma Radiation Surveys*, LMS/DRM/44638, Office of Legacy Management, June.

DOE (U.S. Department of Energy), 2023d. *Integrated Work Control Process Manual*, LMS/POL/S11763-5.1, Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2023e. *Worker Safety and Health Program (10 CFR 851)*, LMS/POL/S14697-4.0, Office of Legacy Management, December.

DOE (U.S. Department of Energy), 2024a. *Defense-Related Uranium Mines Quality Assurance Program Plan*, LMS/DRM/S15867-4.0, Office of Legacy Management, February.

DOE (U.S. Department of Energy), 2024b. *Defense-Related Uranium Mines Verification and Validation Work Plan Campaign 2: Navajo Nation*, LMS/DRM/41156-0.5, Office of Legacy Management, September.

DOE (U.S. Department of Energy), 2024c. *DRUM Report Writing Desktop Procedures*, LMS/DRM/S24089-2.0, Office of Legacy Management, September.

DOE (U.S. Department of Energy), 2024d. *Environmental Instructions Manual*, LMS/POL/S04338-8.1, Office of Legacy Management, February.

DOE (U.S. Department of Energy), 2024e. *External Dosimetry Procedure*, LMS/POL/S16263-2.2, Office of Legacy Management, June.

DOE (U.S. Department of Energy), 2024f. *Integrated Safety Management System Description for LMS in Support of DOE Legacy Management Sites*, LMS/POL/S14463-6.1, Office of Legacy Management, July.

DOE (U.S. Department of Energy), 2024g. *Quality Assurance Manual*, LMS/POL/S04320-19.0, Office of Legacy Management, August.

DOE (U.S. Department of Energy), 2024h. *Radioactive Source Use and Control*, LMS/PRO/S20089-2.0, Office of Legacy Management, June.

DOE (U.S. Department of Energy), 2024i. *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites*, LMS/PRO/S04351-16.7, Office of Legacy Management, September.

DOE (U.S. Department of Energy) and NAMLRD (Navajo Abandoned Mine Lands Reclamation Department), 2022. *Program Support and Safeguarding of Defense-Related Uranium Mines*.

DOE Order 226.1B Chg 1 (Admin Chg), *Implementation of Department of Energy Oversight Policy*, U.S. Department of Energy, May 3, 2022.

DOE Order 414.1D Chg 2 (LtdChg), *Quality Assurance*, U.S. Department of Energy, September 15, 2020.

DOE Order 430.1C Chg 2 (Admin Chg), *Real Property Asset Management*, U.S. Department of Energy, September 17, 2020.

DOE Order 458.1 Chg 4 (LtdChg), *Radiation Protection of the Public and the Environment*, U.S. Department of Energy, September 15, 2020.

EPA (U.S. Environmental Protection Agency), 2001. *Requirements for Quality Assurance Project Plans (EPA QA/R-5)*, EPA/240/B-01/003, Office of Environmental Information, March.

EPA (U.S. Environmental Protection Agency), 2002. *Guidance for Quality Assurance Project Plans (EPA QA/G-5)*, EPA/240/R-02/009, Office of Environmental Information, December.

EPA (U.S. Environmental Protection Agency), 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4)*, EPA/240/B-06/001, Office of Environmental Information, February.

EPA (U.S. Environmental Protection Agency), 2024a. "Regional Screening Levels (RSLs)," https://www.epa.gov/risk/regional-screening-levels-rsls, September 3, accessed September 2024.

EPA (U.S. Environmental Protection Agency), 2024b. "Updated Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities," https://www.epa.gov/superfund/updated-soil-lead-guidance-cercla-sites-and-rcra-corrective-action-facilities, May 17, accessed September 2024.

Harris, M., B. Clucas, J. Stanek, and M. Whitfield, 2019. "Wildlife Mortalities in Open-Topped Pipes in Central California," *Western Wildlife*, v. 6, October, pp. 50–60.

ICRP (International Commission on Radiological Protection), 2007. *The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103.

ISO 9001:2015. *Quality Management Systems—Requirements*, International Organization for Standardization.

Smith, K.S., C.A. Ramsey, and P.L. Hageman, 2000. *Sampling Strategy for the Rapid Screening of Mine-Waste Dumps on Abandoned Mine Lands*, U.S. Geological Survey Open-File Report 2000-16.

USACE (U.S. Army Corps of Engineers), 1987. *Wetlands Delineation Manual*, Wetlands Research Program Technical Report Y-87-1, Waterways Experiment Station, January.

Appendix A

Data Quality Objectives

The EPA seven-step process to achieve DQOs (EPA 2006) was applied as a strategic planning approach to aid in the generation of an adequate quantity and quality of data to support screening assessments of potential human health risks for the DRUM Program. This process is applied to the collection of environmental and analytical data used for the program. This process, however, is not considered applicable to the observational data collected for ecological and physical hazard evaluation. The analytical data collected by the field personnel include radiological data, soil samples, and sediment shed samples. Sections A1.0 through A7.0 present the steps in the planning for data collection.

A1.0 State the Problem

Radionuclides and metals may be present at elevated levels at some DRUM Program mines and could pose a risk to human health via the following exposure scenarios: (1) recreational camping, (2) livestock ranching, (3) residential occupancy based on EPA assumptions, or (4) residential occupancy based on Navajo Nation assumptions. The concentrations and spatial distributions of the potential contaminants at the mines are compared to established benchmarks for each of the four exposure scenarios to determine if there is a potential risk to human health.

A2.0 Identify the Decision

The LMS contractor will collect samples of soil and sediment, measure gamma radiation activity at each mine, and compare the results to benchmarks established for the DRUM Program. These benchmarks are the recreational scenario (BLM 2017; Brown 2017), the livestock rancher scenario (BLM 2017; Brown 2017), the residential scenario (EPA 2024a; EPA 2024b; Brown 2022), and the Navajo Nation surrogate residential scenario (EPA 2024a; EPA 2024b; Brown 2022).

Surface water samples will be collected when site conditions during V&V activities suggest that surface water that could potentially be impacted by the mine is present. Surface water samples are not collected in the case of ephemeral water bodies formed due to recent precipitation that are likely to persist for less than approximately 2 weeks. The analytical results will not be considered in evaluating site risks as they are considered a single snapshot in time and thus insufficient to establish reliable screening values. The presence of water, where observed, will be incorporated into the RSA, and the water quality data will be provided in the individual mine reports.

A3.0 Identify Inputs to the Decision

Unlike the approach used for DRUM Program Campaign 1, a risk ranking score will not be developed for the COI or gamma radiation data in Campaign 2. For Campaign 2: Navajo Nation, COI risk ratios will be developed and reported for each of the four exposure scenarios described in Section A1.0 in order to illustrate actual results rather than assign an individual risk ranking score defined by the DRUM Program. A risk ratio below 1 indicates that COI concentrations at a given mine-related feature should not pose an unacceptable human health risk. Where COI concentrations equal or exceed a screening level, the potential for human health risk may be present assuming that the exposure scenario occurs. The four exposure scenarios assume an equivalent hazard quotient of 1 for noncarcinogens and a threshold of 10^{-6} for carcinogens. The recreational and livestock rancher screening exposure durations are 14 days per year for 26 years and 42 days per year for 26 years, respectively (BLM 2017). Exposure durations for the more conservative residential and Navajo Nation surrogate residential scenarios are 350 days per year for 26 years (6 years as a child and 20 years as an adult) and 350 days per year for 75 years, respectively (EPA 2024a; EPA 2024b). Gamma radiation exposures are based on the standard of 100 mrem/yr, which is the basic international consensus (including DOE) standard for public exposure from all sources (10 CFR 20; DOE Order 458.1 Chg 4 [LtdChg]; ICRP 2007), and on Brown (2022).

A4.0 Inputs to Measurement Data

The following measurements and samples will be collected at DRUM Program mines:

- Gamma radiation measurements obtained using field instruments
- Soil sampling for laboratory analysis of EPA Target Analyte List metals, uranium, and radionuclides from waste rock piles or other significant features
- Radiological dose measurements obtained using field instruments

Sample collection and analytical protocols are identified in the LMS *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2024i) as well as in Section 5.0 and Appendixes C, D, and H of this V&V Work Plan. Instrument calibration practices are described in individual procedures included as attachments to this document. Sample and analytical QC practices are identified in the DRUM QAPP.

A5.0 Define the Study Boundaries

In this document, the word "mine" refers to a mine in the DRUM Program from which AEC recorded purchases of uranium ore for defense-related purposes. Production history is generally limited to the period of 1947 to 1970, when uranium ore was sold to AEC (DOE 2014a). LM defines a mine as a feature or complex that is generally associated with a patented or unpatented mining claim (established under the General Mining Law of 1872, as amended) or a lease of federal, state, or tribal lands or private property (DOE 2014b). A mine may be a feature such as a surface or underground excavation, or it may comprise an area containing a complex of multiple, interrelated excavations. Associated mining-related features typically include adits and portals, surface pits and trenches, highwalls, overburden piles, waste rock piles, structures, shafts for ventilation or other purposes, stockpile pads, mine-water retention basins or treatment ponds, closely spaced development drill holes, historical trash, and debris piles.

The study boundary of each mine will include the area disturbed by mining operations on the ground surface and areas outside the disturbed area where gamma radiation readings greater than 85 µR/hr (sediment shed areas) are measured. Background samples will be taken beyond these boundaries in areas with similar geological, geophysical, and ecological features.

A6.0 Develop a Decision Rule

A decision rule involves developing a prioritization method that assesses the concentrations of the contaminants present at each mine (radionuclides and metals). Table 2 in the V&V Work Plan presents a list of the COIs, associated screening levels, and laboratory detection limits.

A7.0 Data Collection Design, Planning, and Acceptance Criteria

A data collection design specifies the type, number, location, and physical quantity of samples and data, as well as the QA and QC activities that will ensure that sampling design and measurement errors are managed sufficiently to meet the performance criteria specified in the DQOs.

The DRUM Program DQO process achieves a sound and defensible data collection design using the following elements:

- Implementing the attached sampling procedures and radiological scanning protocols
- Adhering to the processes and procedures in this V&V Work Plan and the QAPP

The DRUM Program will generate the quality of data necessary to meet the performance criteria required for the RSA by using an adequate quantity of sampling points. Table C1 of Appendix C describes how the DRUM Program has defined the quantity of samples necessary in particular cases. Appendix C is further organized around the other sampling objectives to guide the quantity and location of sampling efforts. Various levels of QA and QC are included in the DRUM Program (e.g., LMS internal procedures and the DRUM-specific QAPP are additional controls which address data uncertainty and variability and the application of periodic assessments and reviews). Lastly, additional QA and QC steps are noted in the V&V Work Plan as applicable.

Appendix B

Office of Legacy Management Technical Memoranda

BLM Technical Memorandum

Screening Assessment Approaches for Metals in Soil at BLM HazMat/AML Sites

September 2017 Update: Table 1 has been updated to reflect EPA's latest Regional Screening Level summary table values and toxicity updates (June 2017). The only metal whose screening levels changed from the previous version of this memorandum is uranium, which decreased an order of magnitude due to a new oral toxicity value recommended by EPA.

Introduction: The screening of chemicals present at a site constitutes the first phase of the assessment of human health and environmental risk. This paper discusses strategies and considerations for conducting a screening assessment, and describes a "multiple lines of evidence" approach to support site decision making.

At most BLM HazMat/AML sites, inorganics (metals and metalloids) are the primary concern, but many of the approaches in this document also applies to organic compounds. A screening level assessment typically consists of a comparison of site data with a risk-based concentration to evaluate whether a release has occurred and to get an initial understanding of the potential risks. Screening levels (SLs) are concentrations of chemicals in soil intended to be protective of human health and/or the environment under a defined exposure setting. SLs can be developed for all media, but are most commonly used at sites with soil contamination (or tailings). By their nature SLs are conservative (i.e., health protective) since they are acting in lieu of information gathered during a more detailed site investigation. Considerations for the development of SLs should include land use and habitat at the site, the presence and activities of human and ecological receptors, possible contaminant migration, and naturally occurring background concentrations. As a general rule, SLs are generic and do not take into account site-specific issues.

SLs are often used in the early phases of an environmental investigation program when only minimal data is available – for example, during the Preliminary Assessment and Site Inspection (PA/SI) phase. Data collected during more comprehensive site assessments, such as an Environmental Evaluation and Cost Analysis (EE/CA) or Remedial Investigation and Feasibility Study (RI/FS), may also be compared with SLs as part of a site-specific risk assessment. The data considered in a PA/SI screening assessment should include samples collected from site locations considered to be the most contaminated. The maximum detected chemical concentrations (max detects) may then be compared with SLs to get an initial understanding of the degree of potential risk present at the site. The approach of comparing max detects with conservative SLs tends to provide a worst-case portrait of potential risk. This worst-case evaluation tends to overestimate true risks and should be interpreted cautiously and in conjunction with the other site factors discussed in this memo.

Screening Basics: There are a number of assumptions inherent in SLs that need to be considered before conducting a site screening. In brief, the specific populations and receptors of interest, the primary pathways, and chemical toxicity all affect the appropriateness of an SL. For example, human health SLs can be developed for residents, workers, or recreational visitors, and may consider either cancer or noncancer endpoints. Alternatively, ecological SLs may be developed for soil dwelling organisms (e.g., invertebrates, small mammals), vegetation, birds, or herbivores. In general, SLs tend to be most appropriate for long-term, chronic exposure scenarios. In many cases at BLM sites, human exposures tend to be more occasional and short-term (e.g., a recreational hiker). Casual use of SLs should not replace an understanding of site setting and the development of a conceptual site model (CSM) that links chemical sources to potentially exposed receptors.

The results of a risk-based screening are typically presented as the ratio of the site concentration of a specific chemical to its respective health-protective screening value. This may be referred to as a numerical or quantitative screen. When the ratio (the "hazard quotient", or HQ, in risk assessment terms) exceeds one (1), that chemical is considered to pose a potential risk and should be evaluated further. If the max detect for a chemical is below its SL, it is often concluded that this chemical does not pose a risk and may be dropped from future consideration. Examples of widely used screening levels for chemicals in soil are presented in Table 1.

Screening can be made on a chemical-by-chemical as well as a media-specific basis. Most commonly, the max detect of a specific chemical is compared against a screening value for that same chemical. If the max detect is less than the SL, often it is concluded the chemical doesn't pose a risk and is not considered further. If the max detect for all chemicals are below their respective SLs, it is often concluded that the site soil doesn't pose a significant risk. Chemicals that exceed their respective SLs are termed "chemicals of potential concern" (COPCs) and it is generally considered that further action (i.e., more comprehensive investigation) is needed. If exceedances are substantial and the CSM suggests the exposures are ongoing, an emergency or time-critical removal action may be appropriate. More typically, however, additional data is collected to further evaluate how extensive the contamination and potential risk is before any remedial action is taken. It should be kept in mind that mine tailings and waste rock are not soil, although they are commonly evaluated as such in screening level assessments. Their physical and chemical attributes are different than actual soil, which may affect some risk assessment assumptions (e.g., bioavailability, which represents the amount of chemical actually absorbed into the bloodstream). The ecological habitat provided by tailings and waste rock may be of minimal value, since tailings are mostly devoid of nutrients and organic matter. As a general rule, it is not recommended that ecological SLs developed for soil be applied to tailings and waste.

Although screening level assessments are commonly mentioned in regulatory documents, there is not much available in the way of formal guidance. EPA's PA/SI, EE/CA, and RI/FS and Risk Assessment Guidance for Superfund (RAGS) should be reviewed if additional information is needed. In addition, some states have SLs available as guidance or written into regulation.

Background Concentrations: Screening against naturally occurring background concentrations is an important step at most AML sites. Background concentrations can vary significantly between locations, particularly in mineralized zones where mining is typically done. A background screen provides a different perspective from a risk-based screen; depending on the site setting and the chemical, the background concentration can be higher or lower than a risk-based screening value. Typically both a risk-based and a background screening comparison are conducted to determine which chemicals pose a potential risk above and beyond naturally occurring concentrations. A site may exceed risk-based SLs yet be below background levels; this should be taken into consideration when evaluating a screening assessment.

Table 2 presents a summary of representative background concentrations of naturally occurring metals in soil throughout the western US. These concentrations may not describe mineralized zones, however, and should only be used if site-specific values are not available. The data in Table 2 are provided as a general reference but are not meant to replace site-specific values. Background values are best used in combination with SLs to evaluate whether a release of hazardous substances has occurred at the site.

Using Screening Results: Screening level evaluations should be interpreted cautiously when making site management decisions. Screening assessments are usually based on limited site data; making informed decisions often requires that additional data be collected to better define the problem. It can be tempting to conduct a "quick and dirty" comparison of some data and conclude that the site does or doesn't pose an unacceptable risk. It should be noted that a screening level evaluation is only as useful as the site data (e.g., has a sample [or samples] been collected from the area of expected highest concentration?) and the appropriateness of the SL (e.g., a human health SL doesn't inform as to ecological risk). Screening levels are NOT default cleanup levels, and site decisions should not be based solely on exceedances of these levels.

The proper way to interpret a screening level assessment is by combining an understanding of possible human health risk, ecological habitat and exposure potential, site characteristics, contaminant migration potential, and background levels. An important initial step is developing a CSM, usually represented as a diagram that links contaminant source areas to human and ecological receptors via exposure and transport pathways (Figure 1).

Human Health Screening

The most widely used human health screening values are the Regional Screening Level (RSLs) developed by the US EPA for residential and industrial populations (http://www.epa.gov/region9/superfund/prg/). These values are very conservative (e.g., overly protective) for most BLM sites, since they assume more frequent and routine site exposure than typically occurs on BLM land. For example, the residential RSLs assume exposure to site soil for 350 days/year for 26 years and the industrial RSLs assume worker exposure for 225 days/year for 25 years. Although highly conservative for most BLM sites, EPA's RSLs can be useful in gaining an initial understanding of the magnitude of potential risk and at sites where off-site residents live in immediate proximity of the contamination. In addition to soil, EPA has developed RSLs for air, tapwater, and protection of groundwater. Some state health agencies have also developed screening levels, but like EPA they only address residents and workers. EPA SLs for residential and industrial exposure are shown in Table 1.

Recreational visitors are the most common group of human receptors on BLM land. This is a broad category that can cover a range of possible activities, including camping, hiking, hunting, biking, ATV riding, horseback riding, etc., all with somewhat different exposure profiles. An example CSM for recreational visitor land use is shown in Figure 1. Most BLM land has no formal use or access restrictions, so conservative, yet realistic, assumptions must be made regarding the frequency of recreational use. BLM has developed a set of recreational SLs for metals most commonly found at AML sites. BLM's recreational SLs (Table 1) take into account the limited exposures associated with most recreational activities. The yearly recreational exposure frequency is assumed to be14 days/year, based on the assumption that individuals are unlikely to spend more time at an individual site on an annual basis. The exposure duration assumed for recreational visitors, 26 years, is the default exposure duration recommended by EPA for residents. It has been assumed that two years of the exposure occur as a child and 24 years as an adult; appropriate exposure parameters have been included in the calculations to account for these integrated age groups. The recreational RSLs were calculated using EPA's online screening level calculator. BLM will update the values in Table 1 periodically based on EPA's updates of toxicity values and exposure assumptions.

Ecological Screening

Terrestrial Receptors: A numerical ecological screening evaluation is not typically done in the initial phase of an environmental investigation. It is important to first identify habitat types present, possible receptors, and whether threatened or endangered (T&E) species may be present. This can be done through an investigation of site history and a literature search, and should be incorporated into the CSM. At most BLM mine sites, the ecological screening step will be more dependent on various qualitative endpoints, such as habitat, availability of food and shelter, and general ecological "attractiveness" of the site (such as proximity to waterways). Many BLM AML sites consist of tailings or waste rock piles, and provide little or no functional habitat to ecological receptors.

Ecological SLs for chemicals in soil for different receptors are available from EPA, US Fish and Wildlife, and other groups. These levels have many assumptions built into them, and should be considered only when the initial qualitative screening step indicates that that may be potentially significant exposures to sensitive receptors at the site. EPA ecological risk guidance notes a difference between potential impacts to individual organisms and population groups. An ecological screen at BLM mine sites needs to consider how widespread the site effects may be; impacts to receptors (real or calculated) assumed to be directly exposed to the site need to be considered in light of impacts to the local or regional population. In broad terms, common receptors are protected at the population level, while T&E species are protected at the individual organism level.

Conducting a quantitative ecological risk assessment (e.g., a "baseline" risk assessment) remains an option, should the screening step raise concerns over possible ecological risk. The ecological protective levels mentioned previously would be considered as part of a site-specific risk assessment. This level of detail is only needed at a relatively small proportion of BLM HazMat/AML sites.

Aquatic Receptors: Some BLM mine sites directly impact aquatic habitat by draining into nearby wetlands, streams, or rivers. Tailings may have been dumped directly into waterways, may be slowing migrating over time, or acid mine drainage may be coming from an adit. Both contaminated surface water and sediments can adversely affect aquatic receptors, which are sensitive to the toxic effects of some metals. Sites that impact wetlands and waterways are generally of greater concern, due to potential widespread impact and the high toxicity of many metals to aquatic life.

Not all waterways run year round; many of the smaller streams near mine sites on BLM lands in the Western US are ephemeral in nature and are dry part of the year. This obviously limits the types of receptors that may be present. The CSM should determine whether aquatic or wetlands species need to be considered. Depending on the flow volume and regularity, ambient water quality criteria (AWQC) may be identified as "applicable or relevant and appropriate requirements", or ARARs.

Developing a "Multiple Lines of Evidence" Discussion for a Screening Assessment

A screening assessment should not be considered as a single step, rather it should assemble multiple lines of evidence that provide a more complete picture of contamination and risk at a site. Although every site has its unique characteristics, typically a screening analysis should consider the following factors as part of a multiple lines of evidence evaluation.

- Site characteristics: Location, proximity and access issues, historical activities
- Attractive nuisances: holes and adits, old equipment
- Contamination: distribution, concentration, types of chemicals, speciation
- Human health: signs of use, types of likely or possible use, numerical screening results
- Ecological: habitat types, presence of water, size of site, receptors, T&E species
- Groundwater and surface water: hydraulic connections, transport, leachability
- Background concentrations: mineralized zone vs. standard locations
- Offsite migration potential:

Figure 2 shows a schematic representation of how multiple lines of evidence may be combined to support decision making. It is not a fixed process with mandatory inputs; rather it is a flexible approach that combines a variety of relevant site information into an overall matrix that can provide the basis for informed decision making. The weighting of each line of evidence will vary depending on the quality and importance of the data. As the lines of evidence are developed, there are opportunities to collect additional information as project uncertainties are identified.

Taken collectively, the overall weight of evidence should allow the project manager to conclude whether the site is not likely to pose any risk or whether potential risk is present and the site should be evaluated further. The lines of evidence and their findings should be presented in the PA/SI (or other document) and used to support the overall conclusions of the investigation and help chart the path forward.

After the Screening Assessment

Screening assessments are most commonly used to evaluate sites and determine if they clearly pose minimal or no risk, may pose a potential risk, and those that clearly exceed acceptable risk levels. Future site activities may be developed based on the findings of the screening assessments. Sites with minimal risk may be candidates for a "no further action" determination; sites with potential risk may require a modest amount of additional information be collected to support decision making; and sites with high risk may be candidates for an EE/CA, an RI/FS, or more extensive intervention.

Initial site COPCs are typically identified in the screening assessment and may require further consideration. The lines of evidence discussion will help identify areas of uncertainty and data gaps that need to be addressed. Finally, screening levels may be useful as preliminary remediation goals, but should not automatically be considered as default cleanup values.

For additional information on screening assessments and risk assessments, please contact Doug Cox at the National Operations Center at dcox@blm.gov or 303-236-9451.

Table 1
Human Health Screening Levels (SLs) for Chemicals in Soil At BLM HazMat/AML Sites (mg/kg)

Chemical	BLM Recreational SL	EPA Residential SL	EPA Industrial SL
Aluminum (Al)	>1,000,000	77,000	>1,000,000
Antimony (Sb)	782	31	470
Arsenic (As)	30.6	0.68	3
Barium (Ba)	390,000	15,000	220,000
Beryllium (Be)	3,910	160	2,300
Cadmium (Cd)	1,780	71	980
Chromium (III) (Cr)	>1,000,000	120,000	>1,000,000
Cobalt (Co)	586	23	350
Copper (Cu)	78,200	3,100	47,000
Iron (Fe)	>1,000,000	55,000	820,000
Lead (Pb)	800[a]	400	800
Manganese (Mn)	46,700	1,800	26,000
Mercury (elemental) (Hg)[b]	271	11	46
Molybdenum (Mo)	9,780	390	5,800
Nickel (Ni)	39,000	1,500	22,000
Selenium (Se)	9,780	390	5,800
Silver (Ag)	9,780	390	5,800
Thallium (Tl)	19.6	0.78	12
Uranium (U)[c]	391	16	230
Vanadium (V)	9,850	390	5,800
Zinc (Zn)	587,000	23,000	350,000
Primary Exposure Assumptions	14 days/year, 26 years, adult/child	350 days/year, 26 years, adult/child	225 days/year, 25 years, adult

[a]The recreational SL for lead is based on EPA's industrial SL, which assumes regular and chronic exposure to soil, although not as frequently or extensively as the residential SL.

[b]Mercury is the only metal on the list whose SL is based on the inhalation pathway. EPA made some minor changes in their volatilization modeling in 2015 and the SL increased slightly. SLs for all populations may exceed the soil saturation concentration (Csat), an estimate of the concentration at which the soil pore water, pore air, and surface sorption sites are saturated. Above this theoretical threshold concentration, mercury may be present in free-phase within the soil matrix.

[c]Uranium screening values updated per changes in EPA's oral toxicity value.

Table 2
Representative Background Concentrations of Metals In Soils of the Western US (mg/kg)[a]

Chemical	Typical (Average)	High End (Maximum)
Aluminum (Al)	5,800	100,000
Antimony (Sb)	0.62	2.6
Arsenic (As)	7	97
Barium (Ba)	670	5,000
Beryllium (Be)	0.97	15
Cadmium (Ca)	< 1.0	11
Chromium (III) (Cr)	56	2000
Cobalt (Co)	9	50
Copper (Cu)	27	300
Iron (Fe)	26,000	> 100,000
Lead (Pb)	20	700
Manganese (Mn)	480	5,000
Mercury (Hg) (elemental)	0.065	4.6
Molybdenum (Mo)	1.1	7
Nickel (Ni)	19	700
Selenium (Se)	0.34	4.3
Silver (Ag)	0.5	5
Thallium (Tl)	9.8	31
Uranium (U)	2.7	7.9
Vanadium (V)	88	500
Zinc (Zn)	65	2,100

[a] Values are indicative of the range of naturally occurring soil concentrations in the western United States. Variations can occur from site to site. Concentrations in local mineralized zones may not be included.

Source: Elements in North American Soils, 2nd Ed. 2005.

Figure 1
Example of a Human Health Conceptual Site Model (CSM)

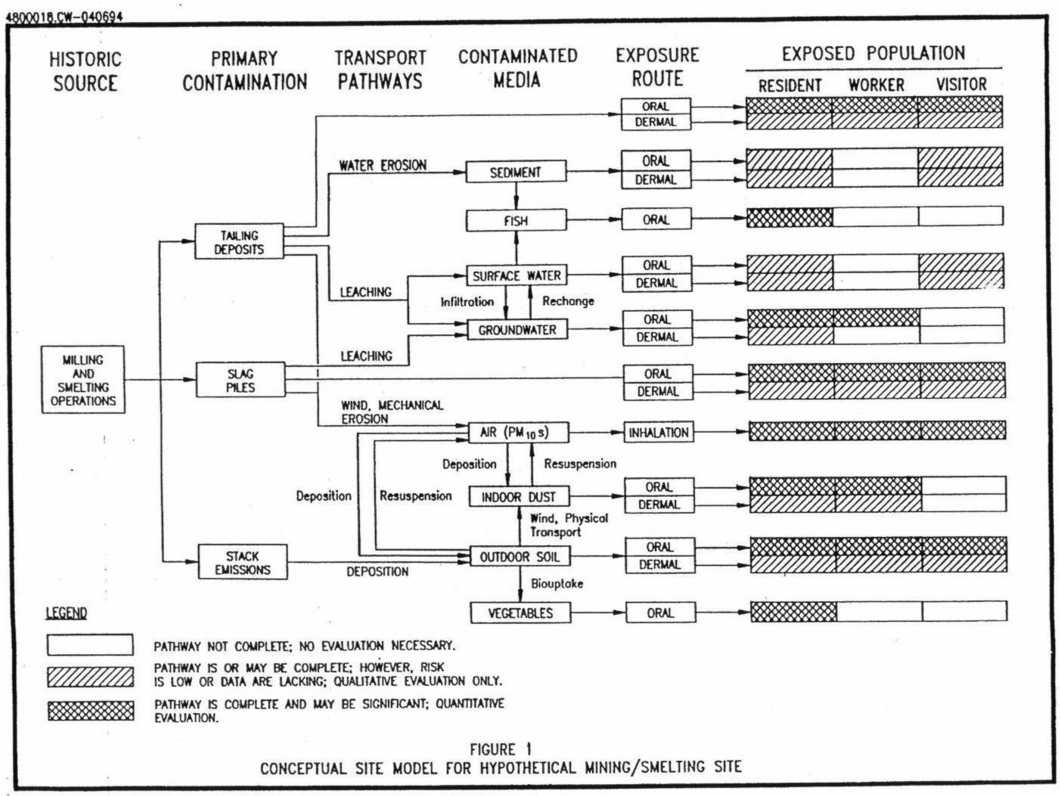
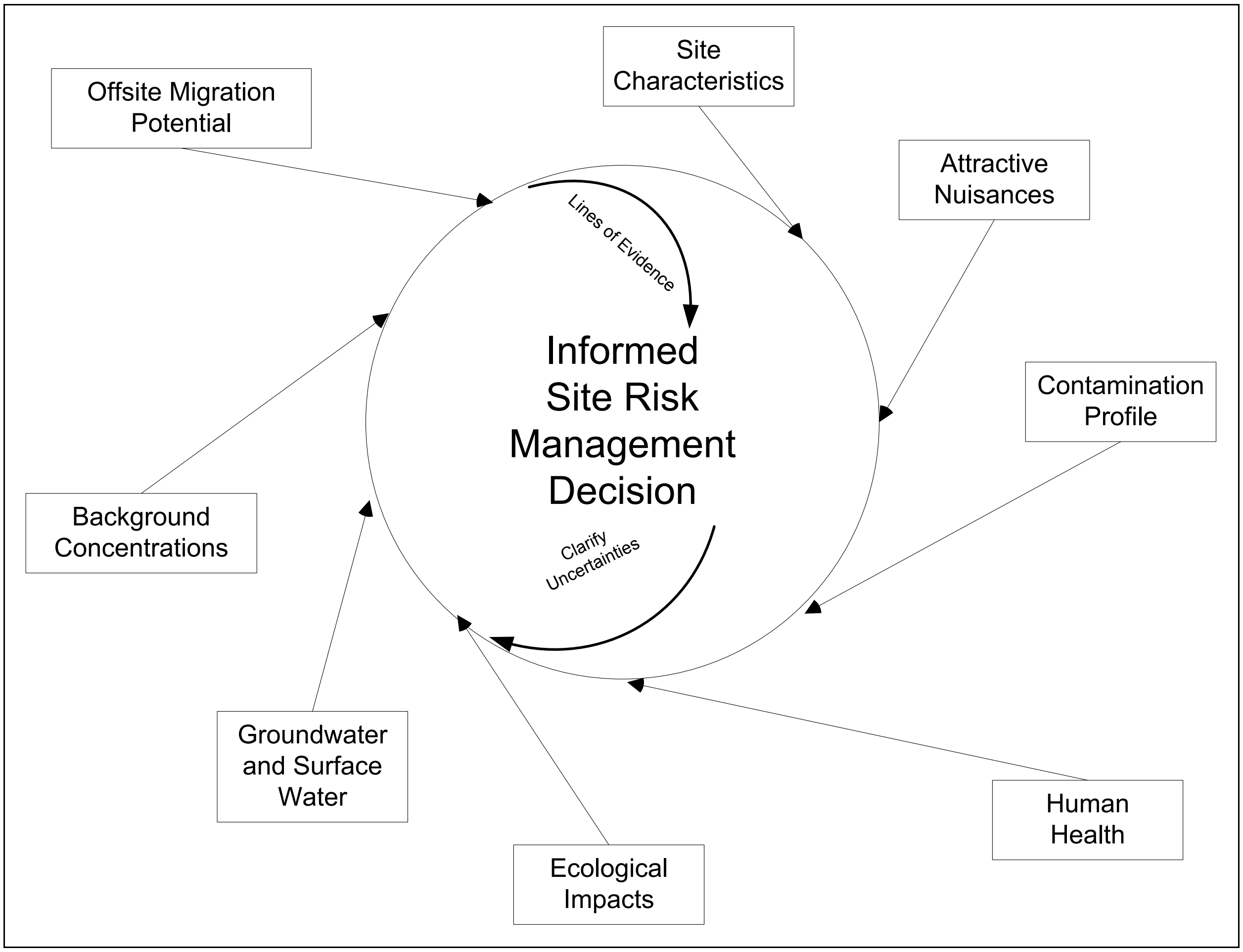


Figure 2
Using Multiple Lines of Evidence to Support a Screening Assessment



Establishing Radiological Screening Levels for Defense-Related Uranium Mines Sites on BLM Land Using a Recreational Future Use Scenario

Prepared for Navarro Research and Engineering, Inc.
Grand Junction, CO
Final July 27, 2017

Prepared by
Steven H Brown, CHP
SHB Inc. Centennial, CO

Establishing Radiological Screening Levels for Defense-Related Uranium Mines on BLM Land Using a Recreational Future Use Scenario

Table of Contents

Tables and Figures

Establishing Radiological Screening Levels for Defense-Related Uranium Mines Sites on BLM Land Using a Recreational Future Use Scenario

1.0 Background and Discussion

In Brown 2016a, a suggested general approach and associated technical basis was described for establishing "screening levels" for Defense-Related Uranium Mines (DRUM) sites on U.S. Bureau of Land Management (BLM) land based on relatively easy-to-measure average external (gamma) radiation exposure rates. This is provided as Attachment 1. One general form to using screening levels, as presented in Attachment 1, is as follows:

- ≤ Background (BKG) = No action
- Between BKG and *X* times BKG = Further evaluation (e.g., perform refined calculations, make some additional measurements, collect some samples for verification)
- ≥ *X* times BKG = More comprehensive site assessment and survey may be necessary

The future use scenario that was defined and is considered in further detail here is recreational, in which a camper spends 2 weeks/year at the site. It is assumed that the majority of DRUM locations are rural, relatively arid sites in the Southwestern United States (e.g., states of Colorado, Utah, Arizona, Wyoming, and New Mexico), which limits to some degree the credible pathways of exposure that need to be considered. The characteristics of the recreational scenario proposed and references supporting its assumptions were originally provided in Table 1 of Attachment 1. Similarly, the choice of relevant exposure pathways for this scenario and associated supporting references and assumptions were provided in Table 2 of Attachment 1.

The basic approach to define the screening levels (external exposure rates) involves establishing an exposure rate for each pathway (including both external and internal exposure as applicable) based on a unit concentration of radionuclides in soil. Since the contaminant of concern at DRUM sites is naturally occurring radioactive material (NORM) as uranium ores (mixed with waste rock), it is reasonable to assume that the uranium is in equilibrium with all progeny in the ^{238}U decay chain (including ^{226}Ra, for example). Accordingly, it is relatively straightforward to do this and the justification of the assumptions, and the results of this "calculation" are the subject of this paper.

A concentration of ^{238}U and all other radionuclides in the uranium decay series in soil is established as 1 pCi/g. The exposures over 2 weeks for each of the relevant exposure pathways are then calculated based on this soil concentration. The applicable pathways are:

1. External exposure from the soil (i.e., ground shine, which often will be the dominant pathway for natural uranium sites if there is not a "residential" indoor radon/progeny pathway)
2. Casual ingestion of soil
3. Inhalation of dusts

4. Special case of dust inhalation for an off-highway vehicle (OHV) rider
5. Inhalation of radon gas and particulate progeny

The total effective dose equivalent (TEDE) is the sum of the dose equivalents from each pathway:

$T = E_x + S_{ing} + I_d + I_{ohv} + I_{Rn}$

Where:

T = TEDE for a 14-day recreational exposure scenario per pCi/g of each of the ^{238}U plus ^{235}U series radionuclides in soil

E_x = Dose equivalent (DE) from external exposure from the soil

S_{ing} = Committed effective dose equivalent (CEDE) from casual ingestion of soil

I_d = CEDE from inhalation of dusts

I_{ohv} = CEDE from inhalation of dusts during use of OHVs

I_{Rn} = CEDE from inhalation of ^{222}Rn and progeny

The use of the 2 weeks/year recreational camper scenario with the associated pathways listed above is consistent with what was assumed in USDOE 2014 (with exception of the OHV rider). For reasons presented in Table 1 of Attachment 1 (Brown 2016a), we assume that other common recreational activities often considered in these analyses (i.e., fishing for food, hunting for food, eating forage vegetation, water ingestion) are not relevant for these semiarid, relatively remote DRUM sites.

It is recognized that hunting for food (both small and large game animals) is a common activity in some areas of the Uravan mineral belt of the Southwest. However, although the recreational user may hunt and/or fish and eat the "catch", lack of sufficient forage vegetation at these semi-arid sites, particularly on or in the immediate vicinity of waste (ore) rock and spoils areas, would suggest the animals are migratory and would not have spent their lives subsisting in the "contaminated zone".

Once the "2-week dose" for each of the relevant exposure pathways per unit concentration in soil is calculated, they are summed to determine the TEDE. Using an appropriate and acceptable annual public dose exposure limit (choice to be determined by the U.S. Department of Energy (DOE), see Section 7.2) we can then establish the associated external exposure rate as well as the associated equilibrium soil concentration that assures the exposure for 2 weeks/year will be less than the selected "exposure limit."

2.0 External Exposure (E_x)

Table 5.1 of NCRP Report No. 94 (NCRP 1987) indicates that the absorbed dosed rate in air from 1 pCi/g in soil of "U-238 + daughters" is 139 µGy/year (microgray/year). Using the methodology described therein for converting between absorbed dose rates and exposure rates in air results in an exposure rate of 1.8 µR/hr. Accordingly, the total external exposure associated with 1 pCi/g for each of the uranium series radionuclides in soil during the 2-week period is simply:

E_x = (14 days) × (24 hr/day) × (1.8 µR/hr) = 605 µR = 0.60 mrem per pCi/g.

3.0 Casual Ingestion of Soil (S_{inj})

From USDOE 2014 Table 4, 100 mg/day is used as the soil ingestion rate for a recreational visitor. The footnote associated with this value states:

Value recommended by EPA (1989) for adults in residential settings. The recommended value for adults in occupational setting is 50 mg/day (EPA 1991). However, assuming reclamation activities would result in more contact with soils, the ingestion rate that was assumed for residents was used for reclamation workers as well. For recreational visitors, using the same ingestion rate provides a more conservative estimate of the potential risk.

Accordingly, using the more conservative value, 100 mg/day × 14 days = 1.4 g soil ingestion over a 2-week period (1).

A dose conversion factor (DCF) (e.g., DCF = Sv per Bq ingested) for the aggregate of radionuclides contained in uranium ore at equilibrium could not be found as such in the literature. Accordingly, an "aggregate DCF" is calculated in Table 1 using the most important ("highest") specific DCFs for radionuclides in the decay chains for natural uranium. Where multiple solubility class/absorption type DCFs are provided for a nuclide, the value for the least soluble species is used (longest residence time/larger DCF). The radionuclides from the actinide (^{235}U) decay series have been ignored since the ratio of ^{235}U activity to ^{238}U activity in uranium ore dust is the natural abundance ratio of 0.046 to 1 and contributions to the aggregate ingestion DCF would be quite small. Some radionuclides in the ^{238}U decay series have been ignored since their DCFs are < 10^{-9} Sv/Bq and would have no material impact on the result.

TABLE 1: Ingestion Dose Conversion Factors (DCFs in Sv/Bq intake)

Radionuclide	DCF from USEPA 1988	DCF from ICRP No. 68 (1994a) and/or ICRP No. 78 (1997)
^{238}U	6.9×10^{-8}	4.4×10^{-8}
^{235}U	7.2×10^{-8}	4.6×10^{-8}
^{234}U	7.6×10^{-8}	4.9×10^{-8}
^{234}Th	3.7×10^{-9}	3.4×10^{-9}
^{230}Th	1.5×10^{-7}	2.1×10^{-7}

^{226}Ra	3.6×10^{-7}	2.8×10^{-7}
^{210}Po	5.1×10^{-7}	2.4×10^{-7}
^{210}Pb	1.4×10^{-6}	6.8×10^{-7}
Aggregate DCF	$\mathbf{2.6 \times 10^{-6}}$	$\mathbf{1.6 \times 10^{-6}}$

[1] USEPA 2000 and 2007 use the value of 120 mg/day as a "general population tendency." Specifically regarding soil ingestion by children, USEPA 2011a recommends using a value of 50 mg/day for ages 1–21 with an "upper percentile value" for children of 200 mg/day. It is also noted that a behavior referred to as "pica" is mentioned in the literature in which a young child ingests several grams of soil in a single event. However, this is an "extreme" circumstance and not considered sustainable over multiple days without possible medical implications and is therefore ignored here.

The values from ICRP Publication 68 and 78 are based on much more recent metabolic data and models than the values in USEPA 1988 (by about 25 years), although it is noted that the FGR No. 11 (USEPA 1988) aggregate DCF is about 60% higher. Nonetheless, the aggregate DCF calculated from individual radionuclide values in USEPA 1988 are used here in the interest of conservatism and given that the contribution of the soil ingestion pathway to the TEDE of the sum of all relevant pathways is small (see Section 7.1).

Accordingly, the CEDE for incidental soil ingestion over a 14-day period is calculated:

$I_{ing} = (2.6 \times 10^{-6}$ Sv/Bq$) \times (10^{5}$ mrem/Sv$) \times (1/28$ Bq/pCi$) \times (1.4$ g$) \times (1$ pCi/g$) = 0.012$ mrem per pCi/g

4.0 Inhalation of Dusts (I_d)

The dose per unit concentration (e.g., per pCi/g ^{238}U in the soil) is calculated as follows:

$I_d = DCF_{Uore}(1/PEF)C\ BR\ T$

Where:

I_d = CEDE from inhalation of uranium ore in dusts per unit concentration in soil (in mrem)

DCF_{Uore} = CEDE from inhalation for all nuclides in ^{238}U and ^{235}U decay series per unit intake (mrem/pCi of each nuclide in equilibrium) via inhalation of dust containing uranium ore

PEF = Particulate emission factor from USEPA 2007, Section 3.3.3 = 1.32×10^{9} m^3/kg

C = Concentration of ^{238}U and each progeny in dust = 1 pCi/g

BR = Breathing (inhalation) rate from USEPA 2007, Section 3.3.3 = 20 m^3/day

T = Time of exposure = 14 days

4.1 Determining DCF_{Uore} for Inhalation of Uranium Ore Dusts

Assumptions:

- Dust that is inhaled is from uranium-bearing ore only and contribution from the natural thorium

(^{233}Th) series is negligible and consistent with general background of ^{232}Th.

- The ore dust inhaled is in full radioactive equilibrium.
- The ratio of ^{235}U activity to ^{238}U activity in uranium ore dust is the natural abundance ratio (0.046).
- The particle size distribution of the dust inhaled is represented by the standard default activity mean aerodynamic diameter (AMAD) of 5 µm.
- The chemical form of each radionuclide in the dust inhaled is that corresponding to the slowest lung absorption type specified in ICRP Publications 68 and 78 (i.e., Clearance Type M or S [Moderate or Slow]); this maximizes residence time in the lung and, therefore, the dose).

Table A-I of IAEA 2004 presents the quantities (activities) of radionuclides inhaled and the corresponding committed effective doses in mSv for the inhalation of ore dust containing 1 Bq of ^{238}U. This is reproduced here as Table 2. The doses are calculated using the dose coefficients listed in IAEA 1996. Using the values of total alpha activity and total committed effective dose calculated in Table 2, the committed effective dose per unit intake of alpha activity[(2)] = 0.0035 mSv/Bq.

TABLE 2: Inhalation Dose Conversion Factors for Uranium Ore Dust (Per Bq/g of ^{238}U at Equilibrium)

Series	Radionuclide	Type	Type of emitter	Inhalation dose coeff's. (5 um AMAD) (Sv/Bq)	Specific Activity (Bq/g)	Effective 5 um inhalation dose coeff's. (Sv/αBq)
URANIUM	Uranium-238	S	α	5.7E-06	1.00	5.7E-06
	Thorium-234	S	β	5.8E-09	1.00	5.8E-09
	Protactinium-234m		β	0.0E+00	1.00	0.0E+00
	Uranium-234	S	α	6.8E-06	1.00	6.8E-06
	Thorium-230	S	α	7.2E-06	1.00	7.2E-06
	Radium-226	M	α	2.2E-06	1.00	2.2E-06
	Radon-222		α	0.0E+00	1.00	0.0E+00
	Polonium-218		α	0.0E+00	1.00	0.0E+00
	Lead-214	F	β	4.8E-09	1.00	4.8E-09
	Bismuth-214	M	β	2.1E-08	1.00	2.1E-08
	Polonium-214		α	0.0E+00	1.00	0.0E+00
	Lead-210	F	β	1.1E-06	1.00	1.1E-06
	Bismuth-210	M	β	6.0E-08	1.00	6.0E-08
	Polonium-210	M	α	2.2E-06	1.00	2.2E-06
ACTINIUM	Uranium-235	S	α	6.1E-06	0.046	2.8E-07
	Thorium-231	S	β	4.0E-10	0.046	1.8E-11
	Protactinium-231	S	α	1.7E-05	0.046	7.8E-07
	Actinium-227	S	β	4.7E-05	0.046	2.2E-06
	Thorium-227	S	α	7.6E-06	0.046	3.5E-07
	Radium-223	M	α	5.7E-06	0.046	2.6E-07
	Radon-219		α	0.0E+00	0.046	0.0E+00
	Polonium-215		α	0.0E+00	0.046	0.0E+00
	Lead-211	F	β	5.6E-09	0.046	2.6E-10
	Bismuth-211		α	0.0E+00	0.046	0.0E+00
	Thalium-207		β	0.0E+00	0.046	0.0E+00
	Gross alpha activity concentration (αBq/g)				8.322	2.9E-05
	Weighted dose conversion coefficient (alpha only) (mSv/Bq)					0.00350
	Weighted dose conversion coefficient (alpha only) (Sv/Bq)					3.500E-06

[2] Contribution from beta activity is very small. See Table 2.

4.2 Calculation of CEDE for Incidental Inhalation of Dusts

Accordingly, the CEDE for incidental inhalation of uranium ore in dusts over a 14-day period is:

$I_d = DCF_{Uore}\,(1/PEF) C\, BR T$

I_d = (0.0035 mSv/Bq) × (1/28 Bq/pCi) × (100 mrem/mSv) × (1/1.32 × 10^9 m^3/kg) × (10^3 g/kg) × (1 pCi/g) × (20 m^3/day) × (14 days)

$I_d = 2.6 \times 10^{-6}$ mrem per pCi/g

5.0 Inhalation of Dusts During Use of OHVs (I_{ohv})

Several references provide perspectives on dust generation and exposure associated with the use of OHVs and all-terrain vehicles during recreational activities.

EPA derived site-specific PEFs for OHV riding at two mine sites in Colorado. The baseline human-health risk assessments for the Standard Mine Site and the Nelson Tunnel/Commodore Waste Rock Pile used the results from activity-based air sampling to calculate PEFs for OHV riding (USEPA 2008, 2009, 2011b). A PEF of 8.47 × 10^5 m^3/kg (equivalent to 1.18 × 10^{-6} kg/m^3) was calculated from the Standard Mine Site data and an "average PEF" of 1.65 × 10^4 m^3/kg (6.08 × 10^{-5} kg/m^3) was calculated from the combined PEFs for three metal-specific studies at the Nelson Tunnel site.

In USDOI 2014, it is indicated that the baseline human-health risk assessment performed for the Topock Compressor Station Remediation Project site (California) referenced the derived PEF for OHV riding based on airborne dust measurements collected during sampling at the Standard Mine Site (USEPA 2008, 2009). Because it was based on actual measurements collected during OHV riding, the Standard Mine Site PEF (8.47 × 10^5 m^3/kg) was considered to be the most accurate value for estimating airborne respirable dust levels from OHV riding at the Topock site. It was further indicated in this memorandum that this recommended PEF for OHV riding is very similar to the default value recommended in DTSC 2011 for construction workers of 1.0 × 10^6 m^3/kg.

In USEPA 2007, Section 3.3.4, it was assumed that a rider of an OHV recreational vehicle at legacy uranium sites would be involved in recreational activities and that the vehicles travel at an average speed of 40 mph. The airborne concentration of respirable dust, 5 mg/m^3 (equivalent to 5 × 10^{-6} kg/m^3 or a PEF = 2 × 10^5 m^3/kg), was based on the average of three measured dust concentrations taken at the side of a road composed of dirt and crushed slag, during the passage of medium-duty vehicles (3–4 tons). The dust had a mass-median diameter of 10–11 μm and, thus, corresponds to the approximate range of respirable particles. It was further indicated that this concentration is also equal to the Occupational Safety and Health Administration (OSHA) protective exposure limit (PEL) for nuisance dust set forth in 29 *Code of Federal Regulations* (CFR) 1910.1000 and, thus, constitutes a reasonable upper bound to the average dust loadings that could be comfortably tolerated by the rider.

The above references provide suggested values for PEFs associated with OHV use during recreational activities in the range of 1.65×10^4 (USEPA, 2008; 2009) to 1×10^6 m^3/kg (DTSC 2011). The value suggested in USEPA 2007 of 2×10^5 m^3/kg is used here because:

- It is based on measurements performed at an actual legacy uranium site,
- It included measurement of mass-median diameter demonstrating particle size to be within the respirable range,
- It is approximately midway between the range of suggested values referenced above, and
- The suggested PEF would result in a concentration equal to the OSHA PEL for nuisance dust set forth in 29 CFR 1910.1000, and thus constitutes a reasonable upper bound to the average dust loadings that could be comfortably tolerated by the rider.

Accordingly, assuming the OHV rider spends 4 days (3) of 8 hours each during the 14-day recreational exposure riding the OHV, the CEDE from inhalation of dusts during use of OHVs (I_{ohv}) is calculated:

$$I_{ohv} = DCF_{Uore}\,(1/PEF)\,C\;BR\;T$$

Where parameters are defined as in Section 4 above except for the PEF, which for OHV use is taken to be 2×10^5 m^3/kg and the breathing rate (BR) taken to be 1.2 m^2/hr during OHV use (USEPA 2007)

$I_{ohv\,=} =$ (0.0035 mSv/Bq) × (1/28 Bq/pCi) × (100 mrem/mSv) × (1/2 × 10^5 m^3/kg) × (10^3 g/kg) × (1 pCi/g) × (1.2 m^3/hr) × (32 hr) = 2.4×10^{-3} mrem

[3] Admittedly, this value is somewhat arbitrary as there is no clear technical basis for choice of 4 days.

6.0 Inhalation of Radon-222 and Progeny (I_{Rn})

6.1 Background Discussion on the Emission and Dosimetric Implications of Radon and Progeny

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) provides information on sources of radon and the processes that affect the release of radon from soils (UN 2000). A key parameter that controls radon transport in soils is the radon diffusion coefficient. A number of models for estimating the radon flux from the surface of porous media such as soil, uranium ore, or waste rock are reported in the literature (e.g., USNRC 1980, USEPA 1983). For dry soils, using the methods and values reported in USNRC 1980, the estimated unit area radon flux per unit ^{226}Ra activity concentration (in becquerels per gram) is about 1 Bq/m^2-sec (or in picocuries per gram, about 1 pCi/m^2-sec). The use of this value has been the basis for historical calculations of radon emission from soils and land surfaces and is considered conservative since diffusion occurs through the unsaturated pore space of the soil and therefore the diffusion of radon in soil, where the soil is compacted or the pore space is filled with water (saturated), will be much slower than in noncompacted or unsaturated soils. However, for our application here, involving semiarid environments and generally unconsolidated waste rock or spoils piles, etc., 1 pCi/m^2-sec ^{222}Rn per pCi/g ^{226}Ra in soil is considered reasonable.

IAEA 2011b presents findings of an investigation to determine the doses expected to be received by members of the public exposed to large NORM residue deposits (including uranium series radionuclides), with consideration being given to all potentially significant exposure pathways. The investigation was carried out under contract to the IAEA by SENES Consultants Limited (SENES 2010) using an evidence-based approach involving the review of available information from examples of actual uranium residue deposits, as well as a calculation approach involving the modeling of radionuclide migration from a "representative" large uranium residue deposit at a unit concentration of uranium series radionuclides assumed to be in natural secular equilibrium (i.e., 1 Bq/g of each radionuclide in the naturally occurring decay chains).

Specifically regarding the radon inhalation pathway, ^{222}Rn emissions from a representative uranium residue deposit were calculated using a simple air dispersion model. The outdoor radon concentration was found to be about 10–20 Bq/m^3 in the immediate vicinity of the deposit (0.4–0.7 pCi/L, about the same as typical "background," see below and NCRP 2009). This range of radon concentrations is comparable with the range of natural variability of outdoor radon concentrations (UN 2000). Given this intrinsic variability in natural radon levels and the fact that the "fresh radon" released from the soil disperses quickly with the wind, the authors stated that it would be very difficult to identify any clear increase in radon levels outdoors in the vicinity of a uranium residue deposit.

It is also noted that although additional sources of radon could include "point sources" such as vents and portals, they are typically unsafe and unstable areas, and it is reasonable to assume that people would not spend appreciable time there.

Figure 4-1 from USEPA 1982 presents results of calculations of radon concentrations in air at various distances from uranium tailings piles of several sizes (5–80 hectares) with an initial ^{222}Rn emission rate (flux) of 20 pCi/m^2-sec demonstrating how quickly the radon is dispersed and the concentrations in air decrease with distance from the edge of the piles. For example, for the 5-hectare pile, the air concentration is predicted to be only about 10% at a location measured 120 meters from the center of the pile. This figure is reproduced here as Figure 1.

The "dose" from radon comes primarily from its short-lived particulate progeny, which attach to lung surfaces depositing alpha energy, not from the inert gas itself, most of which is quickly exhaled**.** The importance of this dosimetric relationship between radon gas and its progeny was well documented early in the history of uranium mining (Altshuler et al., 1964; Coleman et al., 1956; Holaday et al., 1957; Jacobi, 1964). That is, without time for ingrowth of the radon progeny, inhalation of ^{222}Rn by itself results in little dose.

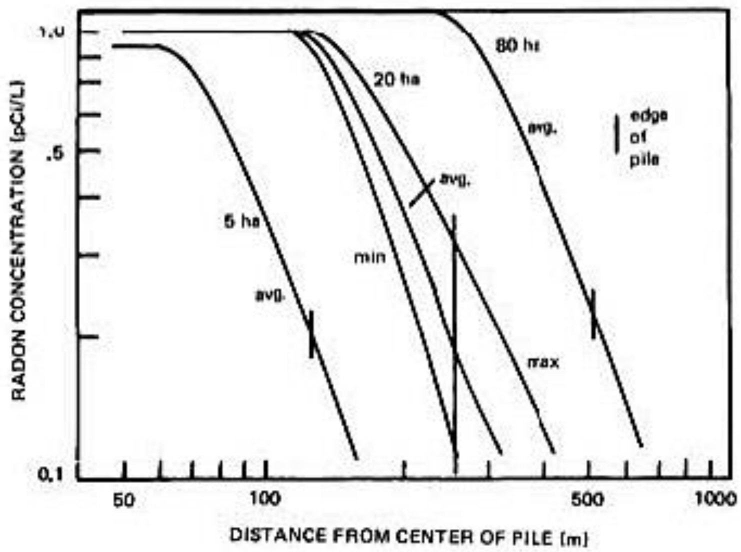


FIGURE 1: Radon Concentrations in Vicinity of Tailings from Flux of 20 pCi/m^2-sec
(reproduced from USEPA 1982, Figure 4-1)

At the point radon diffuses out of the soil and rocks, the concentration of associated progeny is zero because the progeny have been captured in the earth. As soon as radon is airborne, progeny ingrowth continues until equilibrium between the activity of radon and that of its progeny is approached (pCi/m^3 ^{222}Rn = same for all short-lived particulate progeny). The "equilibrium fraction" is the fraction of potential alpha energy from progeny relative to the maximum at equilibrium. The unit of progeny concentration is the working level (WL)[(4)]. Since the radon and progeny are transported by the wind, the equilibrium fraction increases with increasing distance (and time) from the sources (waste rock/spoils piles, etc.), although the concentration in air is decreasing rapidly with increasing distance. Accordingly, there is typically very little progeny ingrowth and therefore very little dose associated with fresh radon in the immediate vicinity of the "waste rock pile." Although in enclosed environments (such as "stale air" in mines and/or adits) the equilibrium fraction can approach 100%, in the outdoors there are practical limits. For example, the equilibrium fraction for outdoor exposures recommended by the National Council on Radiation Protection and Measurements (NCRP 2009) is a nominal value of 0.6 for "aged global air" with typical values to be in the range of 0.5–0.7 (for perspective, NCRP 2009 considered the average background radon concentration outdoors to be 0.4 pCi/L).

[4] Any combination of radon and radon progeny in 1 liter of air that will result in the emission of 1.3 × 10^5 MEV of alpha particle energy; equivalent to 100 pCi/L ^{222}Rn in equilibrium with its alpha-emitting progeny. The associated unit of exposure is the working-level month, which is a concentration of one working level incurred over 170 hours (or any combination of WL and time that results in 170 WL hours)

6.2 Calculating ^{222}Rn Dose for the Recreational Exposure Scenario (I_{Rn})

As discussed above, the contribution to dose is expected to be relatively small from this pathway since in the recreational exposure scenario defined here, the visitor is not spending appreciable time immediately on top of (“living on”) ore/waste rock piles within enclosed spaces. The magnitude of dose is primarily associated with the degree of ingrowth of ^{222}Rn progeny (the “equilibrium factor”), which is a function of time and therefore distance from the sources (“waste rock pile”). Table 9.11 of USNRC 1980 presents estimates of radon progeny concentrations in air in WL units in structures above and near uranium tailings piles. At an initial radon emission rate (flux) of 1 pCi/m^2-sec (corresponding to our unit concentration of 1 pCi/g ^{226}Ra in the soil) (USNRC 1980, USEPA 1983), a progeny concentration of 5.7×10^{-5} WL is estimated near the edge of the disposal pile (“approximately 100 meters downwind”).

The relationship between working-level months (WLM) of exposure from radon progeny and effective dose is established in national and international radiation protection standards. In USNRC regulations (e.g., 10 CFR 20) the annual occupational exposure limit of 5 rem/yr is assumed equivalent to the annual exposure limit of 4 WLM/yr exposure to radon and progeny, which results in a dose conversion factor of 1.25 rem/WLM. However, note that in ICRP Publication 65, the International Commission on Radiological Protection recommends a conversion factor of 5 mSv (500 mrem) per WLM (ICRP 1994b), although in recently issued ICRP 126 (ICRP 2014), a dose conversion factor of 12 mSv (1200 mrem) per WLM is recommended.

The value used by the USNRC in 10 CFR 20 is used here since it represents a U.S. occupational radiation protection compliance standard, although ICRP’s recommended values represent international consensus and are based on much more recent epidemiological studies of underground uranium miners and similarly exposed populations.

It is assumed that the recreational visitor spends 50% of their time during the 14-day visit onsite in the general vicinity of waste rock/spoils piles or other significant radiological sources. Although it is assumed that at most DRUM sites, the percent of total site acreage associated with these features is quite small, the recreational visitor could “set up camp” near these “easy to find,” visible surface features. Accordingly, the dose to the recreational visitor as a result of exposure to ^{222}Rn and its progeny per pCi/g ^{226}Ra in the soil is calculated:

$I_{Rn} = CT\ DCF_{wl}$, where

$I_{Rn} =$ dose in mrem from inhalation of radon and progeny

C = concentration in air in working levels

T = time of exposure in hours

$DCF_{wl} =$ dose conversion factor; 1250 mrem per WLM of 170 hr

$I_{Rn} = (5.7 \times 10^{-5}\ \text{WL}) \times (14\ \text{days}) \times (24\ \text{hr/day}) \times (0.5) \times (1/170\ \text{hr/WLM}) \times (1250\ \text{mrem/WLM})$

Therefore,

$I_{Rn} = 0.07$ mrem

7.0 Screening Levels

7.1 Calculating the TEDE to the Recreational Visitor

Again, the TEDE in mrem is the sum of the dose equivalents from each pathway.

$T = E_x + S_{inj} + I_d + I_{ohv} + I_{Rn}$

Using the values previously derived, the TEDE is calculated:

$\boldsymbol{T = 0.60 + 0.01 + 10^{-6} + 10^{-3} + 0.07 = 0.68}$ **mrem per pCi/g**

Where:

T = TEDE for a 14-day recreational exposure scenario per pCi/g of each of the ^{238}U plus ^{235}U series radionuclides in soil

E_x = DE from external exposure from the soil

S_{ing} = CEDE from incidental ingestion of soil

I_d = CEDE from inhalation of dusts

I_{ohv} = CEDE from inhalation of dusts during use of OHVs

$I_{Rn} =$ CEDE from inhalation of ^{222}Rn and progeny

7.2 Establishing Screening Levels

The analysis above indicates the contribution to the TEDE from external gamma exposure is 0.60/0.68 = 88%. Accordingly, this relationship can be used directly to establish an average gamma radiation exposure rate above background, below which would ensure compliance to the selected annual public exposure limit as well as establish the associated concentration of each uranium series radionuclide in soil (equilibrium assumed). It is recommended for this demonstration that 1 mSv (100 mrem)/year above background be used for this purpose [(5)]. This limit can be justified because it has long been the fundamental public exposure criteria associated with nuclear facilities and activities under the U.S. Atomic Energy Act (AEA) as codified in the AEA implementing regulations of both USNRC (10 CFR 20.1301) and USDOE (10 CFR 835.208). Furthermore, 1 mSv/year is the basic international consensus standard for public exposure above background from all sources (e.g., ICRP 2007).

[5] Other options could include USEPA's criteria of 25 mrem/yr dose equivalent to any organ from the nuclear fuel cycle from 40 CFR 190, although this would require complex calculations of organ-specific doses per methodologies of >50 years ago from ICRP 1959; 15 mrem/yr per EPA's CERCLA 3×10^{-4} slope/risk factor for 30 years; USNRC's 25 mrem TEDE for decommissioning and license termination from USNRC 2006, etc. However, it is also noted that 100 mrem/year (1 mSv/year) is well within the variability of natural background in the United States, and in particular, in consideration of the elevated natural backgrounds associated with the locations of many DRUM sites, much lower values are potentially "lost in the noise" and the uncertainties of measurement at these low levels. It also represents the international consensus standard for public exposure above background.

Obviously, application of this method relies heavily on a defensible definition of radiological background for the region within which each DRUM site is located. This implies that different sites, with slightly differing radiological backgrounds, would in fact have slightly different screening levels. This is appropriate and scientifically justified, however may be impractical on a site-by-site basis. Accordingly, it is assumed that background reference areas will be properly established for the geological and mineralogical region within which the site (or a group of sites) is located. A technical basis document has been prepared to aid in the establishment of background reference areas (Brown 2016b).

Using 100 mrem/year above background as the public exposure limit that defines the exposure magnitude during each annual 14-day recreational use visit to a DRUM site and given that the contribution from the external exposure pathway is 88% of the TEDE from all relevant pathways for the recreational use scenario as defined herein, the "screening level" is simply:

(100 mrem) × (0.88) × (1/14 days) × (1/24 hr/day) = 0.262 mrem/hr = 262 µR/hr above background.

And the associated concentration in soil would simply be 100 mrem/0.68 mrem per pCi/g = 147 pCi/g each of ^{238}U, ^{226}Ra, and all other progeny in equilibrium.

Accordingly, a "set" of screening levels to consider could be as follows:

Level A: < 60 µR/hr above background (≤25 mrem TEDE/year during 2-week recreational period) = no action required.

Level B: > 60 µR/hr but <250 µR/hr above background = conduct additional gamma surveys, soil sampling, and other assessments necessary to verify actual exposure rates and/or soil concentrations are less than those that could result in exceeding the 100 mrem/year limitation and evaluate credibility of access to the site (e.g., remote location) and "accessibility" of possible pathways of exposure (e.g., waste rock on a hillside).

Level C: > 250 µR/hr = consider and evaluate reclamation and/or remedial action options to reduce exposures to future recreational users to < 100 mrem/year TEDE.

8.0 REFERENCES

Altshuler et al., 1964. Altshuler, B., Nelson, N., and Kuschner, M., 1964, "Estimation of Lung Tissue Dose from the Inhalation of Radon and Daughters," *Health Physics Society*, 10: 1137–1161.

Brown 2016a. Brown S. to Elmer J. January 29, 2016, "Concept Paper – Suggested General Approach for Developing 'Screening Levels' for DRUM Sites on BLM Land Based on External Exposure Rates," SHB Inc.

Brown 2016b. *Selecting Background Reference Areas and Determining Radiological Background for Defense-Related Uranium Mine sites, Draft 2*, March 15, 2016, SHB Inc.

Coleman et al., 1956. Coleman, R.D., Kusnetz, H.L., Woolrich, P.F., and Holaday, D.A., 1956, "Radon and Radon Daughter Hazards in Mine Atmospheres," *American Industrial Hygiene*

Association Quarterly 17, p. 405.

DTSC 2011. California Department of Toxic Substances Control. Human Health Risk Assessment (HHRA) Note Number 1, California EPA, Office of Human and Ecological Risk (HERO), May.

Holaday et al., 1957. Holaday, D.A., Rusing, D.E., Coleman, R.D., Woolrich, P.P., Kusnetz, H.L., and Bale, W.F., 1957. “Control of Radon and Daughters in Uranium Mines and Calculation of Biological Effects.” U.S. Public Health Serv. Publ., 494.

IAEA 1996**.** International Atomic Energy Agency, *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*, Safety Series No. 115, Superseded by IAEA 2011a.

IAEA 2004. International Atomic Energy Agency, *Occupational Radiation Protection in the Mining and Processing of Raw Materials*, No. RS-G-1.6, Annex: “Relationships Between Gross Alpha Activity and Committed Effective Dose For The Inhalation of Ore Dust Containing Uranium or Thorium.”

IAEA 2011a. International Atomic Energy Agency, *Radiation Protection And Safety Of Radiation Sources: International Basic Safety Standards*, IAEA Safety Standards Series No. GSR Part 3 (Interim).

IAEA 2011b. International Atomic Energy Agency, *Exposure of the Public from Large Deposits of Mineral Residues*, IAEA-TECDOC-1660, prepared for IAEA by SENES Consultants Limited**.**

ICRP 1959. International Commission on Radiological Protection. *Report of Committee II on Permissible Dose for Internal Radiation.*

ICRP 1994a. International Commission on Radiological Protection, *Dose Coefficients for Intakes of Radionuclides by Workers*, ICRP Publication 68.

ICRP 1994b. International Commission on Radiological Protection, *Protection Against Radon-222 at Home and at Work*, ICRP Publication 65.

ICRP 1997. International Commission on Radiological Protection, *Individual Monitoring for Internal Exposure of Workers*, ICRP Publication 78.

ICRP 2007. International Commission on Radiological Protection, *The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103.

ICRP 2014. International Commission on Radiological Protection. *Radiological Protection Against Radon Exposure*, ICRP Publication 126.

Jacobi, W., 1964. “The Dose to the Human Respiratory Tract by Inhalation of Short-lived ^{222}Rn and ^{220}Rn Daughters,” *Health Physics Society*, 10: 1–1163.

NCRP 1987. National Council of Radiation Protection and Measurements. *Exposure of the Population in the United States and Canada from Natural Background Radiation*, NCRP Report No. 94.

NCRP 2009. National Council of Radiation Protection and Measurements, *Ionizing Radiation*

Exposure of the Population of the United States, NCRP Report 160.

SENES 2010. SENES Consultants, *Human Exposure to Radioactivity from Mining and Industrial Residues*, report prepared for the International Atomic Energy Agency.

UN 2000. United Nations, *Sources and Effects of Ionizing Radiation*, Report to the General Assembly, with Scientific Annexes, Vol. 1: Sources, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

USDOE 2014. U.S. Department of Energy, *Abandoned Uranium Mines Assessment of Radiological Risk to Human Health and the Environment Topic Report*, LMS/AUM/S11072**,** February.

USDOI 2014. U.S. Department of the Interior, *Revised Technical Memorandum Recreational Visitor Exposure Scenario for Federal Land PG&E Topock Compressor Station Remediation Project, California*.

USEPA 1982. U.S. Environmental Protection Agency, *Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192), Volume 1*, EPA 520/4/82/013-1, October.

USEPA 1983. *Final Environmental Impact Statement for Standards for the Control of Byproduct Materials from Uranium Ore Processing (40 CFR 192), Volume 1*, EPA 520/1-83-008-1, September.

USEPA 1988. U.S. Environmental Protection Agency, Federal Guidance Report No. 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors For Inhalation, Submersion and Ingestion*, EPA-529/1-88-020.

USEPA 1989. U.S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Interim Final*, OSWER Directive 9285.7-01a, Office of Emergency and Remedial Response, September.

USEPA 1991. U.S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Supplemental Guidance, "Standard Default Exposure Factors," Interim Final*, OSWER Directive 9285.6-03, Office of Emergency and Remedial Response, March.

USEPA 2000. U.S. Environmental Protection Agency, *Soil Screening Guidance for Radionuclides: User's Guide*, OSWER Directive 9355.4-16a, Office of Radiation and Indoor Air, October.

USEPA 2007. EPA 402-R-08-005. Technical Report On Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining. Volume 2

USEPA 2008. U.S. Environmental Protection Agency, *Baseline Human Health Risk Assessment for the Standard Mine Site, Gunnison County, Colorado*, prepared by Syracuse Research Corporation for USEPA Region 8.

USEPA 2009. U.S. Environmental Protection Agency, *Baseline Human Health Risk Assessment for the Standard Mine Site, Gunnison County, Colorado, Addendum*, prepared by SRC for U.S. Environmental Protection Agency Region 8.

USEPA 2011a. U.S. Environmental Protection Agency, *Exposures Factors Handbook: 2011 Edition*, EPA/600/R-090/052F, September.

USEPA 2011b. *Remedial Investigation, Nelson Tunnel/Commodore Waste Rock Pile, National Priorities List Site, Creede, CO*, prepared for U.S. Environmental Protection Agency Region 8 by HDR Engineering, Inc. and TechLaw, Inc., November, http://www.epa.gov/sites/...Nov2011.pdf.

USNRC 1980. U.S. Nuclear Regulatory Commission, *Final Generic Environmental Impact Statement on Uranium Milling, Project M-25*, NUREG 0706, October.

USNRC 2006. U.S. Nuclear Regulatory Commission, *Consolidated Decommissioning Guidance, Decommissioning Process for Materials Licensees*, NUREG-1757, Volumes I–III.

ATTACHMENT 1

SHB INC., 7505 S. XANTHIA PLACE, CENTENNIAL, COLORADO 80112

Steven H Brown, Certified Health Physicist
303 941 1506; shb12@msn.com
29 January 2016

TO: John Elmer, Navarro Engineering and Research, Inc.

RE: Concept Paper – Suggested General Approach for Developing "Screening Levels" for DRUM Sites on BLM Land Based on External Exposure Rates

John:

Consider this a "concept paper" for your concurrence prior to initiating calculating numbers. My general approach for developing screening levels for DRUM sites on BLM land based on external exposure rates (e.g., µR/hr) is described here. Following your concurrence of this general approach and concepts, I will send you a listing of other important assumptions, suggested input parameters, and the associated references and technical basis for them, also for discussion and your concurrence. This list is almost completed. Following these discussions, the calculations themselves should not take very long at all.

The concept of screening levels does not have to be complicated. Something of the following general form is what I envision:

- ≤ background (BKG) = No Action
- Between BKG and *X* times BKG = Do this (e.g., perform refined calculations, make some measurements, collect some samples for verification)
- ≥ *X* times BKG = More comprehensive site assessment and survey may be necessary

I did find an example of precedence for the concept of a graded approach to risk assessment for legacy sites somewhat similar to our concept of screening levels in BLM 2004. From page 11, "How to Interpret Risk Management Criteria":

- Less than criteria: low risk
- 1–10 times the criteria: moderate risk
- 10–100 times the criteria: high risk
- >100 times the criteria: extremely high risk

<u>Recommended Future Use Scenario and Associated Pathways of Exposure</u>

The basic future use scenario is recreational, in which a camper spends 2 weeks/year at the site. It is assumed that all locations are rural, relatively arid sites in the Southwestern U.S. (e.g., states of Colorado, Utah, Arizona, New Mexico), which limits to some degree the credible pathways of exposure that need to be considered. In researching other examples of recent federal agency work plans/assessments for legacy sites, they are generally site specific. Many are in locations which allow for water-related recreational activities, including fishing, as well as adequate forage cover to support grazing animals (and most do not involve radiological contaminants of concern). It is assumed for our purpose that these are not applicable site conditions for us. The characteristics of the recreational scenario I propose we use and references supporting its assumptions are provided in Table 1. Similarly, the choice of relevant exposure pathways for this scenario and associated supporting references and assumptions is provided in Table 2.

Table 1: Precedence for an Exclusive Recreational Exposure Scenario for DRUM Sites on BLM Land

Characteristic	**Reference**	**Basis from Reference**
Camper spends 2 weeks/year at site engaged in recreational activities	CH2MHill 2015	Footnote for Table 2-1: Screening Levels for Assessing Potential Human Health Risks: *Screening levels in soil are developed using a recreational scenario assuming an individual is potentially exposed for 14 days/year over 30 years* *NOTE:* This appears to be a "generic" work plan to conduct field assessments for a number of Freeport legacy sites on BLM land at which uranium and vanadium exploration and/or mining was conducted.
	USEPA 2007	Section 3.1: Potential Scenarios and Exposure Pathways for the General Public *Since most uranium locations are on federal lands, the primary exposure scenarios to TENORM wastes at uranium mines would involve recreational use of the site in which the abandoned mine is visited*

		occasionally by hikers, campers, or driven through by all-terrain vehicles (ATVs). … *Users would likely visit unreclaimed uranium mines for short periods of time, such as two weeks, which is the common maximum time for which the National Park Service issues backcountry permits* Section 3.4: Other Recreational Use Scenarios *Other recreational use scenarios were considered as part of the present analysis. These include swimming, boating, fishing, and hunting, along with the consumption of on-site fish and game. These scenarios are either unlikely to occur, or would be an insignificant component of the risk, as reviewed in an EPA study (1983).*

Table 2: Pathways of Exposure Relevant to Recreational Scenario Defined in Table 1

Pathways of Exposure:	**Reference**	**Relevancy**
(1) External exposure from ground (expected to dominate since no “indoor” radon/progeny inhalation or water ingestion pathways). (2) Radon inhalation from ground flux. (3) Incidental ingestion of soil. (4) Recreational use of OHV including incidental inhalation of dust (soil)	USDOI 2014	Page 5, Table 2 and Figure 2 define exposure scenarios and parameters including only surface soil (direct contact and incidental ingestion) and airborne dust inhalation including OHV use.

Note: No traditional ingestion pathways are considered since the camper is not going to consume locally grown vegetables. Although camper may hunt or fish and eat the catch during the 2 weeks, due to general lack of forage vegetation, animals would be transitory/migratory through the area and not “exposed” to the contamination their entire lives.	USEPA 2007	Section 3.3: Recreational Scenario Risk Calculations Pathways considered include only external exposure from ground, incidental soil ingestion, and inhalation of fugitive dust. Although an ATV/OHV driver was also used, it was considered “not the same individual exposed to all the other pathways” Section 3.4: Other Recreational Use Scenarios *The majority of mine sites found in the uranium location database are typically in an arid environment that does not readily support plant life unless irrigated. In such arid environments, the overburden or protore piles are not expected to be able to provide much forage for animals, especially if they are covered with a desert varnish. In addition, the size of the abandoned mine sites would typically be relatively small and thus provide little forage for game animals.* *Consequently, any game taken on a mine site would be expected to have obtained most of its forage elsewhere. The meat from such game is thus not expected to be significantly contaminated with TENORM from a mine site.*

	Marston et al., 2011	For assessment of the Browns Hole legacy uranium site in Utah, three exposure pathways were considered: external gamma, inhalation, and incidental ingestion of soil over an exposure duration of 14 days
	Weston 2008	At the Workman Creek uranium mine site in Arizona, a human health risk assessment to recreational visitors (camper, hiker, OHV user) was evaluated via a streamlined risk assessment process. The primary pathway of exposure is external gamma radiation.
	Tetra Tech 2011	This risk assessment was performed to support the development of an Engineering Evaluation/Cost Assessment for the Ross-Adams legacy uranium mining site on the Alaskan coast. Pathways of exposure evaluated included radon inhalation, particulate (soil) inhalation, external exposure, and incidental soil ingestion.
	IAEA 2011	Although not specific to a particular public use scenario, this International Atomic Energy Agency Technical Document (TECDOC) evaluates public exposures from a nominal NORM deposit volume of 2 million m^3 covering 10 ha with the presence of radionuclides in the U-238 and/or Th-232 decay series, each at a concentration of 1 Bq/g. Pathways of exposure evaluated included external exposure from

		ground, incidental soil ingestion, inhalation of radon and particulates, and locally grown food and groundwater ingestion.

Methodology

The basic approach to define the screening levels (exposure rates) involves establishing an exposure rate (including from both external and internal exposure sources as applicable) for each pathway based on a unit concentration of radionuclides in soil. Since it is reasonably assumed that the uranium is in equilibrium with all progeny in the U-238 decay chain (including Ra-226, for example), it is relatively straightforward to do this [(1)]. We establish a concentration of U-238 in soil of 1 pCi/g. Therefore, all other radionuclides in the chain will be present at 1 pCi/g. We then calculate the exposure over 2 weeks for each of the relevant exposure pathways based on this soil concentration. Again, the pathways I am recommending we use are:

1. External exposure from the soil (i.e., ground shine, which I expect will dominate; for natural uranium sites it almost always does if there is not a "residential" indoor radon/progeny pathway)
2. Casual ingestion of soil
3. Inhalation of dusts
4. Special case of dust inhalation for an OHV rider
5. Inhalation of radon and progeny

The use of the 2 weeks/year recreational camper scenario with the associated pathways listed above is consistent with what was assumed in USDOE 2014 (with exception of the OHV rider). For reasons presented in Table 1 above, I am suggesting that other common recreational activities often considered in these analyses, such as swimming, fishing for food, hunting for food, eating forage vegetation, and water ingestion, are not relevant for our semiarid, relatively remote DRUM sites.

Once we have calculated the "2-week dose" for each of the relevant exposure pathways per unit concentration in soil, we just sum them. This gives us the TEDE from all pathways for the 2-week period of interest per unit concentration in soil. Using an appropriate and acceptable annual public dose exposure limit (e.g., 15 mrem/yr per EPA's CERCLA 3×10^{-4} slope/risk factor for 30 years; NRC 100 mrem/year per 10 CFR 20; USNRC's 25 mrem TEDE for decommissioning and license termination from USNRC 2006; EPA's 25 mrem/yr dose equivalent to any organ from the nuclear fuel cycle in 40 CFR 190), we can then establish the external exposure rate as well as the associated equilibrium soil concentration that assures the exposure for 2 weeks/year will be less than the chosen "limit."

Looking forward to your thoughts. Will continue to finalize recommended draft input/parameter values for your review.

[(1)] The radionuclides from the actinide (^{235}U) decay series may be initially ignored since the ratio of ^{235}U activity to ^{238}U activity in uranium ore is the natural abundance ratio of 0.046 to 1; this will be evaluated further.

REFERENCES:

BLM 2004. U.S. Bureau of Land Management, Risk Management Criteria for Metals at BLM Sites, Technical Note 390, October.

CH2MHill 2015. CH2M Hill, *Workplan for Screening Potential Risks Associated with Historic Mine Sites on Bureau of Land Management Land*, prepared for Freeport Minerals, April.

IAEA 2011. International Atomic Energy Agency, *Exposure of the Public from Large Deposits of Mineral Residues, prepared for IAEA by SENES Consultants Limited*, IAEA-TECDOC-1660.

Marston et al., 2011. Marston, Thomas M., Beisner, Kimberly R., Naftz, David L., and Snyder, Terry, *Assessment of Nonpoint Source Chemical Loading Potential to Watersheds Containing Uranium Waste Dumps Associated with Uranium Exploration and Mining, Browns Hole, Utah*, Scientific Investigations Report 2011-5230, U.S. Department of the Interior, U.S. Geological Survey.

Tetra Tech 2011. Tetra Tech Inc., *Human Health Risk Assessment for the Engineering Evaluation/Cost Analysis Ross-Adams Mine Site Tongass National Forest, Prince of Wales Island, Alaska*.

USDOE 2014. U.S. Department of Energy, *Abandoned Uranium Mines Assessment of Radiological Risk to Human Health and the Environment Topic Report,* LMS/AUM/S11072, February.

USDOI 2014. U.S. Department of the Interior, *Revised Technical Memorandum Recreational Visitor Exposure Scenario for Federal Land PG&E Topock Compressor Station Remediation Project, California*.

USEPA 1983. U.S. Environmental Protection Agency, *The Potential Health and Environmental Hazards of Uranium Mine Wastes Volume 2*, EPA 520/1-83-00, June.

USEPA 2007. U.S. Environmental Protection Agency, *Technical Report on Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining, Volume 2*, EPA 402-R-08-005.

USNRC 2006. U.S. Nuclear Regulatory Commission, *Consolidated Decommissioning Guidance, Decommissioning Process for Materials Licensees*, NUREG-1757, Volumes I–III.

Weston 2008. Weston Solutions Inc. *Final Engineering Evaluation/Cost Analysis, Workman Creek Uranium Mine Sites, Pleasant Valley Ranger District, Tonto National Forest, Arizona*, prepared for USDA Forest Service, Albuquerque, New Mexico. October.

SHB INC., 7505 S. XANTHIA PLACE, CENTENNIAL, COLORADO 80112

Steven H Brown, Certified Health Physicist
303 941 1506; shb12@msn.com; http://www.shbinc.us

TO: John Elmer - Navarro Research and Engineering
CC: Steve Renner, Michael McDonald - Navarro Research and Engineering
DATE: March 14, 2018

RE: Addendum - Establishing Radiological Screening Levels for DRUM sites on BLM Land Using a Recreational Future Use Scenario by SH Brown CHP. May 23 2016

On page 14 of the subject document, the primary radiological screening level is calculated as follows:

Using 100 mrem/year above background as the public exposure limit that defines the exposure magnitude during each annual 14-day recreational use visit to a DRUM site and given that the contribution from the external exposure pathway is 88% of the TEDE from all relevant pathways for the recreational use scenario as defined herein, the "screening level" is simply:

(100 mrem) × (0.88) × (1/14 days) × (1/24 hr/day) = 0.262 mrem/hr = 262 μR/hr above background

However, it is understood that their may have been some confusion subsequent to the issuance of this document as a result of an example that was presented further on this same page, for the purpose of demonstrating how this screening level might be used:

Accordingly, a "set" of screening levels to consider are as follows:

Level A: < 60 uR / hr. above background (≤ 25 mrem TEDE / year during 2-week recreational period) = No action required

Level B: > 60 uR / hr. but < 250 uR /hr. above background = conduct additional gamma surveys, soil sampling and other assessments necessary to verify actual exposure rates and / or soil concentrations are less than those that could result in exceeding the 100 mrem / year limitation and evaluate credibility of access to the site (e.g., remote location) and "accessibility" of possible pathways of exposure (e.g., waste rock on a hillside).

Level C: > 250 uR / hr. = consider and evaluate reclamation and/or remedial action options to reduce exposures to future recreational users to < 100 mrem / year TEDE.

The use of the "rounded" value of 250 uR / hour was presented only to demonstrate one suggested approach (and of course there are others) of delineating a small set of radiological conditions (several ranges of exposure rates) that could be input to the overall "multiple lines of evidence" screening process being used by BLM for prioritization of the DRUM sites on Federal land. At the time of preparation of this document, it was still to be determined how these radiological criteria might be used with the wide area gamma surveys being conducted at the DRUM sites as part of DOE LM's Verification and Validation (V&V) Program.

Additionally, an earlier version of this document (20 April, 2016) used 256 uR/ hr. above background as the primary screening criteria derived from the 100 mrem/year above background public exposure limit. This difference (256 vs. 262 uR/hr.) was due to a small update made in the dose conversion factor associated with the soil ingestion pathway. This resulted in making a reduction in the already small contribution from the soil ingestion pathway thereby increasing the contribution from the direct gamma (ground shine) pathway from 86 % to 88% of the total dose. However, it must be recognized that even for a well designed and executed wide area field gamma survey under typical scanning conditions (surveyor with instrument is moving), the uncertainty of any single measurement would be expected to be upwards of 5% or more. Accordingly, it is unlikely there would be a statistically meaningful difference between these two values.

Furthermore, it is recognized that the annual limit being used of 100 mrem / year is in fact an effective dose rate in tissue (in Rem) while the primary screening criteria was expressed as an exposure rate in air (in Roentgens). Due to the difference in the mass absorption coefficients (density) of air vs. human tissue and several other factors of physics, a 1 Rem dose in tissue is equivalent to an exposure of approximately 1.14 Roentgens in air for most X and gamma rays (1 Roentgen = 100 ergs per gram in air vs. 1 Rem of x or gamma rays = 87 ergs / gram in tissue).

Since it was unknown at the time of the preparation of these two documents whether tissue equivalent dose rate or air exposure rate radiological survey instruments were to be used for conduct of the DRUM site radiological surveys, this distinction was ignored and the screening criteria were expressed in Roentgen units. Historically, instruments providing exposure rates in air have been the more common practice for wide area gamma surveys at uranium sites. Given this uncertainty at that time, this approach was considered conservative as the actual tissue equivalent dose rate associated with an exposure rate in air of 262 uR / hr. would be approximately 262 uR / 1.14 uR per uRem = 230 uRem per hour, equivalent to an annual exposure of about 77.2 mrem.

Nonetheless, regardless of which type of instrument(s) are used in the future, equivalency can be approximated with the use of the simple conversion factor of 1 uRem = 1.14 uR.

Although the primary radiological screening criteria developed in the revised report of 23 May 2016 is 262 uRem / hour above background for a 2 week / year recreational use scenario at a DRUM site, a radiation survey result of 256 uRem / hr is currently being used as the DRUM project's upper-tier radiological screening level value. Using this slightly lower screening level value (256 uRem / hr) adds a level of conservatism to the measurement process. Areas where 256 uRem / hr or greater are measured are now being identified as the "higher risk" areas at a DRUM site. Additionally, 256 uRem / hr and 262 uRem / hr can be considered statistically equivalent as the project's upper-tier radiological screening level value (based on measurement uncertainties associate with the instrumentation being used for radiological surveys being performed at DRUM sites). Consequently, the assumptions and calculations presented in the subject document and as further clarified herein, ensure an annual dose to future recreational users of DRUM sites of ≤ 100 mrem Total Effective Dose Equivalent (TEDE).

[redacted]

SHB INC., 7505 S. XANTHIA PLACE, CENTENNIAL, COLORADO 80112

Steven H Brown, Certified Health Physicist
303 941 1506; shb12@msn.com; http://www.shbinc.us

DATE: 7 July 2022
TO: Thomas Johnson, RSI
CC: John Zutman, RSI

RE: Establishing Radiological Soil Screening Levels (SSLs) for DRUM Sites on Tribal Land – Final

Tom – as DOE had no comments on the Draft Final of 27 September 2021, we should now be able to issue this document as the "Final". Note that this submittal was intended to meet the task order milestone for Support for DRUM's Campaign 2 – Tribal Lands, to develop draft input parameters and benchmarks for radiological screening levels by I October 2021 which the Draft Final had accomplished.

1.0 Background and Objective

The purpose of this document is to make a preliminary determination of radiological soil screening levels (SSLs) for DRUM sites consistent with the characteristics of a future full time resident exposure scenario. It is DOE- LM's intention to consider the final results of this assessment for the radiological characterization and hazard prioritization of DRUM sites on tribal lands.

Previously, DOE – LM had developed similar radiological screening levels for DRUM sites located on public lands using a future recreational exposure scenario (e.g., sites on BLM managed land – See Brown et al, 2018). The recreationist scenario that has been used is consistent with BLM's definitions and approach for assessment, characterization and hazard ranking of most legacy / abandoned mines in the western US (primarily metal mines) including DRUM sites and other legacy / abandoned uranium mines (BLM 2017).

For this assessment, we have relied heavily on EPA's approach for establishing radiological soil screening levels for radiologically contaminated sites using the definitions and many of the associated default input values for various parameters provided in EPA 2001a and 2001b, including requiring the use of the residential exposure scenario as the most "conservative" approach in most cases. EPA uses limitations on carcinogenic risk and associated carcinogenic slope factors to establish levels of "acceptable risk" and constrain these analyses. However, consistent with DOE-LMs previous approach that was used for the recreationist scenario on public lands, we have used herein a dose-based risk limitation of 1 mSv (100 mrem) above background per year, every year, as the primary constraint. This annual exposure limit has long been the fundamental public exposure criterion associated with nuclear facilities and activities under the US Atomic Energy Act, as codified in the AEA implementing regulations of both the U.S. NRC (10 CFR 20.1301) and the U.S. DOE (10 CFR 835.208). Furthermore, 1mSv / yr. is the basic international consensus standard for public exposure above background from all sources (e.g., ICRP 2007).

2.0 Technical Approach

We establish a unit concentration of 1 pCi/g of ^{238}U in soil. Then all other radionuclides in the uranium decay series will be present at 1 pCi/g (0.036 Bq/g) since secular equilibrium is assumed. The exposure as a Total Effective Dose Equivalent (TEDE) over a 1-year period is the sum of the dose rates from each of the relevant nuclides within each relevant exposure pathway. The relevant pathways defined in EPA 2001a and b for a residential exposure scenario are as follows. Note that exposure pathways based on consumption and/or use of contaminated groundwater are not considered relevant for these sites as discussed below:

1. External exposure from the soil, i.e., ground shine
2. Casual ingestion of soil
3. Inhalation of dusts (resuspension of soil)

Except as specifically noted otherwise, all parameter inputs are derived from default values provided in EPA 2001a and b.

Although most risk assessments typically include groundwater as a drinking water source and/or to provide water for home vegetable gardens, this screening-level evaluation assumes that mining activities and waste rock have minimal impact on sustainable groundwater sources and that other water sources (water transported from municipal sources easily accessible to the public) would be more likely used by nearby residences.

The Total Effective Dose Equivalent (TEDE) is the sum of the dose equivalents from each pathway:

$T = E_x + S_{ing} + I_d$

Where:

T = TEDE for a 350 days per year residential exposure scenario per pCi/g of each of the ^{238}U plus ^{235}U series radionuclides in soil.

E_x = Dose Equivalent (DE) from external exposure from the soil – sum of exposure while outdoors ($Ex_{outside}$) + indoors (Ex_{inside})

S_{ing} = Committed Effective Dose Equivalent (CEDE) from incidental ingestion of soil

I_d = CEDE from inhalation of fugitive dusts

2.1 Eternal Exposure Pathway

Table 3.1 of US NRC 1995 (NUREG 1506) provides conversion factors for open field exposure rates (essentially an infinite plane at the soil surface) in uR / hr. at 1 meter above the ground per pCi per gram in soil for both the natural uranium (U-238) and thorium (Th-232) series. This is pCi per gram of the parent nuclide (U-238 and Th-232 respectively) and as secular equilibrium is assumed, it includes a pCi per gram of each nuclide in the decay series down to the stable lead isotopes at the end of each chain. Accordingly, the total external exposure associated with 1 pCi/g of each of the uranium series radionuclides in soil assuming secular equilibrium, during a one-year period (350 days) is defined:

$Ex = E_{x\ outdoors} + Ex_{\ indoors}$

$E_{x\ outdoors} = (EF)(ACF)(ET_{outdoors})(ER)$

Where:

Ex = annual exposure (uR) to resident from external pathway per pCi / gram.

$E_{x\ outdoors}$ = Contribution from external exposure during time resident is out of doors, but at the residence

$Ex_{\ indoors}$ = Contribution from external exposure during time resident is inside of home

EF = exposure frequency (hrs.) for 350 days / year = 8400

ACF = area correction factor of 0.9 [1]

ET = Exposure time factor (unit less); outdoors = 0.073 ; indoors = 0.683

[1] From EPA 2001b, Section 2.4: *The concept of an "infinite slab" means that the thickness of the contaminated zone and its aerial extent are so large that it behaves as if it were infinite in its physical dimensions. In practice, soil contaminated to a depth greater than about 15 cm and with an aerial extent greater than about 1,000 m^2 will create a radiation field comparable to that of an infinite slab. For calculation of SSLs for a residential setting, an adjustment for small areas is considered to be an important modification…. since in most residential settings the assumption of an infinite slab source will result in overly conservative SSLs. Thus, an area correction factor, ACF, has been added to the model for the calculation of SSLs*.

Note that the value of 0.9 for the ACF is based on a source area of 2000 m2. For smaller areas, the ACF is reduced (See Tables 5.1 and 5.2, EPA 2001b). For example, an ACF of 0.75 is recommended for a source area of 100m^2 containing ^{226}Ra and progeny.

GSF = gamma shielding factor while indoors = 0.4 (unit less) [2]

ER = Exposure rate (uR / hr.) per pCi / gram U 238 in equilibrium with progeny (from NRC 1995 – see above) = 1.9

$E_{x\ outdoors}$ = (EF = 8400 hrs.) (ACF = 0.9) (ET outdoors = 0.073) (ER =1.9 uR / hr. per pCi / gram) = 1048 uR

Ex $_{indoors}$ = (EF = 8400 hrs.) (ACF = 0.9) (ET indoors = 0.683) (GSF = 0.4) (ER = 1.9 uR / hr. per pCi / gram) = 3924 uR

1048 + 3924 = 4972 uR from external exposure pathway = 4.97 mrem per pCi / gram

2.2 Casual Ingestion of Soil

From USEPA 2001b, Section 2.2, 120 mg/day is used as the age averaged soil ingestion rate for a residential exposure scenario. Accordingly, 120 mg/day × 350 days = 42 g soil ingested over a 1-year period. [3]

A dose conversion factor (e.g., DCF = mSv per Bq ingested) for the aggregate of radionuclides contained in uranium ore at equilibrium could not be found in the literature. Accordingly, an “aggregate DCF” is calculated here (Table 1) using the most important (“highest”) specific DCFs for radionuclides in the decay chains for natural uranium. Where multiple solubility class or absorption type DCFs are provided for a nuclide, the value for the least soluble species was used (longest residence time/larger DCF). The radionuclides from the actinide (^{235}U) decay series have been ignored in Table 1 since the ratio of ^{235}U activity to ^{238}U activity in uranium ore related dust is the natural abundance ratio of 0.046 to 1 and contributions to the aggregate ingestion DCF from the ^{235}U series is quite small. Some radionuclides in the ^{238}U decay series have also been ignored since their DCFs are $< 1 \times 10^{-9}$ Sv/Bq and would have no material impact on the result.

[2] In U.S. EPA, 1981, the authors performed a review of experimentally measured indoor/outdoor gamma ray shielding reduction factors for fallout. The authors concluded that “reduction factors of 0.2 to 0.4 are recommended as representative values for above-ground lightly constructed (wood frame) and heavily constructed (block and brick) homes, respectively.” On the basis of this review, U.S. EPA 1996, suggests that a default gamma shielding factor of 0.4 based solely on the contribution of terrestrial radiation might be a more appropriate value to use at sites with soil contaminated with radionuclides. Based on this rationale, the value of 0.4 was adopted as the default gamma shielding factor (EPA 2001a and b).

[3] USEPA 2011 recommends 50 mg/day for ages 1–21 with an “upper percentile value” for children of 200 mg/day. It is also noted that a behavior referred to as “pica” is mentioned in the literature in which a young child ingests several grams of soil in a single event. However, this is an “extreme” circumstance and not considered sustainable over multiple days without possible medical implications and is therefore ignored here.

Table 1: Ingestion Dose Conversion Factors (DCFs = Sv/Bq Intake)

Radionuclide	DCF from USEPA 1988	DCF from ICRP No. 68 (1994) and/or ICRP No. 78 (1997)
^{238}U	6.9 E-8	4.4 E-8
^{235}U	7.2 E-8	4.6 E-8
^{234}U	7.6 E-8	4.9 E-8
^{234}Th	3.7 E-9	3.4 E-9
^{230}Th	1.5 E-7	2.1 E-7
^{226}Ra	3.6 E-7	2.8 E-7
^{210}Po	5.1 E-7	2.4 E-7
^{210}Pb	1.4 E-6	6.8 E-7
Aggregate DCF	**2.6 E-6**	**1.6 E-6**

The values from ICRP 68 and 78 are based on much more recent metabolic data and models than the values in USEPA 1988, although it is noted that the Federal Guidance Report No. 11 (USEPA 1988) aggregate DCF is about 60% higher. Nonetheless, the aggregate DCF values calculated from individual radionuclide values in USEPA 1988 are used here in the interest of conservatism and given that the relative contribution of the soil ingestion pathway to the TEDE of the sum of all relevant pathways is < 10%, as is subsequently demonstrated.

Accordingly, the CEDE for ingestion of incidental soil over a 350 day period is calculated:

$S_{ing} =$ (DCF_{inj}) (M) where S_{ing} = CEDE from ingestion of uranium ore in soil; DCF_{ing} is the aggregate ingestion DCF from Table 1 (USEPA 1988); and M = soil mass ingested in 350 days (grams)

S_{ing} = (2.6×10^{-6} Sv/Bq) (10^5 mrem/Sv) (1/27 Bq/pCi) (42 g) (1 pCi/g) = 0.4 mrem per pCi/g.

2.3 Inhalation of Fugitive Dusts

The dose per unit concentration (e.g., per pCi/g ^{238}U in the soil) is calculated as follows:
$I_d = DCF_{inh}$ (1/PEF) (C) (BR) (T)

Where:

$I_d =$ CEDE from inhalation of uranium ore in dusts per unit concentration in soil

$DCF_{inh} =$ CEDE from inhalation for all nuclides in ^{238}U and ^{235}U decay series per unit intake (mrem/pCi or mSv/Bq of each nuclide in equilibrium) via inhalation of dust containing uranium ore (see Table 2)

PEF = Particulate Emission Factor (inverse of air concentration) from USEPA 2001a and b = 1.32×10^9 m^3/kg

C = Concentration of ^{238}U and each progeny in resuspended soil dust = 1 pCi/g (0.036 Bq/g)

BR = Breathing (inhalation) rate from USEPA 2001a and b = 20 m^3/day

T = Time of exposure = 350 days

The DCF_{inh} values for inhalation of uranium ore dusts were determined using the following assumptions and methods.

Assumptions:

- Dust that is inhaled is from uranium-bearing ore only and contribution from the natural thorium (^{232}Th) series is negligible and consistent with general background of ^{232}Th.
- The ore dust inhaled is in radioactive equilibrium.
- The ratio of ^{235}U activity to ^{238}U activity in uranium ore dust is the natural abundance ratio (0.046 to 1).
- The particle size distribution of the dust inhaled is represented by the standard default activity mean aerodynamic diameter of 5 µm.
- The chemical form of each radionuclide in the dust inhaled is that corresponding to the slowest lung absorption rates specified in ICRP 1994 (ICRP 68) and/or ICRP 1995 (ICRP 71); i.e., clearance Type M or S (Moderate or Slow). This maximizes residence time in the lung and therefore the dose.

IAEA 2004 presents in its Table A-1, for the inhalation of ore dust containing 1 Bq of ^{238}U, the radionuclides inhaled and the corresponding committed effective doses in mSv. This is reproduced in Table 2. The doses were calculated using the dose coefficients listed in IAEA 1996 (superseded by IAEA 2011). Using the values of total alpha activity and total committed effective dose calculated in Table 2, the aggregate committed effective dose per unit intake of alpha activity = 0.0035 mSv/Bq (1.3×10^{-2} mrem / pCi) [4.]

Accordingly, the CEDE for incidental inhalation of uranium ore in dusts over a 350-day period is:

$I_d = (DCF_{inh})(1/PEF)\ (C)\ (BR)\ (T)$

I_d = (0.0035 mSv/Bq) (1/27 Bq/pCi) (100 mrem/mSv) ($1/1.32 \times 10^9$ m^3/kg) (10^3 g/kg) (1 pCi/g) (20 m^3/day) (350 days)

$I_d = 6.8 \times 10^{-5}$ mrem per pCi/g

[4] The contribution from beta activity is very small; see Table 2.

Table 2: Inhalation Dose Conversion Factors for Uranium Ore Dust (Per Bq/g of ^{238}U at Equilibrium; from Table A-1 of IAEA 2004)

Series	Radionuclide	Type	Type of emitter	Inhalation dose coeff's. (5 um AMAD) (Sv/Bq)	Specific Activity (Bq/g)	Effective 5 um inhalation dose coeff's. (Sv/αBq)
URANIUM	Uranium-238	S	α	5.7E-06	1.00	5.7E-06
	Thorium-234	S	β	5.8E-09	1.00	5.8E-09
	Protactinium-234m		β	0.0E+00	1.00	0.0E+00
	Uranium-234	S	α	6.8E-06	1.00	6.8E-06
	Thorium-230	S	α	7.2E-06	1.00	7.2E-06
	Radium-226	M	α	2.2E-06	1.00	2.2E-06
	Radon-222		α	0.0E+00	1.00	0.0E+00
	Polonium-218		α	0.0E+00	1.00	0.0E+00
	Lead-214	F	β	4.8E-09	1.00	4.8E-09
	Bismuth-214	M	β	2.1E-08	1.00	2.1E-08
	Polonium-214		α	0.0E+00	1.00	0.0E+00
	Lead-210	F	β	1.1E-06	1.00	1.1E-06
	Bismuth-210	M	β	6.0E-08	1.00	6.0E-08
	Polonium-210	M	α	2.2E-06	1.00	2.2E-06
ACTINIUM	Uranium-235	S	α	6.1E-06	0.046	2.8E-07
	Thorium-231	S	β	4.0E-10	0.046	1.8E-11
	Protactinium-231	S	α	1.7E-05	0.046	7.8E-07
	Actinium-227	S	β	4.7E-05	0.046	2.2E-06
	Thorium-227	S	α	7.6E-06	0.046	3.5E-07
	Radium-223	M	α	5.7E-06	0.046	2.6E-07
	Radon-219		α	0.0E+00	0.046	0.0E+00
	Polonium-215		α	0.0E+00	0.046	0.0E+00
	Lead-211	F	β	5.6E-09	0.046	2.6E-10
	Bismuth-211		α	0.0E+00	0.046	0.0E+00
	Thalium-207		β	0.0E+00	0.046	0.0E+00
	Gross alpha activity concentration (αBq/g)				8.322	2.9E-05
	Weighted dose conversion coefficient (alpha only) (mSv/Bq)					0.00350
	Weighted dose conversion coefficient (alpha only) (Sv/Bq)					3.500E-06

3.0 Calculation of the Soil Screening Level

The annual Total Effective Dose Equivalent (TEDE) associated with 1 pCi / gram U 238 in soil can now be calculated. The exposure as a TEDE over a 1-year period is the sum of the dose rates from each of the relevant pathways listed again below. Note that exposure pathways based on consumption and/or use of contaminated groundwater are not considered relevant for these sites as discussed in Section 1.0:

1. External exposure from the soil, i.e., ground shine
2. Casual ingestion of soil
3. Inhalation of fugitive dusts (resuspension of soil)

$T = E_x + S_{ing} + I_d$

Where:

T = TEDE for a 350 days per year residential exposure scenario per pCi/g of each of the ^{238}U plus ^{235}U series radionuclides in soil.

E_x = Dose Equivalent (DE) from external exposure from the soil – sum of exposure while outdoors ($Ex_{outdoors}$) + indoors ($Ex_{indoors}$) = 4.97 mrem per pCi / gram

S_{ing} = Committed Effective Dose Equivalent (CEDE) from incidental ingestion of soil

I_d = CEDE from inhalation of dusts = 0.4 mrem per pCi / gram

Accordingly, T = 4.97 + 0.4 + 6.8 × 10^{-5} = 5.4 mrem per pCi / gram

Since the annual public exposure limit constraint used for this analysis = 100 mrem, the SSL for any radionuclide in the U 238 decay chain (e.g., Ra 226) is simply :
100 mrem / 5.4 mrem per pCi / gram = 18.5 pCi / gram above background

4.0 Application to Field Surveys – Screening Levels Expressed as an Exposure or Dose Rate

As stated in EPA 2001a (page 1-7):… *the external exposure pathway is, for most radionuclides, the dominant exposure and typically represents the most significant risk* . This has been demonstrated specifically for the uranium series radionuclides at DRUM sites. In Brown et al 2018, a similar analysis as described in this document for the future resident scenario was performed for future recreational users at DRUM sites on public land (e.g., BLM as land manager).

In the recreationist analysis, in addition to the three exposure pathways considered here, radon / radon progeny inhalation out of doors [5] and enhanced inhalation of dusts generated by recreational vehicle use (e.g. off highway vehicles – OHV) were also included. In that analysis, the external exposure pathway was shown to represent > 85 % of the dose contribution from all pathways and therefore external exposure rates as measured in the field in current time have been used directly as general screening levels for initial hazard ranking and prioritization of the DRUM sites on public land. The analysis herein presents similar results in that the external exposure pathway represents > 92 % of the annual TEDE per pCi / gram in soil (about 5 mrem external / 5.4 mrem total).

Accordingly, as has historically been used at DRUM sites on public land, real time external exposure rate measurements can be used directly as screening criteria for relative hazard ranking and prioritization of sites at which the future resident exposure scenario is appropriate (methods described in USDOE 2019 and Brown et al 2019).
Accordingly, using the previously referenced relationship of 1.9 uR / hr. per pCi / gram for the uranium series nuclides in soil (NRC 1995) relative to the 18.5 pCi / gram SSL calculated above, the equivalent exposure rate screening level is simply calculated:
(18.5 pCi)(1.9 uR /hr. per pCi / gram) = 35 uR / hr. above background

[5] Regards to the applicability of the radon / progeny inhalation pathway for the residential exposure scenario, EPA indicates in Section 2.2.1 of EPA 2001a that since homes built atop soil with identical levels of radium can have orders of magnitude differences in indoor radon levels, reducing the radium content in the soil may not result in any reduction in indoor radon levels and therefore evaluation of this exposure pathway is not necessary

5.0 Summary and Conclusions

An analysis was performed to estimate radiological screening levels (uR per hr.) for DRUM sites on tribal lands using a future full time residential exposure scenario. EPA guidance was used to define the applicable exposure pathways relevant to this scenario. Additionally, many of the input parameters required to perform the associated calculations were "default values" taken from the applicable EPA documents. The exposure pathways considered applicable to the application of a future residential scenario at DRUM sites included:

1. External exposure from the soil, i.e., ground shine
2. Casual ingestion of soil
3. Inhalation of fugitive dusts (resuspension of soil)

As a result, a screening level of 35 uR / hr. was estimated, based on an average soil radium 226 concentration of 18.5 pCi / gram.

It is important to note that as expected, these values are considerably less than those which were developed for the recreationist scenario on public lands (Brown et al 2018). This is due primarily to the fact that the recreationist's annual period of exposure was limited to 2 weeks (336 hrs.) in accordance with BLM's definitions and approach for assessment, characterization and hazard ranking of most legacy / abandoned mines in the western US (BLM 2017). However, for the residential scenario used above, EPA recommends an annual exposure period of 350 days (8400 hrs.), a significantly greater annual exposure period.

If you have any questions or require further information on these matters, please contact me at your pleasure. All the best and regards.

[redacted]

Steven H. Brown, CHP

REFERENCES

BLM 2017. U.S. Bureau of Land Management. BLM Technical Memorandum Screening Assessment Approaches for Metals in Soil at BLM HazMat/AML Sites. Update of September.

Brown et al 2018. Brown S, Edge R, Elmer J and McDonald M. Establishing Radiological Screening Levels for Defense-Related Uranium Mines (DRUM) Sites on BLM Land Using a Recreational Future Use Scenario. Health Physics Radiation Safety Journal. June 2018, Volume 114, Number 6.

Brown et al 2019. Brown S, Elmer J and Lewis B. Development of Radiological Screening Levels and Associated Gamma Survey Methodologies for Radiological Characterization at US DOE Office of Legacy Management Defense-Related Uranium Mine Sites. International Atomic Energy Agency. Proceedings of the NORM IX Conference, 23 – 27 September

IAEA 1996. International Atomic Energy Agency. *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*, Safety Series No. 115. Superseded by IAEA 2011.

IAEA 2004. International Atomic Energy Agency. Occupational Radiation Protection in the Mining and Processing of Raw Materials; No. RS-G-1.6. Annex: *Relationships Between Gross Alpha Activity and Committed Effective Dose For The Inhalation of Ore Dust Containing Uranium or Thorium.*

IAEA 2011. International Atomic Energy Agency. *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards*, IAEA Safety Standards Series No. GSR Part 3 (Interim).

ICRP 1994. International Commission on Radiological Protection. *Dose Coefficients for Intakes of Radionuclides by Workers,* ICRP Publication 68

ICRP 1995. International Commission on Radiological Protection. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides, Part 4: Inhalation Dose Coefficients*, ICRP Publication 71.

ICRP 1997. International Commission on Radiological Protection*. Individual Monitoring for Internal Exposure of Workers*, ICRP Publication 78.

ICRP 2007. International Commission on Radiological Protection. The 2007 recommendations of the International Commission on Radiological Protection. Oxford: Pergamon Press; Publication 103.

USDOE 2019. Radiation Protection Program Plan. LMS/POL/S04373-7.0. Prepared for USDOE – LM by Navarro Science and Engineering Inc. September

USEPA 2011. U.S. Environmental Protection Agency. *Exposures Factors Handbook*: *2011 Edition*, EPA/600/R-090/052F, September
USEPA 1988. U.S. Environmental Protection Agency. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion*, Federal Guidance Report No. 11.

USEPA 1981. U.S. Environmental Protection Agency. *Population Exposure to External Natural Radiation Background in the United States*, ORP/SED-80-12.

USEPA 2001a. U.S. Environmental Protection Agency. Soil Screening Criteria for Radionuclides: Users Guide. 9355.4-16A.EPA/540-R-00-007

USEPA 2001b. U.S. Environmental Protection Agency. Soil Screening Criteria for Radionuclides: Technical Basis Document. 9355.4-16.EPA/540-R-00-006

USEPA 1996. U.S. Environmental Protection Agency). *Soil Screening Guidance: Technical Background Document.* OSWER Directive No. 9355.4-17A. EPA/540/R95/128. Office of Emergency and Remedial Response, Washington, DC. NTIS PB96-963502.

USNRC 1995. U.S. Nuclear Regulatory Commission. Measurement Methods for Radiological Surveys in Support of New Decommissioning Criteria. NUREG 1506

Appendix C

DRUM Soil and Sediment Sampling Procedure

C1.0 Introduction

C1.1 Scope

Soil samples are taken for the purposes of defining the chemical constituents of background soil sample locations, mine waste materials (waste rock), and sediment shed areas. For simplicity the term "soil" is a collective term for the various representative earthen samples (e.g., sediment, waste rock) and "sampling" is a collective term for the procedures used to collect, document, and ship these types of soil samples.

The sampling strategy used to collect a representative sample from an area of interest, whether at a waste rock pile, sediment shed area, or a background location, involves collecting multiple subsamples that are homogenized to form a composite sample. USGS developed a statistically-based strategy for sampling the surficial material of waste rock piles, drainages, and background areas for use in screening and prioritizing historical abandoned mine lands (Smith et al. 2000). This approach focuses on the erodible surface of the area of interest (e.g., within the upper 6 inches of the "soil profile"). Additionally, general sampling protocols specified in the LMS *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2024i) are used to help guide the sampling effort.

Generally, samples will be collected from three different areas: background sample locations, waste rock piles, and sediment shed areas. Waste rock is material associated with an orebody of interest but which, because it had little economic value at the time of extraction, was disposed of onsite. Waste rock may contain COIs and may exhibit elevated gamma radiation; thus, it will be sampled as described below and utilized in the DRUM Program risk scoring process. Sediment shed areas are the result of the offsite migration of mine-related soils by erosional forces and will also be sampled as described below. Background sample collection procedures will also be conducted in a manner consistent with that described below.

Because sampling locations cannot be precisely described before all mines are visited, opportunistic sampling may occur (see Section C3.2.4). Such flexibility in field sampling locations may occur so a more complete site evaluation can be achieved. Unique circumstances that lead to opportunistic sampling will be noted and described in the final reporting for each affected mine; however, opportunistic samples are not used in the risk scoring.

COIs are assumed to be collocated; therefore, the area(s) of potential sample collection are mapped via field observation in conjunction with a gamma radiation survey (see Section D1.3). Sampling strategies and grids are established based on these observations and measurements. Sampling procedures for background locations, waste rock piles, and sediment shed areas are identical except that sediment shed sample grids will be constructed in the field using the gamma radiation survey data to define the area of interest, while sample grids for background locations and waste rock piles may be constructed either in the office or in the field.

C2.0 Roles and Responsibilities

The field team lead is responsible for implementing field activities and ensuring that all data are collected, recorded, and checked as described in the V&V Work Plan. To help ensure that all data components are accurately collected and recorded and to facilitate data transfer to the reporting team, the field team lead will compose a narrative describing mine conditions and relevant observations such as sampling events, mine accessibility, safeguard status, and observed site use. The field team members are responsible for field activities, such as radiological and GPS data gathering or soil sampling. All staff are trained to abide by the procedures of the DRUM Program.

C3.0 Instructions for DRUM Soil Sampling

C3.1 Field Equipment and Supplies

The following is a list of equipment and materials needed by the field team to conduct the soil sampling procedure:

- Field GPS unit and computer preloaded with project-specific information and electronic forms to (1) assist teams with navigation to the mine, (2) record position coordinates of the soil sampling areas, (3) collect field data and attributes, and (4) establish sample grids
- Paper or electronic copies of specific documents, such as the V&V Work Plan, appropriate FOP, and maps to facilitate visual orientation within mine groups
- Stainless steel sampling trowel or shovel for soil sampling to depths of 6 inches
- 10-mesh (2-millimeter) sieve for sieving samples into appropriately sized containers
- Two appropriately sized sample collection containers: one for sampling background areas and one for sampling waste rock piles, drainages, or sediment shed areas with elevated gamma radiation
- Weatherproof field logbook (bound and paginated)
- Rite in the Rain pens
- Permanent markers
- Sufficient number of plastic sample containers (at least 250 milliliters [mL] in volume) with screw-tight lids for the number of samples anticipated to be collected
- Nitrile gloves for handling samples
- Decontamination supplies:
    - Scrub brush
    - Masslinn dust/decontamination cloths
    - Deionized (DI) water
    - Alconox detergent
    - Two spray containers
        - One for decontamination solution (DI water + Alconox)
        - One for DI water (rinse)
- Communication devices (radios and cell phones; a satellite phone and inReach technology) will be provided for every field outing

C3.2 Sample Procedures

The following steps describe the sample collection procedures for sample areas. The general soil sampling approach consists of establishing a sampling grid of the sampling area, which is determined visually by the geologist, supported by the gamma radiation survey (see Section D1.3), and bounded by the gamma radiation value of 20 µR/hr. Generally, waste rock sampling areas will include the relatively flat upper portions and the side-slopes of a waste rock pile to the extent that the slopes can be safely accessed. Sediment shed from the waste rock pile that has migrated off the disturbed area will also be sampled if it exceeds the established gamma radiation threshold of 85 µR/hr and can be safely accessed. The gamma radiation survey will delineate the sediment shed area greater than the area registering gamma radiation of 85 µR/hr by extending the survey to 20 µR/hr or 30 ft whichever comes first, provided the area is accessible. This will occur at the discretion of the field team lead if complicating site conditions exist. The survey will be conducted downgradient and perpendicular to the flow of the sediment shed area if this portion of the mine is accessible. This will achieve the 20 µR/hr delineation goal as described in the Appendix D procedures for terminating transects (parallel gamma radiation survey lines).

For consistency among the field teams, Table C1 describes how multiple composite samples and their nodes will be collected depending on the size of a sample area. The area to be sampled is divided into the appropriate number of sample points (nodes) (Table C1) with field personnel sequentially collecting material from within the upper 6 inches of soil at each node, as described in the USGS mine waste dump sampling strategy procedure (Smith et al. 2000). Approximately equivalent volumes of soil will be collected at each node to achieve the required 600 grams (g) of soil required by the lab for analysis. Sampling will progress from one node to the next until all nodes have been collected. Each sieved subsample will be placed into the sample mixing container, samples will be homogenized to form a composite sample, the composite sample will be transferred to a sample container, the side and lid of the sample container will be labeled, and the sampling equipment will be decontaminated. Details for this sampling procedure follow.

Table C1. Sampling Schema

Sample Area (ft^2)		Sample Area (Acres)		# of Nodes	Composite Samples	Average Distance Between Nodes
0	100	0.00	0.002	0	0	NA
100	5,000	0.002	0.11	5	1	9 ft
5,000	29,000	0.11	0.67	5–30	1	24 ft
29,000	46,500	0. 67	1.07	30	1	33 ft
46,500	117,600	1. 07	2.70	60	2	37 ft
117,600	297,300	2.70	6.83	90	3	48 ft
297,300	751,400	6.83	17.25	120	4	66 ft
751,400	1,899,100	17.25	43.60	150	5	94 ft
1,899,100	4,798,800	43.60	110.17	180	6	136 ft

Abbreviation:
NA = not applicable

C3.2.1 Locations to Sample

Soil samples are collected for the purpose of defining the chemical COIs at specific locations. Samples will be taken at each background location, at waste rock piles, at sediment shed areas which exhibit gamma radiation greater than 85 µR/hr, and at other mine areas that exhibit unique or special circumstances. These areas may include potential ore stockpiles, isolated areas with gamma radiation exceeding 256 µR/hr, and areas where sediment migration to private property is visually identified (even though the migrating sediment is below 85 µR/hr). Other distinct locations that exhibit anomalous conditions as compared to the rest of the mine may be sampled at the discretion of the field team lead. These unique areas will be sampled using the opportunistic sampling techniques described in Section C3.2.4, but the results of the opportunistic sample analysis are not utilized in the risk scoring.

To ensure an adequate representation of undisturbed conditions, background sample locations will be 8,000 to 10,000 ft^2 in area where practicable, so that the sampling schema described in Table C1 may be employed. The area of the background sample plot will be recorded to ensure that the appropriate number of soil sample nodes are utilized. See Section C3.2.3 for more information regarding background sampling.

Generally, waste rock piles will be sampled individually using the sample node compositing techniques described in Section C3.2.2.1. In particular, waste rock piles which exhibit evidence of recreational use (e.g., a campfire ring) are considered to be a single decision unit and will be sampled separately from other waste rock piles. Very small waste rock piles (those with an accessible area of 100 ft^2 or less) will not be sampled unless they warrant an opportunistic sample. Some mines contain multiple small waste rock piles in proximity to one another. These waste rock piles may be combined into the same composite sample if:

- They are within the same disturbed area.
- Each has more than 100 ft^2 of accessible area.
- The materials in each waste rock pile exhibit similar lithology (originate from the same formation and mine).
- Each waste rock pile exhibits a gamma radiation signature below 256 µR/hr. The field team lead will decide if there is an isolated area of gamma radiation greater than 256 µR/hr that warrants a separate opportunistic sample.

If a single waste rock pile has definitive signs of camping, it will be sampled individually.

When two or more waste rock piles meeting these criteria are combined into a single composite sample, the piles will be individually located using the handheld GPS unit, and the team geologist will document in field notes how the sampled waste rock piles meet the above criteria. The combined accessible area of the individual waste rock piles will be used to calculate the number of required sample nodes according to Table C1.

Waste rock piles with elevated gamma radiation (256 µR/hr and higher) as well as waste rock piles which contribute offsite sediment will be sampled individually following the Table C1 sampling node criteria. Opportunistic samples may be collected at waste rock piles of less than 100 ft^2 of accessible area with a gamma radiation signature of 256 µR/hr or greater.

Sediment shed samples will be collected when material is visibly migrating away from the disturbed area and gamma radiation readings are greater than 85 µR/hr. The area with gamma radiation greater than 85 µR/hr will be delineated, and the sampling procedures outlined in Section C3.2.2.1 will be applied. Once the sediment shed area is delineated, where accessible, the team will continue the gamma radiation survey to a distance of 30 ft beyond the sediment shed area or to the 20 µR/hr limit, whichever comes first. If waste material is visibly migrating from Navajo Nation land to private property and is below 85 µR/hr, sediment shed protocols will be instituted, but the sample will be classified as an opportunistic sample.

In some circumstances soil samples may not be obtained because the sample area is not accessible due to safety considerations, such as steep slopes. In these cases, sampling will occur only to the extent that it is feasible given the relevant safety considerations. Such sampling could occur at the waste rock pile crest, toe, or both. The number of sample nodes, however, may deviate from that recommended in the sampling procedures outlined in Table C1 but will be spatially arranged to best represent the area. Nonetheless, the results of the analysis of these samples will be utilized, and a note regarding the sampling restrictions will be included in the V&V report. Detailed field notes and accompanying photographs will be provided to describe why a gridded soil sample was not collected. Notes will include a description of the material observed on the waste rock pile, including observations of mineralization, observations of seepage, or other pertinent information describing the nature of the material.

As an in-field QC step, the field team lead, in conjunction with the team geologist, will confirm that the sampling strategy has been implemented as described. If a variance from the strategy is required due to site-specific conditions, the field team lead and team geologist will ensure that the rationale for the variation is well documented in field notes.

C3.2.2 Preparation for Soil Sampling: Establishing the Sampling Grid

There are two acceptable methods of establishing soil sampling grids: (1) an office-based computer-assisted method which may be employed when sufficient inventory information is available before embarking on an environmental sampling field trip and (2) an in-field grid establishment method which relies on GPS or paced establishment of sample nodes.

C3.2.2.1 Preparation for Sample Grid

Sample grids may be prepared in the office following receipt of inventory information or created in the field as circumstances dictate. Layout of the sample grid pattern is described below.

Field establishment of sampling grids will occur when conditions dictate that this is a more efficient way to complete soil sampling. Field establishment of sampling grids will occur (1) at background sample areas, (2) when inventory and environmental sampling occur during the same mine visit, and (3) when samples are collected from sediment shed areas.

Alternatively, sample grids may be prepared in the office using data provided by the field team or satellite imagery regarding the crest and toe of the waste rock pile(s). The inventory-generated GPS data are loaded into ArcMap and projected into two dimensions so the sample area can be established. These sampling grids may be built in ArcMap, Quantum Geographic Information

System (QGIS), or equivalent before sampling fieldwork begins and will be preloaded onto field computers.

Regardless of whether the sample grid is prepared in the office or in the field, the following method will be used to establish the number of sample grids required for specific areas:

[1] The sample area is compared to Table C1 to determine how many subsamples will be collected by the field team for each composite sample

  [a] If the sample area is less than 100 ft^2, no composite sample will be taken.

  [b] If the sample area is 100–5000 ft^2, samples will be collected from a minimum of five nodes. Equal volumes of soil will be collected from each node so that at least 600 g of combined sieved sample material is collected. The node samples will be homogenized, and a minimum of 600 g of composited sample material will be submitted to the laboratory for analysis.

  [c] If the sample area is 5000–29,000 ft^2, the sample area will be gridded into approximately 30 by 30 ft (900 ft^2) sample nodes. Samples will be collected from each node. These samples will be homogenized, and a minimum of 600 g of material will be submitted to the laboratory as a composited sample for analysis.

  [d] If the sample area is greater than 46,500 ft^2, the area will be compared to the chart below to determine the minimum number of composite samples required. When more than one composite sample is required, the area of interest will be divided into two or more roughly equal sections. At the discretion of the field team lead, the area of each section will be determined by assessing the results of the gamma radiation survey and by the potential for sample heterogeneity as determined by the mine's layout and geologic setting. The field team lead will record the decision, and sampling will then occur as described in Section C3.2.2.1(1)(c) and Table C1, so that the appropriate number of nodes per composite sample are collected. Each composite sample will be homogenized individually, and a minimum of 600 g of material from each composite sample will be sent to the lab for analysis. If the recommended number of nodes cannot be collected because a given sample area is inaccessible, the field team lead will record such limitations, so they can be described in the V&V report.

[2] When the sample grid is prepared in the office, the following method will be used to establish sample node location on the ground:

  [a] The sample grid is built in ArcMap, QGIS, or equivalent to reflect the shape and appropriate number of nodes for each sample area.

  [b] Sample node locations are loaded into the GPS unit or field computer so the field team can navigate to the individual nodes in the field.

  [c] Field teams will use the handheld GPS unit or GPS-capable field computer to navigate to the preloaded sample node locations.

  [d] As a QC check, grid spacing will be evaluated in the field using the GPS unit or GPS-capable field computer. Spacing will be adjusted if needed to ensure appropriate node distribution across the sample area.

  [e] If poor GPS reception prevents use of a field computer or GPS unit to locate sampling nodes, the nodes will be manually established. Manual establishment of

sample nodes requires the use of an engineering tape or pacing to establish the grid pattern. Individual sample nodes will be identified on the ground using pin flags. The sample area will be sketched and the sample node locations noted on the sketch, so an accurate portrayal of the sampling grid is created and saved for future reference.

[3] During field preparation of the sample grid, the node location pattern will be created using the handheld GPS unit or field computer to establish the node locations in the field in the following manner:

[a] The field team lead in conjunction with the team geologist and RCT will determine the extent of the area to be sampled. Adjacent material that is not part of the area being sampled can be included in the grid if the field team lead determines the material will provide a more representative sample and estimate of the COIs. A determination of the total sample area (ft^2) is made.

[b] A visual check of the sample area will be performed to confirm there are no obvious indications of underground utilities (refer to the DSP for details on underground utilities).

[c] The number of nodes required for each sample will be calculated using Table C1.

[d] Sample nodes will be established and logged as sampling progresses using the handheld GPS unit or field computer to establish these locations at the average distances from one another as described in Table C1. Nodes will be spatially distributed to best represent the area sampled.

[e] Grid spacing will be continually evaluated and adjusted as sampling progresses to ensure appropriate sample distribution.

[f] A continuous QC check is performed during node establishment using the handheld GPS unit or field computer to evaluate sample node distribution and spacing to ensure that the appropriate number of sample nodes are within the planned sample area.

[g] If poor GPS reception prevents use of a field computer or GPS unit to locate sampling nodes, the nodes will be manually established using an engineering tape or pacing to establish the grid pattern. Individual sample nodes will be identified on the ground using pin flags. The sample area will be sketched and the sample node locations noted on the sketch, so an accurate portrayal of the sampling grid is created and saved for future reference.

C3.2.3 Collecting Soil Samples

[1] Wearing a clean pair of nitrile gloves and using a decontaminated sample trowel or shovel, field personnel will clear any large surface debris (e.g., organic material and large rocks), collect a sample from within the uppermost 6 inches of soil, and transfer the contents to a 10-mesh sieve. Sample excavations will be large enough to ensure that an approximately equal volume of sample material is collected at each node. Additional material will be collected if the sample particle size distribution at a node is extremely heterogeneous or relatively few nodes are prescribed for a small waste rock pile. In such cases, equal volumes of soil material will be collected from each node to achieve the required 600 g required by the lab for analysis. Material will be sieved into an

appropriately sized decontaminated container. Background samples will be collected in specifically designated appropriately sized containers to ensure waste rock material does not contaminate the background sample.

Note *If the planned sample location has large debris and material (such as cobbles, a boulder, or a log) that prevent sample collection, field personnel will collect the required amount of material by excavating surficial soil within a 5 ft radius of the original sample node point.*

[2] Each sample node location will be logged using the handheld GPS unit or field computer before field personnel move to the subsequent sampling point.

[3] A final visual QC check using the handheld GPS unit or field computer (verifying that an appropriate sample node location and distribution was established) will be done to confirm that all nodes have been collected, logged, and saved.

Note *Items to track as the process is repeated at each node location include:*

- *Whether each sample location has been logged using the handheld GPS unit or field computer.*
- *Whether an approximately equivalent volume of soil per unit area has been obtained from the sample excavation.*
- *Whether the same volume of soil has been retrieved for each sample node, and each node is equivalently represented so that 600 g of sieved soil is collected for the lab sample.*

[4] Field personnel will use a sampling trowel or shovel to homogenize the sieved multinode samples in the sample collection container.

[5] Transfer the composite soil sample to the plastic sample container (at least 250 mL in volume) and place any remaining material in the sample collection container on the ground in the same area from which the sample was collected.

[6] All sampling equipment will be decontaminated (see Section C3.4) following each sample event.

C3.2.4 Collecting Opportunistic Samples

If unique material is encountered in the field that differs from that typically encountered at the mine, the field geologist will determine the need for an opportunistic sample. Opportunistic samples may be obtained for the purpose of identifying mine-feature-specific COIs. Examples of candidates for opportunistic sampling may include the base of a loadout, an ore stockpile location, a sufficiently accessible waste rock pile that either exhibits gamma radiation near 256 µR/hr or has the potential to impact offsite private property, or isolated areas within a waste rock pile with gamma radiation at or above 256 µR/hr. Analytical results of opportunistic samples will be reported for each mine at which they are collected; however, the results will not be applied toward the risk evaluation.

Opportunistic sample locations, or individual sample nodes in the case of multinode opportunistic samples, will be identified using the handheld GPS unit or GPS-capable field computer. Detailed field notes and accompanying photographs will be provided to describe why the sample was collected. Notes will include a description of the material being sampled, observations of mineralization, observations of seepage, and other pertinent information which describes the nature of the material sampled.

An opportunistic sample will consist of an individual sample, or when applicable, a multinode sample (node spacing as described by Table C1), of the atypical material (minimum of 600 g) that is screened through a 10-mesh sieve, thoroughly blended, and packaged in a plastic sample container at least 250 mL in volume. Decontamination and documentation procedures outlined in this appendix will be followed.

C3.2.5 Sampling Background

COIs are metals and radionuclides associated with exploration and mining activities. The natural background concentrations of the COIs are measured as a reference (referred to as "background") to determine whether the mine itself is a source of elevated concentrations or radiation activity. Generally, a single background measurement will be applied to multiple mines where possible. However, specific characteristics of each mine will dictate the background sample location. Based on the recommendation of the field geologist using best professional judgement, a mine-specific background sample will be collected if the geology of the mine differs from that of similar mines in the area or if the area has no background information. The following parameters will be used to choose a suitable background location:

- A target 8,000 to 10,000 ft^2 background sample area, where practicable, will be identified.
- It will be in an undisturbed area with soils and geology similar to those at the mine or of the mining district for a regional background sampling approach.
- It will be as close as is practical to the mine or group of mines being investigated but in an area unaffected by mining. When considering whether a background location is unaffected by mining the following will be taken into account:
  - Background location will be hydrologically upstream, sidegradient, or otherwise unaffected by the mine
  - Background location will be upwind of the prevailing wind direction from the mine

After selecting a background location, the field team will perform a gamma radiation survey using the gamma radiation survey instrument described in Section 5.3.6.2 of the V&V Work Plan to verify that the background sample location is not in a zone of highly mineralized material that is significantly different from that of the mine or district being investigated.

For background soil sampling, a grid will be established according to Table C1, and a soil sample will be collected as described in Section C3.2.2.1.

C3.3 Field Documentation of Soil Samples

C3.3.1 Sample Identification

[1] After tightening the lid of the sample container, the mine name (LM ID number followed by mine name), sample number and type, sampler, date, and time will be recorded using permanent marker on the top and side of each container. The container surface will then be wiped clean using a masslinn cloth.

[2] Samples will be placed in a secured case in a vehicle for transport to the LM Field Support Center (LMFSC) in Grand Junction, Colorado. In cases where it is impractical to transport samples back to the LMFSC, field teams will ship samples to the laboratory from remote locations.

Note

One duplicate soil sample will be collected for every 20 soil samples collected. The sample container will include a notation that the contents are a duplicate sample. The duplicate soil sample will not have an LM ID number, and the data generated by the lab for that sample will be stored in the Environmental Quality Information System (EQuIS) under the duplicate section.

C3.4 Equipment Decontamination

[1] Appropriate personal protective equipment will be used for equipment decontamination, as required by the job safety analysis. Sampling equipment will be decontaminated consistently to prevent potential cross contamination and to ensure the quality and integrity of the samples collected. Sampling equipment includes a stainless steel sampling trowel or shovel, a 10-mesh sieve, and sample collection containers. These and other potentially contaminated materials are surveyed (frisked) in the field to evaluate elevated radioactive contamination. For purposes of evaluating potential contamination, elevated radioactivity is defined as twice the measured background in counts per minute (CPM). If the gamma radiation frisk does not detect elevated radioactive contamination, the materials will be reused. If the gamma radiation frisk detects elevated radioactive contamination, the materials will be cleaned and resurveyed. Equipment which continues to exhibit elevated radioactive contamination will be secured, stored, and disposed of at an appropriately licensed disposal facility. All other one-time-use or disposable sampling equipment and related accessories will be disposed of in permitted municipal landfills. The decontamination process will be performed before composite sample collection; decontamination between subsample increments (i.e., between the sample nodes) is not necessary. Equipment will be decontaminated in a location where materials cannot be released into a surface water body, potential wetland, or other environmentally sensitive location.

[2] Equipment decontamination procedures are as follows:

[a] As much gross contamination as possible (e.g., residual soil) will be removed from equipment at the sampling area.

[b] Sampling equipment will be washed thoroughly and vigorously with DI water containing nonphosphate, laboratory-grade detergent, such as Alconox or its equivalent. A bristle brush or similar utensil will be used to remove remaining residual contamination. Limited quantities of decontamination liquid (wash and

rinse) will be generated during the decontamination process and are allowed to passively infiltrate into the ground surface.

[c] Decontaminated equipment will then be rinsed thoroughly with DI water.

[d] Equipment will be allowed to air dry in a location where dust or other fugitive contaminants will not contact it, or a clean, disposable paper towel can be used to assist the drying process. All equipment must be dry before reuse.

[e] An alternative decontamination method requires the use of masslinn dust cloths. The sampling equipment will be thoroughly wiped down using the masslinn dust cloths. Masslinn dust cloths will be surveyed for residual radioactive contamination following use at a mine and will then be disposed of as municipal waste unless the survey readings exceed twice background as measured in CPM. If the contamination survey of the equipment shows that there are no elevated readings (i.e., twice background as measured in CPM) and that it is free of radioactive contaminants, after being wiped down, the equipment, except the discarded masslinn cloth, may be reused for sampling. If the contamination survey shows elevated readings after the equipment has been wiped down, then decontamination methods as described above in step [b] will be employed.

[f] Decontaminated equipment will be stored in plastic bags to protect it from fugitive contaminants during transport between mines or decontaminated before each use. Decontaminated equipment will be stored at a secure, unexposed location away from adverse weather and potential contaminant exposure. If equipment cannot be protected from fugitive dust during transportation, it must be decontaminated before use.

C3.5 Sample Shipment

[1] Samples will be transported from the vehicle to the designated radioactive materials area in the northeast corner of the soils room in Building 32 at the LMFSC. Samples must remain in the radioactive materials area until they have been surveyed, packaged, and approved for shipment to the lab.

[2] The sampling information recorded in the field on each container is transferred to a Microsoft Excel spreadsheet.

[3] A field team member completes the sample labels and applies them to the sample containers.

[4] The Microsoft Excel spreadsheet information will be provided to the LMS laboratory coordinator for production of the EQuIS database-generated COC forms.

[5] As a QC step, the field team member who completed the Microsoft Excel spreadsheet verifies the accuracy of the information on the COC form when returned from the LMS laboratory coordinator, then signs and dates the COC form. The COC form accompanies the samples during shipment.

[a] COC forms remain with the soil samples while they are held in the radioactive materials area in Building 32 at the LMFSC.

[6] Before shipping the samples:

[a] All soil samples will be sealed and placed in a cooler. COC forms are placed in a plastic bag inside the cooler.

[b] A contamination and dose rate survey will be performed on the sample shipment cooler by a qualified RCT. The survey will be documented in writing and placed in the cooler with the sample COC forms.

[c] The lid will be securely taped shut and a custody seal placed on the cooler.

[d] The cooler will be stored in the radioactive materials area until authorization for shipment is received from the LMS laboratory coordinator.

When the LMS laboratory coordinator gives authorization for sample shipment, a *Shipping Request* form (LMS 1051) will be filled out, and the sample cooler(s) will be taken to Building 2, Shipping and Receiving, for shipment. Analytical parameters, sample volumes, analytical methods, preservatives, and holding times are listed in Table C2.

Table C2. Sample Container, Preservative, and Holding Time Requirements

Parameter	Matrix	Method	Sample Container[a]	Preservative	Holding Time	Storage
Selected metals[b]	Soil	SW-846 6020/7470A	≥250 mL container	None	6 months	None
Soil pH		SW-846 9045			As soon as possible	
Radium-226		Gamma radiation spectrometry			NA	

Notes:
[a] One container to be used for all analyses larger containers may be used until the inventory is diminished.
[b] See V&V Work Plan Section 3.1.1, Table 2.

Abbreviation:
NA = not applicable

C4.0 Instructions for Shipping DRUM Soil Samples to a Laboratory

C4.1 General Information

If a soil sample is shipped to a laboratory for the sole purpose of testing to determine its characteristics or composition, and the package being shipped is not known to exceed surface contamination limits or package radiation dose rate limits outlined in 49 CFR 173, "Shippers – General Requirements for Shipment and Packagings," the package or shipment shall *not* be identified as a Class 7 radioactive hazard and shall *not* be identified, labeled, or placarded as such.

C4.2 Purpose

The specific instructions below apply only to mine soil samples that have not purposefully been collected at the highest radioactivity concentration area at a mine. This instruction is written for soil samples collected that represent the “general area” or a composite of multiple samples intended to represent the average radioactivity of a specific area. Contact the LMS Radiological Control manager and a qualified LMS shipper if shipping something other than general area or composite soil samples from a mine.

C4.3 Specific Instructions

[1] Before placing the individual soil sample container in the shipping container, wipe the outside of the soil sample container (plastic container) to remove loose surface dirt or debris.

[2] Prepare the individual soil sample container so that required sample identification, the COC form, and security seal (as deemed necessary by the receiving laboratory or LMS sample custody protocol) are in place.

[3] Place the individual soil sample container into the shipping container (the shipping package, usually a project-supplied beverage-type cooler). Place and pack the soil sample containers so the containers are secure in the cooler and will not move freely about the cooler during transportation.

[4] Close the lid of the cooler but do not seal it permanently. The cooler lid will be reopened before shipment.

[5] Perform a radiation dose rate survey on the cooler exterior in accordance with LMS Radiological Control organization procedures. Record the survey results on an LMS *Radiological Survey Map* form (LMS 1553).

[6] Perform an alpha and beta smear survey (for loose surface contamination) on the exterior of the cooler in accordance with LMS Radiological Control organization procedures. Record the survey results on an LMS *Radiological Survey Map* form.

Note

As these soil samples are being transported to a laboratory for testing, they are not subject to DOT surface contamination survey limits or the requirement to survey a surface area of 300 square centimeters (cm^2). Use 100 cm^2 as the area to sample.

[7] Once the *Radiological Survey Map* is complete (excluding the reviewer signature), include a copy of the completed *Radiological Survey Map* inside the cooler.

[8] Close and seal the cooler lid in accordance with other shipping and transportation procedures.

[9] Provide the completed *Radiological Survey Map* to the LMS Radiological Control manager for review within 5 working days of survey completion.

Appendix D

DRUM Radiological Measurement and Data Collection Work Instructions

D1.0 Radiological Data Collection

The DRUM Program uses various instruments to collect exposure rate measurements and perform gamma radiation surveys to define the areal footprint of mining-related features and the extent of potential offsite migration of COIs generated from mines.

D1.1 Exposure Monitoring

Exposure monitoring of workers will be used to minimize personnel exposure to radiation while performing V&V fieldwork. Personnel are issued a dosimeter to record and track exposure. In instances where the dosimeter is not functional, a handheld dose or exposure rate instrument, such as the Thermo Scientific FH 40 G Multi-Purpose Digital Survey Meter, Thermo Scientific RadEye, or equivalent, will be used to monitor worker exposure in the field. Refer to the DSP for details on exposure monitoring.

D1.2 Handheld Radiation Dose Rate Measurements

Handheld gamma radiation measurements are performed using the RadEye Personal Radiation Detector (high sensitivity gamma radiation detection and dose rate measurement tool) or its equivalent.

The instrument should be held approximately 3 ft above the ground surface, or from a feature being surveyed, for consistency. It is acceptable, however, to perform handheld gamma radiation surveys at distances less than 3 ft above the ground surface, or from the feature being surveyed, when the surveyor is attempting to identify or delineate discrete sources from dispersed sources of radioactivity.

D1.3 Gamma Radiation Survey

Gamma radiation surveys are performed using the NUVIA Dynamics Inc. model PGIS-2-1, ERG RadScout, or equivalent. Gamma radiation survey detectors will be positioned in a backpack fitted to the RCT during surveys.

The goal for survey coverage density is to collect data sufficient in degree of magnitude and spatial proximity to portray gamma radiation conditions encountered at the site. Data will be reviewed in the field to ensure that the gamma radiation survey adequately covers the extent of the area of interest and that the spatial variations in gamma radiation are mappable with confidence across the site to support the identification of potential onsite source areas above 256 µR/hr and offsite releases above 85 µR/hr. To that end, the field team lead in consultation with the RCT and team geologist will define the extent of the gamma radiation survey boundaries based on a field evaluation of the disturbed area boundary. Adjustments to the disturbed area boundary may be made during this presurvey evaluation.

The distance between adjacent transects (parallel gamma radiation survey lines) will be established in the field to ensure an adequate degree of coverage based on the approximate surface area of the mine and the procedures described below. Practical considerations such as safety, terrain, and natural obstructions will dictate distances between transects. A minimum of one transect will be surveyed across a waste rock pile or other areas that will be soil sampled. To ensure that the extent of elevated gamma radiation is mapped, transects will extend until the surrogate background gamma radiation value, as described below, is encountered (see Section D2.2).

D2.0 Collection of Gamma Radiation Data

D2.1 Background Gamma Radiation Data

The background gamma radiation collection and background soil sample collection processes are conducted at the same location. See Appendix C for more information regarding the location of soil and gamma radiation background sample plots. Background radiation data will be used to document specific baseline conditions to which individual mine COIs and gamma radiation data may be compared. A gamma radiation value of 20 μR/hr will be used to establish the exterior margins, or boundaries, of gamma radiation surveys, as described below.

Regional or mine-specific background gamma radiation measurements are obtained for each mine evaluated. These background gamma radiation values are reported on a mine-by-mine basis and are intended to provide a baseline assessment of characteristic conditions at similar areas undisturbed by mining activities.

Background gamma radiation may be variable over relatively limited distances. Factors that contribute to this variability include the degree of mineralization in multiple strata and the variability of the colluvial thickness which may exist at either the background measurement area or areas adjacent to mines. Furthermore, a degree of spatial variability may be introduced because regional gamma radiation background values are preferred to mine-specific gamma radiation background values.

Gamma radiation background values will be collected as described below:

- Select a common soil and gamma radiation background location. Section 5.3 and Appendix C of the V&V Work Plan describe the selection of both regional and mine-specific background sample locations.
- Gamma radiation data will be collected from the background soil sample plot by traversing the area using the gamma radiation survey instrument. A minimum of 60 gamma radiation measurements will be made and recorded during the traverse(s) of the background sample location.

D2.2 Collection of Gamma Radiation Data

The gamma radiation survey is performed to obtain radiological data that represent the magnitude and spatial distribution of gamma radiation across the mine from which potential onsite sources and areas of offsite transport can be identified. To do so, field teams will use the following procedure. If mine-specific conditions require deviation from this procedure, such conditions will be documented, and an explanation of any alternative procedures which were implemented will be provided so that there is no ambiguity as to the gamma radiation survey information. As described in Section 5.3.4 of the V&V Work Plan, a gamma radiation value of 20 μR/hr will be used to bound the gamma radiation surveys at mines.

The field team lead, in consultation with the RCT and team geologist, will define the extent of the gamma radiation survey boundaries based on a field evaluation of the extent of the disturbed area. In general, the areas to be surveyed will consist of the field-defined disturbed area and the end, or termination, points of individual transects, taking into account adjacent topography and safety considerations. Transects will terminate when the surrogate 20 μR/hr background gamma radiation value is encountered and recorded on the gamma radiation survey instrument. Therefore, the termination points of transects will typically be beyond the margins of the disturbed area. Safety considerations, geologic conditions, or topographic constraints may require early termination of a transect. In such instances, the RCT and the team geologist or field team lead must make detailed field observations, which are documented in notes describing the conditions encountered.

When practicable, adjacent, parallel transects will be walked to complete the gamma radiation survey. However, natural obstructions and other physical barriers may prohibit walking parallel paths. Under these circumstances, nonlinear paths and patterns, including paths parallel to the disturbed area boundaries, may be employed to capture gamma radiation data which best represent site conditions. In these instances, the RCT will use best professional judgement to obtain a representative gamma radiation survey of the mine. Such judgement must take into account the goal of obtaining gamma radiation data representing the accessible portions of the mine and the requirement to walk beyond the disturbed area until the 20 μR/hr value is measured. When site conditions require a deviation from the parallel transect measurement method, the RCT and field team lead must make observations, which are documented in detailed notes describing the conditions encountered.

For most mines, the distance between adjacent transects will be established at the discretion of the field team lead and RCT and may vary between 20 and 50 ft, depending on site conditions. However, adjustments to this spacing may be made in the field to ensure an adequate degree of coverage based on the approximate surface area of the mine. If transect spacing greater than 30 ft is used, the field team lead will determine if areas of additional transects (fill-in) are required. The distance between parallel transects will not exceed 50 ft for most mines, unless prohibitive topographic conditions are encountered and documented, according to Section 5.3.6.2 of the V&V Work Plan. Practical considerations such as safety, terrain, and natural obstructions will dictate actual distances maintained between adjacent transects.

While 20 to 50 ft transect spacing reliably documents site conditions for most mines surveyed, for larger mines where the disturbed area exceeds 10 acres, it is appropriate to increase the transect spacing to as much as 100 ft. This increased spacing is useful to efficiently collect the screening level data needed to evaluate site conditions for large mines. When large mines are encountered during V&V activities, the field team lead, after consultation with the RCT, will contact the V&V technical manager for approval to measure transects with a spacing up to 100 ft. When a request to alter the gamma radiation measurement method is approved by the V&V technical manager, the team will conduct a gamma radiation survey with transects at the approved spacing. The use and approval of the expanded transect spacing will be documented by the field team lead.

The following protocols will be employed when implementing expanded transect spacing:

- If gamma radiation measurements near the margin of the disturbed area that meet or exceed 85 µR/hr are encountered, additional measurements will be made between the 100 ft transects to bracket or delineate the area of elevated gamma radiation.
- The team will complete perimeter gamma radiation survey measurements outside the disturbed area boundary to document the absence or presence of sediment shed with elevated gamma radiation (85 µR/hr). This could occur concurrently with the demarcation of the disturbed area.
- Existing sediment shed sampling protocols will be employed if elevated gamma radiation (85 µR/hr or greater) is encountered.
- Opportunistic sampling protocols will be employed when sediment migration (with a gamma radiation signature less than 85 µR/hr) onto adjacent private property is visually observed.

Gamma radiation survey transects will continue beyond the margins of the disturbed area or sediment shed until the surrogate gamma radiation value of 20 µR/hr is encountered and recorded or until the survey is conducted for 30 ft from the margin of the disturbed area, whichever comes first. The RCT will use a distance of approximately 15 ft from the edge of the disturbed area or sediment shed as a waypoint to compare the gamma radiation survey value to the gamma radiation value of 20 µR/hr. At the 15 ft point, or sooner at the discretion of the RCT, the gamma radiation survey data will be compared to the surrogate gamma radiation value of 20 µR/hr. If the gamma radiation survey value is less than or equal to 20 µR/hr, that transect will be considered complete. If the gamma radiation survey value is greater than 20 µR/hr, the RCT will continue walking the current transect until the gamma radiation survey value is equal to or less than 20 µR/hr. If the gamma radiation survey value of 20 µR/hr is not encountered at 30 ft from the disturbed area boundary, the transect measurement will be terminated, and detailed field notes will be created by the RCT in consultation with the team geologist to document such a condition. If geologic conditions, obstacles, or safety hazards prevent completion of the gamma radiation survey as described, this information will be documented in the field notes.

The severity of slopes or other topographic obstacles which prohibit safe access to an area may prevent the completion of gamma radiation surveys. In some instances, only the accessible portions of the crest or toe of a waste rock pile will be surveyed due to topographic or other physical limitations. In these cases, detailed field notes and accompanying photographs will be provided to describe the circumstances and limitations which caused early termination of the gamma radiation survey, or which dictated that only discrete portions of an area were surveyed. Notes should include a description of the condition(s) that prohibited completion of the survey. In addition, observations of the area not surveyed should be provided to the extent possible, including a description of waste rock (e.g., estimated area, mineralization, or water seepage).

Following completion of the gamma radiation survey, data will be reviewed in the field to ensure that the survey adequately covered the extent of the area of interest. This QC check will be made by the field team lead and RCT in consultation with the team geologist. The survey will be considered complete if a determination is made that the data adequately represent the accessible areas of the site. Such a determination will include consideration of (1) the ability to complete the survey so that the gamma radiation value of 20 µR/hr was encountered, (2) the adequacy of transect spacing for the area evaluated, (3) whether the data are sufficient to document the presence of onsite sources, and (4) whether sediment migration occurred. If a determination is made that the data are inadequate, those areas that require additional information will be identified, and additional gamma radiation survey data will be collected (or conditions that prohibit further data collection will be documented).

The field data QC check will be made by importing the real-time gamma radiation survey data and an aerial image of the mine onto a field computer. The gamma radiation data will be displayed over the aerial image so the sufficiency of the extent of the survey, adequacy of transect spacing, and adjacent gamma radiation conditions, including offsite migration potential, may be evaluated before the field team leaves a mine. Field workers will save the image, which depicts the combined gamma radiation survey data and the aerial image, for use in data validation.

In the event that an aerial image for a mine is unavailable, the QC check will be completed without the benefit of the image. In these cases, the gamma radiation data will be evaluated before the field team leaves the mine so that the sufficiency of the extent of the survey is confirmed (including an assessment of whether the gamma radiation value of 20 µR/hr was encountered and whether the data are sufficient to document whether offsite sediment migration occurred). In these circumstances, the RCT will exercise particular care in the field to collect the necessary amount of survey data at and adjacent to a mine.

D3.0 Field Operation of the Gamma Radiation Survey System

D3.1 Scope

This work instruction provides guidance for performing gamma radiation surveys using the ERG RadScout, NUVIA Dynamics model PGIS-2-1, or equivalent. The collected gamma radiation survey results will be compiled and presented in a graphical format so survey results can be used to ascertain the potential radiological risks at the mine.

D3.2 Roles and Responsibilities

D3.2.1 Radiological Control Technician

The RCT, or designees, shall:

- Perform a gamma radiation survey using the ERG RadScout or NUVIA Dynamics model PGIS-2-1 gamma radiation survey system.
- Provide gamma radiation survey results for processing and inclusion in the V&V report.
- Be well versed and up to date in the operation of the gamma radiation survey systems used to collect field data at mines.
- Ensure that all required actions in this work instruction are performed before, during, and after data collection is completed.

- Periodically ensure that data are being collected on the paired mobile PC or data collection interface unit.
- Ensure that completed records are handled in accordance with *Records and Information Management* (DOE 2021).

D3.3 Operation of the Gamma Radiation Survey Systems

D3.3.1 ERG RadScout Gamma Radiation Survey System

The Ludlum Measurements, Inc. (Ludlum) Model 44-10 detector and Ludlum Model 3000 count rate meter components shall be placed in the RCT's backpack during the gamma radiation survey. It is important that the relative geometry between the Model 44-10 detector and the environmental sources of radiation remain consistent with the original RadScout correlation evaluation. It is also important to ensure that no dense materials that may provide additional radiation shielding, such as drinking water in a bladder, be placed within 2 inches of the Model 44-10 detector. To ensure consistent geometry and prevent additional shielding, foam blocks are provided with each RadScout unit. The Model 44-10 detector shall be placed vertically, cable side up, in the bottom of the backpack, surrounded by the foam. Only lightweight materials, such as clothing, may be placed adjacent to the Model 44-10 detector. The RCT must verify correct Model 44-10 detector placement before each gamma radiation survey. The Model 3000 count rate meter may be placed anywhere in the RCT's pack where operation is convenient. During the survey, this will most likely be at the top of the pack.

A typical DRUM gamma radiation survey will require the following steps:

[1] Ensure proper geometry and no additional shielding around the Model 44-10 detector.

[2] Power on the Model 3000 count rate meter, Geode GPS receiver (or equivalent), and Mesa field tablet (or equivalent). Mute the Model 3000, if desired.

[3] Start the RadScout software on the Mesa field tablet (or equivalent data recording device).

[4] Ensure that the Model 3000 and Geode (or equivalent global navigation satellite system [GNSS] receiver) are connected and visible in the RadScout software display.

[5] Ensure that the GNSS receiver is connected to multiple satellites and achieving high location accuracy, as indicated by a blue satellite icon in the RadScout software.

[6] Create a new survey file name in the RadScout software.

[7] Load any necessary layers, such as background imagery or previous survey files.

[8] Ensure that the gamma radiation levels and colors for the legend are set as follows:

- Blue: 0–20 µR/hr (0–21,350 counts per minute [cpm])
- Green: 20–35 µR/hr (21,351–47,700 cpm)
- Yellow: 35–85 µR/hr (47,701–135,400 cpm)
- Orange: 85–256 µR/hr (135,401–497,500 cpm)
- Red: >256 µR/hr (>497,500 cpm)

The RadScout displays and records gamma radiation measurements in cpm. Measurements are converted to units of exposure rate in μR/hr during the field QA process. Conversion equations are provided in Environmental Restoration Group, Inc. RadScout Instrument Evaluation for Defense-Related Uranium Mines Program Gamma Radiation Surveys *(DOE 2023c).*

Note

[9] Start recording and begin the gamma radiation survey.

[10] Stop recording when gamma radiation survey is complete.

[11] Download the survey file(s) to an encrypted drive using the RadSync software.

[12] Transfer the survey file(s) to a field computer operating the RadScene software.

[13] Using the RadScene software, create the .csv or .shp files as needed for a QC check of the data.

[14] Power off and secure all RadScout components.

Procedures for operating the ERG RadScout gamma radiation survey system are detailed in the ERG RadScout *User Guide: Setup and Operation of the ERG Model 105G (GPS Handheld System)* and *ERG Model 105G Quick Guide*. Paper copies of each should be kept in the RadScout's travel case. The guides are available electronically at: \\lm\projects\Task113\Uranium Initiative\DRUM\V&V\Gamma\Safety Equipment Manuals.

D3.3.2 NUVIA Dynamics PGIS-2-1 Gamma Radiation Scanning Detector System

See the PGIS-2-1 User's Quick Reference Manual at the end of Appendix D.

D3.4 DRUM Standard Operating Procedure for After Calibration Response Check

D3.4.1 Introduction

D3.4.1.1 Purpose

This procedure provides instructions for determining radiation instrument response to a gamma radiation source. These checks are performed to ensure the stability of instrument operation between calibrations.

D3.4.1.2 Scope

This procedure applies to DRUM-specific equipment for gamma radiation surveys.

D3.4.1.3 Applicability

This procedure applies to portable radiation survey instrumentation used to detect ionizing radiation. It is not applicable to non-DRUM gamma radiation surveys.

D3.4.2 Precautions, Limitations, and Notes

- ***Precautions*: ** Handle sources in accordance with *Radioactive Source Use and Control* (DOE 2024h). Use standard ALARA principles to minimize exposure.
- ***Limitations*: ** Personnel using this procedure must be currently qualified as RCTs or task-qualified.
- ***Notes*: ** Portable radiation survey instruments are required to be source-response checked daily to ensure they are working correctly.

The after-calibration source response (ACSR) check should be performed promptly upon receipt of an instrument following calibration.

D3.4.3 Prerequisite Actions

[1] Inspect the instrument to ensure that the calibration is still current. For the ERG RadScout, this will include calibration of the Ludlum Model 44-10 detector and the Ludlum Model 3000 count rate meter.

[2] Check the batteries to ensure that sufficient battery strength is available.

[3] Check the physical condition of the instrument to ensure that there is no obvious damage that might affect proper instrument response.

D3.4.4 Frequencies

[1] Perform an ACSR check:

  [a] Before use in the field following calibration.

  [b] If a new source is to be used to perform daily response checks.

  [c] As a necessity to ensure accurate data.

[2] Perform response checks before instrument use or at the discretion of the operator.

D3.4.5 Instrument Response Checks

D3.4.5.1 ACSR Check

[1] Select the correct source (in accordance with Table D1) for the type of instrument.

[2] Record the following information at the top of the *After-Calibration Source Response Checks Data Sheet* (LMS 1974):

- Location (site) (e.g., LM Field Support Center at Grand Junction, Colorado)
- Date
- Instrument manufacturer, model number, and serial number
- Probe manufacturer, model number, and serial number
- Instrument and probe calibration due date
- Radioactive check source identification number and isotope

[3] Line the source up with the correct location on the gamma radiation survey instrument.

[a] For the ERG RadScout, insert the Ludlum Model 44-10 into the open end of the source case, select **Parameters** from the **Settings** menu, perform a 1-minute count, and record the total integrated counts reported by the RadScout software. Save a screenshot of the completed check.

[b] For the PGIS-2-1, line the source up with the sharpie markings on the PGIS-2-1 case (this should be directly over the crystal) with the source box closed, wait 60 seconds, and record the data on the PeiCore app.

[4] Record this information and the instrument response on the *After-Calibration Source Response Checks Data Sheet*.

Note: *PGIS-2-1 PEI information is stored in the phone under the **PEI>ARGS>DATA** folder. RadScout screenshots should be stored to the default location and transferred using the RadSync application.*

[5] Calculate the values 20% above and below the instrument response AND record these values in the appropriate locations on the *After-Calibration Source Response Checks Data Sheet*.

Table D1. Instruments and Applicable Check Sources

Instrument Type	Source Isotopes
Gamma radiation exposure or dose rate survey instruments	Cesium-137 or radium-226

D3.4.6 Daily Instrument Response Check

[1] Obtain the same source used to perform the ACSR check.

[2] Record the following information at the top of the *Daily Instrument Response* form (LMS 1974a):

- Radioactive check source identification number and isotope
- Instrument scale unit
- Instrument model number and property number
- Probe model number and property number
- Month and year
- Response (scale or decade)

[3] Measure the instrument using the same source-to-detector distance, geometry, and shielding as that listed on the *After-Calibration Source Response Checks Data Sheet*.

[4] Record the instrument's response dose rate on the *Daily Instrument Response* form for each scale (decade) checked.

[5] *IF* the instrument response falls within ±20% of all the ACSR dose rate range, *THEN*:

[a] Initial the applicable block on the *After-Calibration Source Response Checks Data Sheet*.

[b] Release the instrument for use.

[6] *IF* the instrument response is outside any of the ±20% ranges, *THEN:*

[a] For the PGIS-2-1 only: export the daily response check to PEIview. Check to see if the 662 kiloelectronvolts (keV) from the cesium-137 source is registering at 662 keV on the PGIS-2-1.

[b] If the 662 keV is lining up (PGIS-2-1 only), or if using the RadScout, move to a different area, double check detector and source positioning, and conduct another response check.

[c] If the instrument response remains outside any of the ±20% ranges, tag the instrument as defective, remove the instrument from service, and return the instrument for repair or recalibration.

D3.4.7 Records

- *After-Calibration Source Response Checks Data Sheet*
- *Daily Instrument Response*
- Instrument response check data file (PGIS-2-1) or screenshot (RadScout) to V&V gamma radiation drive

Appendix E

Risk Scoring Assessment

E1.0 Defense-Related Uranium Mines Risk Scoring Assessment

The Defense-Related Uranium Mines (DRUM) Program risk scoring process is designed to optimize risk evaluation by providing flexibility to the risk evaluator. This scoring process uses a two-part approach for identifying mines with no known hazards (i.e., a “none” ranking) and for prioritizing mines with hazards into high-, medium-, and low-priority categories. The overall approach focuses first on ranking primary site hazards (physical safety) and secondarily on the scoring of modifying factors. One objective of the first step is to identify mines that are at opposite ends of the hazard spectrum: (1) those that have no physical hazards and likely require no additional consideration and (2) those that pose clear physical hazards and would benefit from safeguarding (i.e., those that are high-priority). The emphasis in this prioritization approach is to put mines that pose similar hazards into categories.

Initially, rankings are based on the following possible hazards: physical hazards that are structures (e.g., an ore chute) and physical hazards that are mine features (e.g., an adit or subsidence feature). Physical hazards risks for a mine are first designated as “none,” “low,” “medium,” or “high” based on their severity. These rankings indicate whether hazards or potential risks are present.

Scores for the modifying factors are provided in the V&V report risk scoring assessment and are applied to the risk screening process. Modifying factors include (1) potential ecological and environmental impacts, (2) access and suitability criteria, and (3) the hazard complexity criterion. Application of the modifying factors may increase or decrease the initial mine scoring and ultimately its management priority. For instance, mines that have a score of 0 (or “none”) for physical hazards are considered to possess no known risks and require no additional consideration. However, agencies may want to consider the ecological scoring results for other reasons before making management decisions. For example, safeguarding may be considered for mines that present no physical hazards but where a hazard to migratory birds may be easy and inexpensive to mitigate by safeguarding specific small hazardous features (Harris et al. 2019).

The evaluation criteria for each of the five scoring categories or factors are designed to separate the mines that would benefit from safeguarding from those that would not. The primary ranking categories are intended to provide a relative measure of the severity of the hazards that exist at a given mine; the modifying factors provide an indication of the likelihood that risks posed by each hazard will be realized. The numerical scores for each modifying factor are less important than the relative high-to-low ranking for physical hazards.

The overall objective and approach for the physical hazard evaluation and three modifying factors are discussed further below.

E2.0 Physical Hazard Evaluation

The overall score in this category is based on the feature at the mine site posing the greatest hazard (sites with multiple physical hazards are addressed using the complexity modifying factor). Only mines with a feature that could result in death or severe injury (e.g., an open vertical shaft) are ranked “high” and receive a score of 3. If a mine has no features that pose a physical hazard greater than that of the surrounding topography, the mine receives a score of 0.

A “medium” score is given to mines that have physical hazards that are attractive to visitors and could result in a moderate injury (e.g., open portals that are stable, trench with vertical sides). Mines that are categorized as “low” risk have features that could result in moderate injury (e.g., short falls, sprains) but are not particularly attractive to visitors and could be easily avoided (e.g., a highwall visible from upslope, vertical drill pipes extending above the ground surface). Agencies may want to reclaim these mines to return a site to more natural conditions, but they do not constitute a significant risk.

E3.0 Ecological and Environmental Hazard Evaluation

The ecological and environmental scoring approach ranks both physical hazards and the presence or absence of potential radiological and chemical risk pathways. The two types of hazards are given separate scores. If a given physical feature poses multiple hazards (e.g., to both special-status species and migratory birds), the feature is assigned only the highest score (i.e., a single feature is not scored twice).

A mine will receive a high score in the physical hazard category if evidence of a special-status species or designated critical habitat for a threatened or endangered species is present within 0.25 mile of the mine and there is a potential physical hazard to that species. Special-status species are federally listed or proposed for listing as threatened or endangered; state-listed as threatened, endangered, or sensitive; identified as sensitive by BLM, USFS, or tribal authorities in the district in which the mine is located; or listed as U.S. Fish and Wildlife Service Birds of Conservation Concern for the region in which the mine is located. Special-status species are noted in the risk ranking tables but only receive a score when combined with a potential hazard.

The objective of the risk pathway portion of the ecological and environmental hazard evaluation is to provide an indication of whether a pathway may exist for the exposure of ecological receptors to mine-related contamination, primarily through surface water or the food chain. A gamma radiation measurement greater than 85 μR/hr is used as a qualitative indicator of mine-related contamination for both radioactive and nonradioactive contaminants that could indicate a complete pathway. A single elevated measurement may result in a nonzero score in this category because it is an indicator that a pathway could exist; it is not a determination that a pathway does exist. A mine receives a nonzero score if there is evidence of contamination migration from the disturbed area (a potential pathway could exist) or if contamination from the mine has reached surface water (a pathway is assumed to exist). A mine also receives a nonzero score if contamination is present on a waste rock pile with significant amounts of edible vegetation because this also indicates the potential for a pathway. A zero score indicates that no significant risk pathways are likely to exist at the mine. A nonzero score indicates that a closer evaluation of the chemical and radiological data may be needed before concluding that the mine does or does not present a potential ecological threat.

E4.0 Access and Suitability Evaluation

Scores in this category reflect mine visibility (i.e., attractiveness), accessibility, and suitability. Separate scores are given for access and suitability. Access is relevant to both physical hazards and human health risks with greater accessibility resulting in a higher probability that the hazard can lead to adverse impacts. The suitability score is most relevant in modifying the human health risk ranking; if a mine would likely not be used as a campsite because it is of inadequate size or it has unsuitable topography, then the assumed exposures are unlikely to occur.

Higher access scores are assigned to mines with greater ease of access (e.g., a mine that is accessible by a two-wheel-drive vehicle scores higher than one that requires a hike). A mine gets a single access score based on the easiest method of accessibility (i.e., it does not get a score for both accessibility by vehicle and accessibility on foot). If mine features are readily visible and considered to be an “attraction,” they are also scored higher (features increase the likelihood that people could visit the mine). A high score in the access category is only important when coupled with a physical hazard or human health risk; if no hazards are present, the access score is irrelevant. However, if physical safety hazards or potential human health risks are present, the access score is important in determining the likelihood that they will be encountered.

Suitability is an indication of whether a mine site can be used for the camping scenario. A mine needs to be of adequate size and appropriate topography for a camping scenario to be feasible. Direct evidence that a site has been used for this purpose is considered to be a better indicator of this use than the distance to residences or other populated places. A mine receives the highest suitability score if there is direct evidence of camping (e.g., the presence of a fire ring). A lower score is assigned if a site has suitable conditions for a campsite but shows no evidence of human use. A score of 0 means that the mine site is too small for exposures to be feasible or that topography or size precludes this use (e.g., no flat or cleared areas to set up a tent).

E5.0 Complexity Evaluation

The complexity factor is a measure of the degree of additional physical hazards (in addition to the primary hazard) at a mine site. This factor is used to determine if an initial hazard ranking will be elevated due to the presence of multiple hazards. If numerous physical hazards are present, the chances are increased that a visitor could be injured, and the mine might be elevated in priority over a mine with fewer hazards.

Primary Hazards			
PHYSICAL HAZARD EVALUATION—PHYSICAL FEATURES			
Criteria	**Potential Impacts**	**Priority Score**	**Comments and Observations**
At least one physical feature that could cause serious injury or death to people (e.g., an open shaft, a subsidence that is open to the subsurface, or an unstable adit that can be easily entered)	3		
At least one physical feature that could cause a moderate injury to people and may be attractive to visitors or not easily seen (e.g., a stable adit that can be easily entered, an unstable adit that is difficult to enter, or a needs maintenance adit that is not easily entered)	2		
At least one physical feature that could cause a minor to moderate injury but is not attractive to visitors and could be easily avoided (e.g., a prospect, a 4 to 6 ft trench with steep sides but that can easily be seen from a distance, or a deep water-filled feature)	1		
No inherent hazards; no increased injury potential compared to the surrounding area	0		
SUM Physical Hazard Evaluation Score 3 = High, 2 = Medium, 1 = Low, 0 = None			
PHYSICAL HAZARD EVALUATION—STRUCTURES			
Criteria	**Potential Impacts**	**Priority Score**	**Comments and Observations**
At least one structure that could cause serious injury or death to people (e.g., a large unstable structure such as an ore chute or ore bin that may collapse)	3		
At least one structure that could cause a moderate injury to people (e.g., a building or large unstable structure of moderate height)	2		
At least one feature that could cause a minor to moderate injury but is not attractive to people (e.g., a building or unstable structure that is <6 ft in height)	1		
No structures or increased injury potential	0		
SUM Physical Hazard Evaluation Score 3 = High, 2 = Medium, 1 = Low, 0 = None			

Modifying Factors			
ECOLOGICAL AND ENVIRONMENTAL RISK EVALUATION			
Physical Hazard Criteria	**Potential Impacts**	**Priority Score**	**Comments and Observations**
A special-status species or designated critical habitat for threatened or endangered species is present on or within 1/4 mile of the mine (yes or no; list if yes)	Y or N[a]		
One or more mine features (e.g., vertical openings, vents) are present that could cause serious injury or death to a special-status species	5		
One or more mine features (e.g., vertical openings, vents) are present that could cause serious injury or death to a migratory bird	3		
One or more mine features (e.g., vertical openings, vents) are present that could cause serious injury or death to a species that does not have special status	1		
No inherent physical hazards to wildlife compared to surrounding area	0		
SUM Ecological and Environmental Physical Hazard Score 5 or greater = High, 3 to 4 = Medium, 1 = Low, 0 = None			
Pathway Hazard Criteria	**Potential Impacts**	**Priority Score**	**Comments and Observations**
Mine-related contamination[b] has reached surface water	3		
Mine-related contamination[b] has been transported (by wind or water) outside the disturbed area but has not reached surface water (i.e., a sediment shed is present)	1		
Vegetation attractive to wildlife is present in quantities greater than 10% cover on a waste rock pile that has the potential for contamination[b]	1		
No potential pathways for contaminant migration evidenced by sediment shed or vegetation	0		
SUM Ecological and Environmental Pathway Hazard Score 3 or greater = High, 2 = Medium, 1 = Low, 0 = None			

Notes:
[a] If "No," mine cannot receive a score of 5 (i.e., "high").
[b] A gamma radiation measurement greater than 85 μR/hr (not adjusted for background values) is used as an indicator of mine-related contamination for both radioactive and nonradioactive contaminants.

Modifying Factors (continued)			
ACCESS AND SUITABILITY EVALUATION			
Access Criteria	**Potential Impacts**	**Priority Score**	**Comments and Observations**
Mine is readily accessible from a maintained road using a standard two-wheel-drive passenger vehicle or by walking	3		
Mine is not accessible by standard two-wheel-drive passenger vehicle; mine is accessible by four-wheel-drive vehicle or a utility task vehicle	2		
Mine is inaccessible by four-wheel-drive vehicle or utility task vehicle	0		
Mine access requires an easy to moderate hike of <1 mile across relatively flat terrain	2		
Mine access requires a hard hike (e.g., bushwhacking, grade greater than 10% slope, no defined trail, or >1 mile)	0		
Mine feature is visible from a maintained road that is passable by a vehicle, particularly if an attractive nuisance feature is present	3		
Mine is partially visible from a maintained road	2		
Mine is not visible from a maintained road	0		
SUM Access Score 5 or greater = High, 3 to 4 = Medium, 2 = Low, 0 = None			
Suitability Criteria	**Potential Impacts**	**Priority Score**	**Comments and Observations**
Sign of human use associated with camping onsite (e.g., fire ring, abandoned tent stakes, or other related equipment) is present from the period after the mine was abandoned	6		
Sign of human visitation (e.g., trash, vandalism, tire tracks) is present from the period after the mine was abandoned	3		
No sign of human use or visitation is present from the period after the mine was abandoned	0		
The total disturbed area is greater than 2 acres and includes an area that would be suitable for camping. Note the estimated size of the total disturbed area and its mean gamma radiation value in the comments and observations.	3		
The total disturbed area is 1/4 to 2 acres and includes an area that is suitable for camping	2		
The total disturbed area is less than 1/4 acre or contains no areas that are suitable for camping	0		
SUM Suitability Score 6 or greater = High, 3 to 5 = Medium, 2 = Low, 0 = None			
COMPLEXITY EVALUATION			
Complexity Criteria	**Potential Impacts**	**Priority Score**	**Comments and Observations**
Mine is extensive with more than one open entry, has vertical walls or steep slopes that could cause injury, or has unstable structures. Note the number of hazardous mine features and structures in the comments and observations.	3		
Mine has one open entry and some other features that could cause injury (e.g., steep slopes, unstable structures). Note the number of hazardous mine features and structures in the comments and observations.	2		
No reason to increase the score based on mine complexity (e.g., no subsurface access and only minor disturbances that are not likely to cause injury)	0		
SUM Complexity Score 3 = High, 2 = Medium, 0 = Not applicable			

Appendix F

Mine-Related Features

F1.0 Introduction

Mines may contain facilities, structures, improvements, and land disturbances which may pose a risk to human health and environment. Such risks may include (1) physical hazards from mine features or structures such as vertical shafts, adits, open pits, highwalls, subsidence features, prospects, headframes, other structures, and storage facilities; (2) hazards from landform modifications such as access roads and drainage diversions; and (3) risks from elevated concentrations of elements in piles of ore, waste rock, and soil stockpiles.

An inventory of mining-related features will be accomplished to the extent that these may be safely accessed. Some of the mine-related feature types catalogued in the mine inventory are shown in Figure F1 and are described in this appendix. All safely accessible features will be located using a handheld GPS unit and photographed for future reference. The current condition of all features and their safety hazard potential will be recorded. The integrity of any previous reclamation or remediation efforts and safeguards will also be observed and recorded.

This appendix describes the procedures to be used when collecting field data. Terminology used, methods of collecting and reporting DRUM Program-specific information, and precautions to be exercised when collecting these data are described in this appendix.

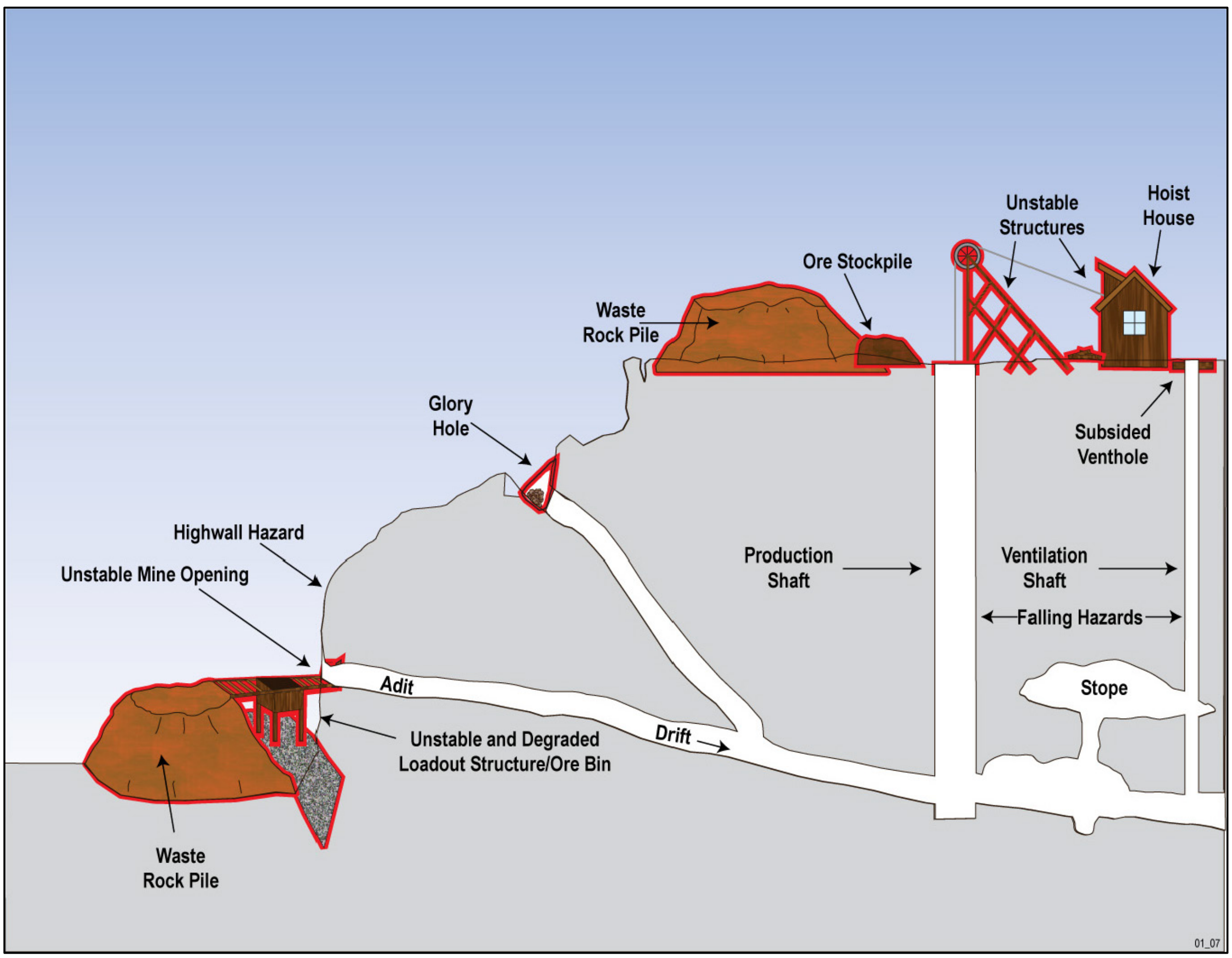


Figure F1. Mine Features

F2.0 Symbol Use

Different mining-related features are denoted by specific symbols. This is done for ease of understanding and for clarity in graphic presentations of data. Figure F2 depicts the GIS style for typical features identified at DRUM Program mines.

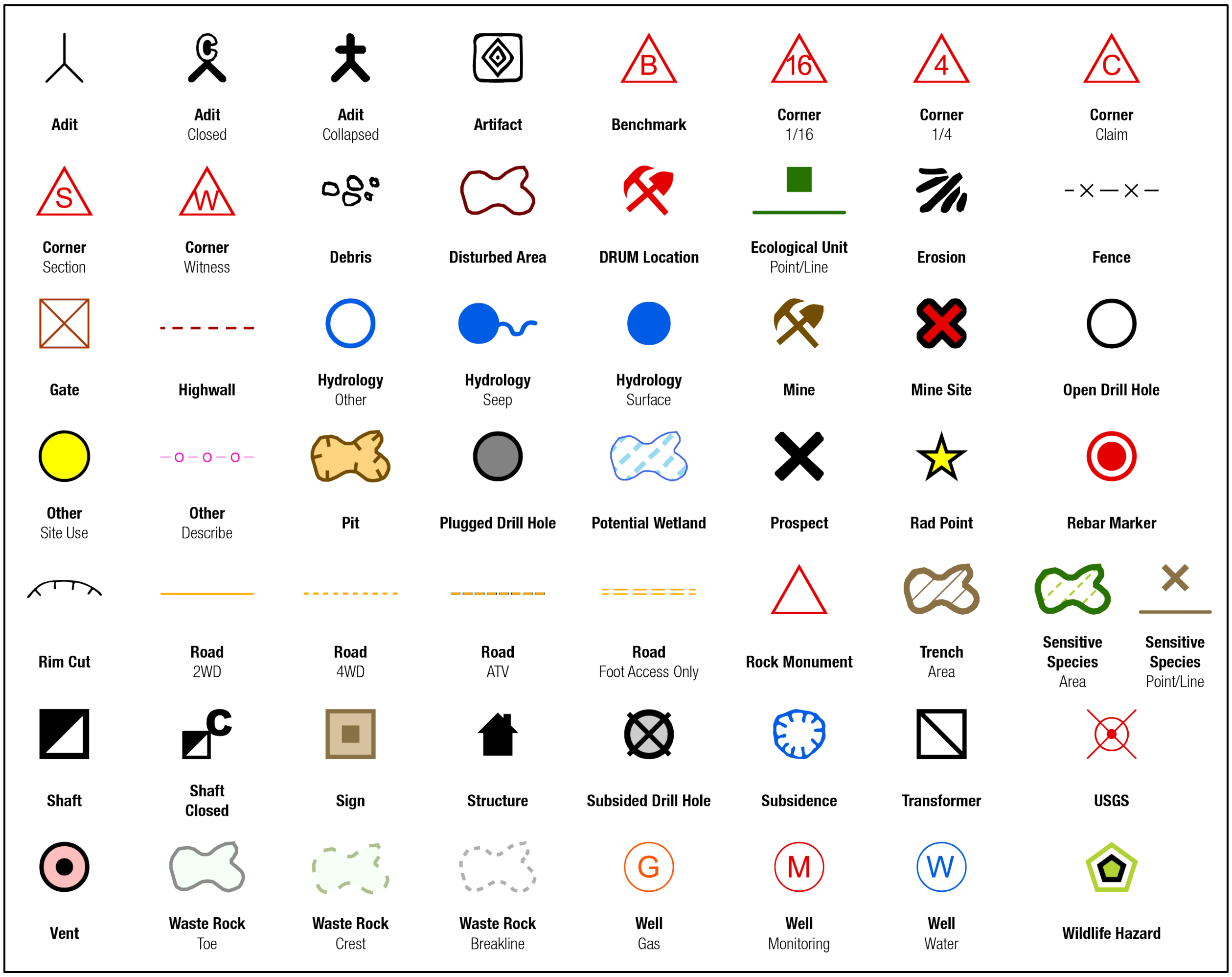


Figure F2. GIS Style for Typical DRUM Program Mine Features

F3.0 Inventory and Environmental Sampling Checklists and Data Transfer Requirements

F3.1 Inventory Features

Inventory of mine features may be completed by partner agencies or LM. Regardless of the entity collecting the data, the information contained in the following checklist will be obtained during the inventory.

The list of information to be collected is comprehensive, and most of the items are essential to the subsequent environmental sampling task and RSA. However, a few items, such as the location of fences, wells, tanks, and utility drops, are noted for future use by land management agencies. To be useful for the purposes of the DRUM Program, latitude and longitude must be collected with a differential GPS unit that has sub-meter accuracy using North American Datum of 1983 (NAD 83) as a datum in the appropriate Universal Transverse Mercator (UTM) zone's projected coordinate system.

Checklist of information to be collected by the field team:

- ☐ Artifacts
- ☐ Debris
- ☐ Drill holes
- ☐ Erosion line features
- ☐ Fences
- ☐ Gates
- ☐ Highwalls
- ☐ Horizontal openings (adits)
- ☐ Hydrology
- ☐ Mine access information
- ☐ Mine site location
- ☐ Mine visitation
- ☐ Ore
- ☐ Other pertinent mine-specific data
- ☐ Perimeter of waste rock pile(s), including toe, crest, and sample area
- ☐ Pits and trenches (declines noted)
- ☐ Ponds
- ☐ Prospects
- ☐ Rim cuts
- ☐ Roads
- ☐ Sediment shed areas
- ☐ Shallow excavations
- ☐ Signs
- ☐ Site use
- ☐ Structures
- ☐ Subsidences
- ☐ Suitable camping area(s)
- ☐ Survey monuments
- ☐ Tanks
- ☐ Total disturbed area perimeter
- ☐ Trash
- ☐ Utility
- ☐ Vents
- ☐ Vertical openings (shafts)
- ☐ Wells

F3.2 Data Transfer Requirements

In many instances, state and federal partners will collect and provide inventory data to LM. To accommodate large quantities of data, a standard file structure has been established so that the information received is most useful to all parties. Partner agencies are encouraged to utilize the following formats when transferring data to their respective file transfer sites at: https://eft.lm.doe.gov.

F3.2.1 GPS Data

GPS data posted to the EFT site will use a standard file structure and include a brief metadata description.

The data creator will:

[1] Create folder structure on the creator's own network and include:

  [a] Agency name and data collection date.

  [b] Metadata spreadsheet.

[2] Present metadata on a simple spreadsheet summarizing the information provided including:

  [a] Data collection dates.

  [b] Organization providing data.

  [c] Name of mine.

  [d] Description of data collected.

  [e] List of data files collected.

[3] Save data:

  [a] Save the data files to the corresponding folder created above

[4] Save metadata.xlsx file (multiple mines can be included in one metadata spreadsheet).

[5] Transfer data:

  [a] Zip the folders into a compressed file

    [i] One zipped folder will contain all the data being transferred on that date (i.e., multiple mines in one zip not a separate zip for each mine)

  [b] Name zipped file: Agency _YYYYMMDD_ description

  [c] Upload the compressed (zipped) folder to the appropriate agency-specific EFT site

  [d] Notify DOE that the data have been transferred

F3.2.2 Digital Images

Digital photos will consist of JPEG images. Photos will be organized in folders that incorporate the mine name. Documentation will include the following as metadata embedded in the image or as a descriptor submitted with a corresponding image:

- Mine name or LM ID number
- Date and time of photo (embedded in photo if using geotagging)
- Photo location (latitude and longitude; embedded in photo if using geotagging)
- Zip the images into a compressed file; may need to have one zip file per mine or multiple mines together depending on size and number of photos and time to upload
- Preferred naming convention is: YYYYMMDD_ description_aspect
- Notify DOE that the data have been transferred

Example GPS Metadata Sheet

Metadata	
GPSDataTransfer YYYYMMDD_ description_aspect	
Data Collection Start Date:	
Data Collection End Date:	
Originator:	*Name of the person, company, or agency (or more than one of these) that collected the data*
Description:	*General information and description of data collection activities*
Mining District:	*Mining district or area name*
Mines:	*List of mines included in the data collection activities*
List of Data Files	**Data File Description**
	Include the names of all mines in the data file

Example Photo Metadata Sheet

Metadata	
Photos YYYYMMDD_ description_aspect	
Data Collection Start Date:	
Data Collection End Date:	
Originator:	*Name of the person, company, or agency (or more than one of these) that collected the data*
Description:	*General information and description of data collection activities*
Mining District:	
Mines:	*List of mines for all photos included*

F3.3 Environmental Sampling Features

Environmental sampling activities will be completed by LM following the receipt of the data collected by the field team. The list of information to be collected is comprehensive; however, not all information will necessarily be collected at each mine visited as not all of these resources exist at every mine. When possible, existing information regarding paleontological resources, cultural resources, ecological units, special-status species, and other environmental resources will be obtained from the local land management agency and verified on a mine-specific basis. To be useful for the purposes of the DRUM Program, latitude and longitude must be collected with a differential GPS unit that has sub-meter accuracy using NAD 83 as a datum in the appropriate UTM zone's projected coordinate system.

Checklist of information to be collected by the field team during environmental sampling:

- ☐ Cultural resources
- ☐ Ecological units
- ☐ Evidence of wildlife
- ☐ Features that could entrap wildlife
- ☐ Hydrologic features
- ☐ Other pertinent mine-specific data
- ☐ Paleontological resources (fossils)
- ☐ Potential wetlands
- ☐ Radiation data
- ☐ Reclaimed features
- ☐ Soil sampling
- ☐ Special-status species or habitat
- ☐ Surface water
- ☐ Vegetation on waste rock piles

To assist in ensuring that all necessary information is collected and recorded at each mine sampled, QA/QC documents geared toward accounting for collection of the specific data points described above will be loaded onto field computers. An example of the *DRUM Verification and Validation Work Plan Process (QA/QC)* (Process Form) is attached to this appendix and described in Section 9.0 of the V&V Work Plan. The Process Form, or an equivalent form stored in an online LMS database, acts as a QC point as it will prompt validation that data collection was completed as described in the V&V Work Plan.

The Process Form, or an equivalent form stored in an online LMS database, and other data prompts will be reviewed before initiating sampling to ensure that the scope of work to be completed is identified before the beginning of work. The Process Form will require positive responses from team members and signatures from the team lead in the field to ensure that all data appropriate to the mine sampled have been collected and recorded before demobilization from the site. Additional positive responses from the field team and signatures from the team lead are required after sample shipment and data processing completion. To complete the Process Form positive responses are required from line management and report staff.

F3.4 Typical Features and GPS Data Collection Method

This section describes some of the features which may be collected at a mine. This section also contains a brief description of each feature, including whether the feature is to be collected as a point, area, and so on.

F3.4.1 Artifact

"Artifact" is a category for historical, cultural, or archeological features. An artifact is defined as an object made by a human being, typically an item of cultural or historical interest. Artifacts may be protected under NHPA.

F3.4.1.1 Artifact Collection

If an artifact is found, the location will be collected using the handheld GPS unit, photographs will be obtained, and the item will be described.

F3.4.2 Cultural Resource

A cultural resource may be defined as the physical evidence or place of past human activity (e.g., site, object, landscape, structure) or a site, structure, landscape, object, or natural feature of significance to a group of people traditionally associated with it.

Elements associated with previous mining activities may have historical or cultural value. These will be described and noted in the field but will not be handled or moved. Such elements may include trash piles, mining equipment, sweat lodges, grave sites, miner or Native American camps, arrowheads, tools, and vehicles. The individual element or collective grouping of these materials may be protected under NHPA, and it is illegal to remove, pick up, or relocate any items with historical or cultural value.

F3.4.2.1 Cultural Resource Collection

When cultural resources are encountered in the field, the perimeter of the area will be collected as a polygon feature, and single resources will be collected as points.

F3.4.3 Debris

Most mines associated with AEC production may have material associated with past mining activities which often remains onsite. Material can vary from steel cans to abandoned mining equipment. Some debris may be protected under NHPA.

F3.4.3.1 Debris Collection

Debris will be collected as a point feature with the type of debris and a description associated with the material. Significant materials and concentrated areas of small debris will be cataloged. Personnel shall exercise caution when inspecting debris; typical hazards include rusty nails, sharp edges, and animal habitation.

F3.4.4 Disturbed Area

The disturbed area is the portion of the ground surface that is impacted by mechanical mining-related activities.

F3.4.4.1 Disturbed Area Collection

The disturbed area will be located using the handheld GPS unit as a polygon to include all of the mine-related features (e.g., pad, portal, waste rock pile). Measuring the disturbed area requires traversing the entire mine, which introduces the potential to encounter all the hazards related to other features. Slips, trips, falling materials, hazardous mine entries, structures, and debris all present safety hazards that will be identified and mitigated during the course of work.

F3.4.5 Drill Holes

During the exploration phase of mine development, surface drilling may have been undertaken to define the extent of subsurface mineralization. Drill holes will cluster in areas around good mineralization and may be used in the field to define the potential extent of a mined area. A drill hole typically consists of a 3-inch diameter steel pipe (standpipe) or a concrete or asbestos collar.

F3.4.5.1 Drill Hole Collection

A single drill hole location is recorded with a handheld GPS unit using a point feature. The point is used to define whether there are multiple drill holes present. Each individual drill hole is not mapped. Caution will be exercised around drill holes. Runoff may have eroded around the collar and affected the stability of adjacent ground. Runoff may also erode the material around the drill hole, creating cavities just beneath the surface leading to unstable conditions.

F3.4.6 Ecological Units

An ecological unit is a distinct vegetation community (e.g., rabbitbrush-dominated shrubland) within a larger vegetation type (e.g., salt desert scrub). Ecological units will be defined, mapped, and characterized during V&V fieldwork. Prefield data will assist in the collection of field data.

F3.4.6.1 Ecological Unit Collection

During the V&V fieldwork, a representative point within each ecological unit will be collected as a point feature, and a brief description of the unit will be entered as text. The successional status of the unit will be noted. Within each unit, a list of dominant species and secondary species will be recorded using the botanical name or its Natural Resources Conservation Service standardized code.

One of six cover classes will be entered for each dominant or secondary species found. Trace species will be recorded as time allows. Trace species will be noted if there is a unique feature about them (e.g., noxious weed, only present on the waste rock pile, not typical of the area). When mapping representative points of ecological units and performing extended species evaluations, personnel will exercise caution to avoid mine hazards and prevent slips, trips, and falls.

F3.4.7 Erosion Line Feature

Drainages, rills, gullies, or general linear erosion features related to a mine are collected under an erosion line feature.

F3.4.7.1 Erosion Collection

Drainages and similar features will be located using the handheld GPS unit as line features. All pertinent attributes will also be collected. When walking in or around drainages, field personnel will evaluate surficial stability and the potential for slip, trips, and falls and consider engulfment hazards.

F3.4.8 Erosion Point Feature

An erosion point is a localized erosion feature (e.g., sheet wash, soil piping, wind erosion, or slope instability) that does not warrant a line or area feature. It can also be used to map linear features (e.g., rills, gullies) that are not safely accessible or are better represented as points.

F3.4.8.1 Erosion Collection

If an erosion point is identified, the feature will be located using the handheld GPS unit, described, and photographed. When approaching erosion features, surficial stability and the potential for slip, trips, and falls will be analyzed.

F3.4.9 Evidence of Wildlife

Evidence of wildlife (e.g., bones, scat, burrowing, nesting, roosting) will be recorded, particularly evidence of game animals, migratory birds, and other birds of prey, which are protected by law. Birds of prey such as hawks, owls, vultures, and eagles have sharp talons and strongly curved beaks. Birds of prey typically nest high in cliffs, trees, and utility poles or structures. Evidence of wildlife inhabiting waste rock piles will be recorded.

F3.4.9.1 Evidence of Wildlife Collection

Personnel will collect evidence of wildlife using primarily point features. If raptors or their nests are encountered in the field, a point feature will be collected below the perch or nest. Offsets will be established and noted when appropriate.

F3.4.10 Fence

When a fence is in a mining area or near a mine (e.g., private ownership boundary), the feature will be located using the handheld GPS unit as a line feature for future reference.

F3.4.10.1 Fence Collection

If a fence is encountered, field personnel will use a GPS unit to locate the fence line to a reasonable extent, as defined by the field team lead.

F3.4.11 Gate

Gates are typically used to control access across property boundaries and are important for future work at a mine.

F3.4.11.1 Gate Collection

If a gate is present, the location will be collected using the handheld GPS unit. The condition will be documented and the gate feature photographed.

F3.4.12 Highwall

A highwall is an excavated, nearly vertical slope constructed to facilitate mining operations. It is not a natural feature. During mining operations, overburden material may be excavated to create a pad area or expose mineralized material. The remnant, nearly vertical slope created by this excavation is called a highwall.

F3.4.12.1 Highwall Collection

If a highwall is encountered, the crest or toe will be located using the handheld GPS unit as a line feature to the extent they are safely accessible. Highwalls present numerous hazards, including falls from steep slopes, falling overhead debris, tripping hazards, and surficial instability. When collecting a highwall feature, field personnel will use an offset to avoid walking near the edge and toe. If surface cracking is present, personnel will immediately move to stable ground before continuing the survey.

F3.4.13 Horizontal Openings (Adits and Portals)

An adit is a mine opening greater than 10 ft deep driven horizontally for the purpose of providing access to a mineral deposit. A portal is a surface entrance to an adit.

An adit that is inaccessible because a safeguard has been installed or a collapse has occurred will be represented with specific symbols, as described above. Safeguards are engineered structures, such as grates, closures with backfill, or bulkheads designed and constructed to prohibit human ingress into a mine. Collapses are natural failures of the mine back or adjacent slope that cause the adit to be obstructed by debris.

F3.4.14 Hydrology

Hydrology features include springs and seeps, streams, and water-filled shafts and adits. Some of these features may have been used by the mining operation or may be influenced by mining activities. Personnel will note surface water and groundwater resources (e.g., ponds, drainages, seeps, water-filled shafts or adits). Evidence of draining adits, shafts, or engineered mine safeguards will be noted as well.

F3.4.14.1 Hydrology Collection

The type of hydrology feature will be collected using the GPS unit along with the estimated flow and a description of the nature of the feature. Hydrology hazards are gauged according to the potential to be immersed in a feature such as a pond, stream, or water-filled shaft or adit. Drowning hazards must be identified and mitigated before working around hydrology features.

F3.4.15 Ore Collection

Features that meet the definition of material that appears to be ore will be located using the handheld GPS unit and recorded as field note feature polygons. Slips, trips, and falls are a hazard while surveying any mine. Field personnel will observe the area being surveyed and navigate around any such hazards. Field crews will be cognizant of gamma radiation exposure and dose rates while working on or near suspected ore stockpiles.

F3.5 Other Information

To assist with potential risk assessment activities, the team will note nearby residences and other potentially habitable structures, towns, recreational facilities (e.g., campgrounds, trailheads), streams, and lakes within 2 miles of the mine.

F3.5.1 Paleontological Resources (Fossils)

Paleontological resources are any fossilized remains, imprints, or traces of organisms preserved in sedimentary rock. Paleontological resources are important for understanding past environments, environmental change, and the evolution of life. These resources will not be disturbed.

F3.5.1.1 Paleontological Resources (Fossils) Collection

If paleontological resources are encountered in the field, the perimeter of the area will be collected as a polygon feature. Individual features will be collected as point features. When possible, existing information from the land management agency will be assessed to determine the degree to which these resources are known by the public, as these may be an attraction to recreationists.

F3.5.2 Pits and Trenches

Pits and trenches were used frequently in historical mining where the ore was shallow and easily accessible or where overburden could be easily removed.

F3.5.2.1 Pit and Trench Collection

Personnel will collect the extent of the pits and trenches as area features. If the trench is associated with an adit, the trench will be collected separately. Decline trenches (sloping, three-sided [two sides and a floor] excavations trending from ground surface elevation to subgrade mine entrances) is a subset of trenches. Personnel shall exercise caution when approaching these features; the side-slopes are usually steep and unstable, presenting an engulfment hazard. Wildlife might use these areas as refuge.

Pits containing highwalls will be mapped as more than one separate feature. In each case, the crest of the pit (circumference) will be considered the pit feature boundary. Highwalls considered to be associated with the pit will be fully contained within the pit area. Dimensions for each feature will be recorded in GIS and in the team lead narrative. Photos will be collected and named for each feature. For pits containing highwalls, the hazard ranking will be based on the highwall. For pits not containing highwalls, the hazard ranking will be based on the pit itself.

F3.5.3 Pond

A pond is any feature constructed to collect water for agricultural or livestock uses or to contain stormwater runoff.

F3.5.3.1 Pond Collection

When a pond is encountered in the field, the perimeter will be located using the handheld GPS unit as a polygon feature. Before a pond feature can be surveyed, field personnel will assess the potential for drowning, slipping, tripping, and falling and for slope instability around the body of water.

F3.5.4 Potential Wetland

The U.S. Army Corps of Engineers defines wetlands as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (USACE 1987). Riparian areas are also associated with higher amounts of available water than surrounding areas and frequently occur along the margins of streams and water bodies. Potential wetlands include both wetlands and riparian areas which differ substantially from the surrounding ecology. When possible, existing information from the land management agency or USFWS will be assessed and verified on a site-specific basis.

F3.5.4.1 Potential Wetland Collection

The perimeter of a potential wetland will normally be collected as a polygon, but a line may be used for large features that continue outside the area of interest. When mapping the boundary of potential wetlands, personnel will use caution to avoid injuries from slope instability and from slips, trips, or falls. If surface water is present, the potential for drowning or encountering animal habitation must be recognized and addressed.

F3.5.5 Prospect

A prospect is an excavation related to mineral exploration activities with a depth between 4 and 10 ft from the surface vertically or horizontally into the underground. Similar in nature to an adit or shaft, a prospect is developed during exploration activities and subsequently abandoned before a mine is substantially developed. Prospects are considered a low hazard.

F3.5.5.1 Prospect Collection

The team will collect prospects as a point feature with all applicable attributes. Dimensions will be collected at the prospect, and the condition will be documented. The team will look for, and record if present, any unique identification number (e.g., tag or brass cap number utilized by the partner or state agency). Such markers are usually near the prospect. If a safeguard has been put in place that prevents human ingress to the subsurface, the feature is considered closed and will be recorded as such. Field crews will perform a cursory assessment of the integrity of mine safeguards and record their observations regarding the functionality of the safeguard. Hazards associated with prospects are similar to those presented by portals, shafts, and open excavations.

Personnel shall exercise caution when approaching a prospect, as it can present several hazards, including an unstable brow and slopes, unstable surrounding ground, snakes, rusty nails, and tripping hazards.

F3.5.6 Reclaimed Feature

In non-CERCLA actions, reclaimed features include waste rock or other portions of the mine, such as roads or ponds, that may have been recontoured or graded to a stable condition. The primary purpose of these actions is to minimize the potential for future erosion and make features blend with the original site topography. This may include covering the site with enough topsoil to enhance revegetation.

F3.5.6.1 Reclaimed Collection

Personnel will collect all features that appear to have been reclaimed. Hazards associated with reclaimed features are typically subsidence and slips, trips, and falls.

F3.5.7 Remediated Feature

Remediated features are mine features that, in CERCLA actions, have been the subject of response actions taken or Action Memoranda signed to mitigate the release or potential release of a CERCLA hazardous substance. The primary purpose of these actions is to mitigate potential risks to human health and the environment. Such features include consolidation areas or repositories.

F3.5.7.1 Remediated Collection

Personnel will collect all features that appear to have been remediated. Hazards associated with remediated features are typically subsidence and slips, trips, and falls.

F3.5.8 Rim Cut

Rim cuts are broad, relatively shallow excavations into an outcrop. Rim cuts are classified as underground openings, although they are generally wider than they are deep.

F3.5.8.1 Rim Cut Collection

The team will collect rim cuts as point features with all applicable attributes. Dimension measurements will be collected at the exterior of the rim cut, and the condition will be documented. The team will look for, and record if present, any unique identification number, (e.g., tag or brass cap number utilized by a partner or state agency). Such markers are usually near the feature. If an engineered safeguard such as a closure with backfill has been put in place that prevents human ingress, the feature is considered closed and will be recorded as such. Field crews will perform a cursory assessment of the integrity of the safeguard and record their observations regarding its functionality. Personnel shall exercise caution when approaching a rim cut, as it can present several hazards, including an unstable brow and slopes, snakes, bats, rusty nails, and tripping hazards. Personnel shall not enter under a rim cut overhang, work around unsupported ground, or step close to steep or unstable slopes.

F3.5.9 Roads

Roads may vary from improved dirt access to two-wheel tracks. These will be recorded to evaluate the ease of access to a mine. Road access from the mine to the closest maintained road will be evaluated once the most efficient way to exit has been established.

F3.5.9.1 Road Collection

The condition of the road and the ease of access will be noted. The condition of the road will be assessed to help evaluate mine accessibility attributes.

F3.5.10 Sensitive Species

Sensitive species include federally listed threatened or endangered species and special-status species designated by an agency such as BLM, USFS, states, or tribes. When possible, existing information from the relevant land management agency will be assessed and verified on a site-specific basis. Ecologists will collect evidence of the presence of sensitive species (e.g., tracks, burrows, scat, or observations of the species itself). Ecologists will also collect evidence of potential habitat for sensitive species (e.g., slopes with the proper aspect and soil type, structures that could provide bat habitat, seeps or springs). Plant samples may be collected in the field. However, suspected threatened or endangered species will not be collected, and suspected sensitive species will be collected nondestructively (i.e., remove as little of the plant as possible and do not disturb the root system). Any evidence of the presence of special-status plant or animal species will be photographed if possible.

F3.5.10.1 Sensitive Species Collection

Evidence of sensitive species or habitat will be collected as a point, line, or polygon.

F3.5.11 Shallow Excavation

A shallow excavation is a horizontal or vertical excavation less than 4 ft deep which is associated with mining activities. The field team will note the location, size, and depth of shallow excavations.

F3.5.12 Sign

A sign is a feature near or at a mine that has posted information pertaining to the mine (e.g., ownership, warning) or features near the mine.

F3.5.12.1 Sign Collection

Any signs present will be located by handheld GPS unit, described, and photographed.

F3.5.13 Site Use

When evidence of public recreation is discovered in or near a mine, a description of the type of use will be necessary for future reference. Evidence of site use includes fire rings, tent stakes, and vehicle tracks. The feature “Site Use Other” is captured as a point feature and is utilized to identify evidence of recent use of a mine by the public when such evidence does not fall into the predefined categories of fire rings, tent stakes, and vehicle tracks. Examples may include spent bullet casings or shotgun shells, recent footprints, water bottles, or miscellaneous equipment or tools observed onsite.

F3.5.13.1 Site Use Collection

When a site use feature is identified, the point will be located using the handheld GPS unit, described, and photographed. When approaching a recreation-related feature, field personnel will note any physical hazards present (misfired ammunition, unburied feces, or evidence of illegal activities). If evidence of illegal activities is found, the team will immediately leave the area and contact local law enforcement.

F3.5.14 Structures

Structures, from outhouses to headframes, may be present at a mine to support the mining operation. In an area where an inhabited structure existed, cisterns are common. Structures will be evaluated for general integrity with instability noted. If underground workings are present regardless of intended use (e.g., a powder magazine), they shall be mapped as horizontal openings (see Section F3.4.13 above).

F3.5.14.1 Structure Collection

The team will survey any structure found at a mine as a point feature. Photographs and horizontal dimensions will be collected and vertical dimensions estimated. The materials used for construction (e.g., wood, tar paper, stone) will be noted. Personnel shall exercise caution when inspecting structures. Typical hazards include rusty nails in boards, instability of the structure (both the overhead and floor), exposure to hantavirus, and wildlife. Personnel shall not enter or climb on structures for any reason.

F3.5.15 Subsidence

Shallow underground mines and mines with weak overburden have a high potential of collapsing from within the mine to the ground surface. This phenomenon results in circular or stove-pipe like features at the ground surface. These collapses sometimes provide access to the mined interval.

F3.5.15.1 Subsidence Collection

A subsidence feature will be located by handheld GPS unit as a point feature with the dimensions and other attributes included in the point. If the subsidence is large, a generic area feature will be used to define the lateral extent of the subsidence.

Due to the subsurface mechanisms of subsidence, most subsidences will not be visible outside of their immediate area. The extent and direction of a subsidence feature is difficult to ascertain from the ground surface. Because these features represent surficial instability, personnel shall exercise extreme caution when approaching them. All measurements and observations will be made at a safe distance from these features. Extreme caution will be exercised above all underground mines and around all observed subsidences to prevent falls into these features.

F3.5.16 Tanks

Tanks once used to store water, air, fuel, or sewage may be present. Tanks may be found on the surface, on stilts, or buried underground.

F3.5.16.1 Tank Collection

Information collected will include an estimate of dimensions. Hazards specific to tanks include a hazardous internal atmosphere and contents that might be harmful to the environment. Personnel shall not enter tanks for any reason.

F3.5.17 Utility

Many larger mines contain older utilities (e.g., power and water drops, power poles, electrical panels) and may host modern utilities (e.g., gas lines, power lines) which may or may not be related to mining activities, but which will be recorded.

F3.5.17.1 Utility Collection

Personnel will use a point feature to capture the type and description of utilities at a mine. Hazards associated with electrical power include downed and live lines that are under load or energized through induction created by wind. Downed power lines will always be treated as live and will not be approached. If a downed line is observed, the appropriate land management agency will be notified.

F3.5.18 Vents

Many underground mines will have one or more associated ventilation shafts. Typically, the larger the mine, the more vent shafts it will have, and the larger the vents will be. Vents are typically remote from the production opening (portal or shaft).

F3.5.18.1 Vent Collection

To locate and identify vents, the team will note the general bearing of the underground workings and investigate the terrain in that direction. If power lines are near the mine, the team will visually trace them and identify termination poles, which may have powered the ventilation equipment, if possible. When a vent is located, personnel will measure dimensions, take photographs, and attempt to estimate the total depth. If the vent is cased, the team will note the casing material (e.g., stovepipe, oil barrels, continuously cased). The team will note whether there is equipment access to the vent or if a road has to be improved to facilitate safety closure construction. If an engineered safeguard has been put in place at the vent that prevents human ingress to the subsurface workings of a mine, the feature is considered closed and will be recorded as such. Field crews will perform a cursory assessment of the integrity of the mine safeguard and record their observations regarding its functionality.

The team will exercise caution when approaching vents; runoff may have eroded around the collar of the vent shaft and affected the stability of adjacent ground. It is common for vent shafts to erode out from beneath casing and grout, creating an unstable condition. Mine vents and portals may exhale subsurface atmosphere. This atmosphere may contain radon progeny in excess of recommended working conditions. Generally, the radon-rich atmosphere dissipates quickly once exhaled to the outside environment. The field team will make dimensional measurements of exhaling mine features at a distance from the vents, shafts, and adits to allow atmospheric mixing and dilution to occur.

F3.5.19 Vertical Openings (Shafts)

Shafts are vertical openings that that lead to an underground mine. They may be associated with support structures (headframes, ore bins, and hoists).

A shaft that is inaccessible because a safeguard has been installed or because of a collapse will be described with specific symbols, as described in Figure F2. Safety closures are permanent engineered structures and include grates, closures with backfill, or panels designed and constructed to prohibit human ingress into a mine. Collapses are natural failures of the side walls that cause the shaft to be obstructed by debris.

F3.5.19.1 Shaft Collection

Shafts will be assessed visually to estimate the size of the opening and determine if the surrounding ground, referred to as the collar, is stable. If the collar is not considered stable, the team will not get close enough to make a measurement. The location will be surveyed, and an offset established to account for the correct feature location when the point is differentially collected. If the area is considered stable (e.g., competent rock), dimensions will be measured. The condition of the shaft (e.g., closed, caved, open, partially open, subsided) will be noted by the field team. If an engineered safeguard has been constructed to prevent human ingress to the subsurface, the feature is considered closed and will be recorded as such. Field crews will perform a cursory assessment of the integrity of the mine safeguard and record their observations regarding its functionality.

Shafts present severe ground collapse and fall hazards. Shafts may be undermined or in the process of collapsing. Therefore, the surrounding ground surface will be carefully evaluated and treated with caution. The condition of the surrounding ground must be carefully assessed to ascertain its stability before approaching a shaft. The team will not approach a shaft if there is any question regarding adjacent ground stability. Personnel will never stand on a shaft closure.

F3.5.20 Waste Rock Piles

Waste rock may contain COIs and may exhibit elevated gamma radiation and thus will be sampled. Waste rock piles comprise subeconomic materials closely associated with a uranium or vanadium orebody which were discarded due to their lack of value. Some mining operations removed materials from several openings and dumped all the material in the same area, creating massive, combined waste rock piles. Some waste rock piles are near or truncated by natural drainages and steep slopes, and material may have eroded from the piles and been deposited downstream.

F3.5.20.1 Waste Rock Pile Collection

The footprint of waste rock piles will be mapped by taking GPS measurements around the outside perimeter and along the crest where accessible. If the waste rock pile is tiered or steep, GPS measurements on each tier or grade break will be collected along with the crest and toe of each waste rock pile to later estimate the volume of material. In all cases, the portion of a waste rock pile that will be sampled will be mapped using the handheld GPS unit. Representative photographs of the area around the waste rock pile will be taken to depict the overall waste rock pile, sample area, slope grade, and existing vegetation. Personnel will exercise extreme caution when traversing waste rock piles as the piles may be constructed of inherently unstable materials, presenting slip and trip hazards. Waste rock piles may have steep grades, may be inhabited by wildlife (e.g., snakes and burrowing animals), and may contain trash and other debris that pose slipping, tripping, or puncture hazards.

If one area of a waste rock pile contains significantly elevated radioactivity (e.g., two to three times higher than adjacent areas) and has anomalous visual indicators (e.g., coloration differences), it is possible that it is an ore storage area. Such observations will be noted and the area mapped and photographed, as described above.

F3.5.21 Well

Although most of the water consumed by mining activities in the southwestern United States was transported to the mine from sources in other areas, wells might be present at the mine.

F3.5.21.1 Well Collection

If wells are present, they will be located by handheld GPS unit. The location and their condition will be photographed and documented.

F3.5.22 Wildlife Entrapment Features

Features that may entrap wildlife include those that are also hazardous to humans, such as subsidence features or unstable structures. Wildlife entrapment hazards may include large features, such as subsidences and hazardous structures, as well as features that could entrap birds or small animals (e.g., dense coils of wire, open drill holes or vents [2–18 inches in diameter], or small structures from which an animal could not escape).

F3.5.22.1 Wildlife Entrapment Features Collection

A wildlife entrapment hazard may be collected as a point, line, or polygon as appropriate for the specific hazard.

RSI ENTECH
In Partnership with Amentum and TFE
United for the Legacy Management Mission

DRUM Verification and Validation Work Plan Process (QA/QC)

This worksheet is implemented to document performance of quality assurance/quality control (QA/QC) checks for V&V Work Plan processes. It includes a defined method to capture, document, and provide accountability and assurance that appropriate QA/QC checks have been made and completed as required in accordance with the *Defense-Related Uranium Mines Quality Assurance Program Plan* and the V&V Work Plan.

Reconciliation Process

Mine Information

LM ID: Click to enter Mine name: Click to enter State: Click to enter

County: Click to enter District: Click to enter Locality: Click to enter

Township: Click to enter Range: Click to enter Section: Click to enter Quarters: Click to enter

Reconciled latitude: Click to enter Reconciled longitude: Click to enter

Land ownership: Click to enter Mine Status: Choose an item

Verify the following:

- Reconciliation process completed, including QA/QC
- Location information updated and loaded into DRUM database; data entry reviewed
- DRUM database coordinates confirmed in geographic information system (GIS)
- Complete an Issuetrak work request for Environmental Quality Information System (EQuIS)/ Field Operations Plan (FOP)

Field Operations Plan

Verify the following:

- Unique project-specific expectations are identified and documented, along with known environmental compliance (EC) issues
- Details for data collection activities are included, as applicable
- Contact information verified; complete and current
- Location maps are current
- Mine list and mine identification, including land ownership or management status is accurate

I confirm that the reconciliation process and FOP has been developed as described in the V&V Work Plan, and if a deviation from the strategy was required, the rationale for such variation is well documented.

Reconciliation geologist:	Choose an item	Date:	Date
Reconciliation reviewer:	Choose an item	Date:	Date
FOP author:	Choose an item	Date:	Date
EC reviewer:	Choose an item	Date:	Date
FOP reviewer:	Choose an item	Date:	Date

Field Inventory

Appendix F, Mine-Related Features

The field team ecologist, geologist and team lead verify the following while in the field:

- Field-confirmed coordinates verified with reconciliation data; all secondary locations visited
- Total disturbed area and all observed mine features collected
- Photographs taken and suitable
- Ecological units described including evidence of special status species, critical habitat, or cultural resources, if observed
- Risk scoring assessment physical hazard evaluation and ecological/environmental risk evaluation complete

DRUM Verification and Validation Work Plan Process (QA/QC)

Environmental Sampling

Appendix D DRUM Radiological Measurement and Data Collection Work Instructions

The field team radiological control technician and team lead verify the following while in the field:

- Gamma radiation measurements were obtained at the same regional or mine-specific locations as background soil sample collection
- Field data QC check was made by importing the gamma radiation survey data and an aerial image of the mine onto a field computer
- Data was reviewed in the field to ensure that the gamma radiation survey adequately covers the extent of the area of interest
- The gamma radiation data displayed over the aerial image is sufficient to determine the extent of the gamma radiation survey, transect spacing, and evaluation of adjacent gamma radiation conditions
- Gamma radiation survey data, relevant mine features, and aerial image are saved for use in data validation (QC check)
- In the instance of an aerial image for a mine being unavailable due to variances in the reconciled location of a mine or other circumstances, ensure the necessary degree of gamma radiation survey data was collected at and adjacent to a mine

Environmental Sampling

Appendix C DRUM Soil and Sediment Sampling Procedure

Were soil samples taken at this site? ☐ Yes ☐ No If no, select rationale: Choose an item

The field team geologist and team lead verify the following while in the field:

- Personal protective equipment required by procedure was worn during sampling activities
- Soil sample areas did not contain any special-status species that could be disturbed by sampling
- Soil samples were taken at each background location
- Soil samples were taken at waste rock piles
- Soil samples were taken at sediment shed areas that exhibit elevated gamma radiation (>64 microroentgens per hour)
- Soil grab samples were taken at other areas of a mine that exhibit unique or special circumstances, or anomalous conditions
- Appropriate number of nodes per sample was collected and homogenized

Appendix H DRUM Surface Water Sampling Procedure

Were water samples taken at this site? ☐ Yes ☐ No If no, select rationale: Choose an item

The field team geologist and team lead verify the following while in the filed:

- Personal protective equipment required by the surface water sampling procedure was worn as prescribed
- Surface water samples were collected as mine site features dictate
- Surface water samples were preserved as required

Appendix H DRUM Surface Water Discharge Measurement

If a surface water sample was obtained, was a surface water discharge measurement made at this mine site? ☐ Yes ☐ No If no, select rationale: Choose an item

The field team geologist and team lead verify the following while in the field:

- Discharge measurement and other relevant information (location, date, and time) recorded on water sample form:

  I confirm that the field activity processes and quality checks defined in Appendix F, Mine Related Features; Appendix D DRUM Radiological Measurement and Data Collection Work Instructions; Appendix C DRUM Soil and Sediment Sampling Procedure, and Appendix H DRUM Surface Water Sampling Procedure were developed as described in the Work Plan, and if a variance from the strategy was required, the rationale for such variation is well documented by field notes prior to leaving the mine.

Field team ecologist: Choose an item Date: Date

Field team radiological control technician: Choose an item Date: Date

Field team geologist: Choose an item Date: Date

Field team lead: Choose an item Date: Date

DRUM Verification and Validation Work Plan (LMS/DRM/S13690)
LMS 4501 DRUM Page 2 of 4 March 2, 2022

DRUM Verification and Validation Work Plan Process (QA/QC)

Sample Shipment

The field team radiological control technician and team lead verify the following:

- Samples were correctly labeled and packaged for shipment
- Chain of custody information as verified and accompanied samples
- Radiological survey performed and a copy accompanied samples
- Authorization for shipment was received
- Shipping container was transferred to Shipping and Receiving

Were soil samples shipped to the lab? ☐ Yes Date: Date ☐ No

Were surface water samples shipped to the lab? ☐ Yes Date: Date ☐ No

Data Processing

Appendix G DRUM Program GPS Procedures

The field team ecologist, geologist and team lead verify the following:

- Upload data to DRUM geodatabase, GPS location data post processed as necessary
- Risk scoring assessment (physical hazard status, ecological or environmental, access and suitability and complexity and magnitude risk evaluation) updated
- Updated database reconciliation coordinate status to field-confirmed coordinates
- Mine township, range, section, quarter section, or land ownership affected by field-confirmed coordinates is updated in database
- GIS information is accurate
- Queries have been reviewed; all errors have been addressed
- Field data has been reviewed

Data Analysis

The data management manager verifies the following:

- Field data has been reviewed
- Analytical results have been reviewed
- Data QA/QC is complete

Line Management Review

Line management verifies the following:

- Mine table has been completed
- Risk scoring assessment complete
- GIS data verified
- Sample data received and validated

I confirm that the sample shipment process, GPS strategy, data analysis process, and verification and validation processes performed to this stage have been developed as described in the V&V Work Plan, QA/QC checks have been verified, the rationale for any variance is well documented, and data is available for report preparation.

Field team radiological control technician: Choose an item Date: Date

Field team geologist: Choose an item Date: Date

Field team lead: Choose an item Date: Date

Data Management manager: Choose an item Date: Date

Technical Manager: Choose an item Date: Date

Title: Enter title Name: Enter text Date: Date

Title: Enter title Name: Enter text Date: Date

DRUM Verification and Validation Work Plan (LMS/DRM/S13690)
LMS 4501 DRUM
Page 3 of 4
March 2, 2022

DRUM Verification and Validation Work Plan Process (QA/QC)

Mine Reports

The report writer (author), field team lead, technical reviewer and report manager verify the following:

- Complete database information retrieval
- Complete risk scoring assessment
- Draft mine report; complete internal review, QA/QC performed
- Mine report complete and all attachments are included
- Technical edit complete and resolved, document production complete
- Draft mine report submitted for LMS senior management review; internal review complete
- Draft mine report submitted for LM review and comment; comments resolved and incorporated
- Final mine report submitted to LM

I confirm that the final mine report has been developed as described in the V&V Work Plan and QA/QC checks are satisfactory.

Report writer (author):	Choose an item	Date:	Date
Technical reviewer:	Choose an item	Date:	Date
Report manager:	Choose an item	Date:	Date

Appendix G

DRUM Program GIS Procedures

Geospatial data collected as part of the DRUM Program are stored in an enterprise geodatabase (see the *Defense-Related Uranium Mines Data Management Plan* [DOE 2023a]). Applications such as ArcMap and ArcGIS Pro can view, load, and edit data in the geodatabase. This appendix presents the steps for recording mine features using the Uinta software and how to load data to the enterprise geodatabase using ArcMap. However, Uinta is not the only software capable of recording GIS data and exporting them in a format suitable to load into the enterprise geodatabase. For example, the Esri Field Maps application provides similar functionality, and before Uinta, the DRUM Program used Trimble, Inc.'s TerraSync software.

Although the procedure described in this appendix is based on the Uinta software, the main procedural steps are similar across different applications and include creating a template or outline for the data collection structure, importing any necessary data in the office (e.g., background imagery, ownership data, or third-party data), recording geospatial data in the field, exporting field-collected data to a compatible file format, and importing field data to the enterprise geodatabase. The DRUM Program will use Uinta or another field data collection software with similar capabilities. If the DRUM Program is required to switch software, this appendix and related sections of the V&V Work Plan will be updated as soon as is feasible.

G1.0 Creating a Template in Uinta

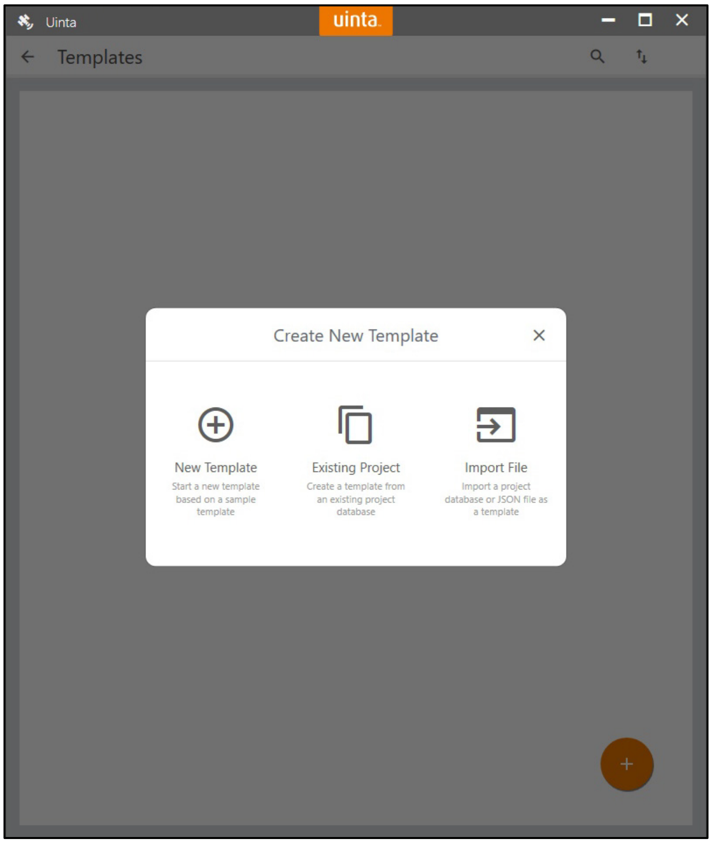
After the features and attributes that need to be documented in the geodatabase are defined, a template will be created for use in the field to facilitate mine data collection. Templates are used to control data collection and manipulation, establish conventions, ensure consistency, and improve quality. For more information about templates, refer to the Juniper Systems, Inc. support website titled, "Working with Uinta Project Templates."

G1.1 Start a Template (.json)

[1] Inside Uinta, click the triple bar button and then select **Templates**.

[2] Click the orange plus button on the bottom right and then select **New Template**.

[3] Choose the **Basic** sample template, give the template a name and description, and then click the check mark button to create the file.

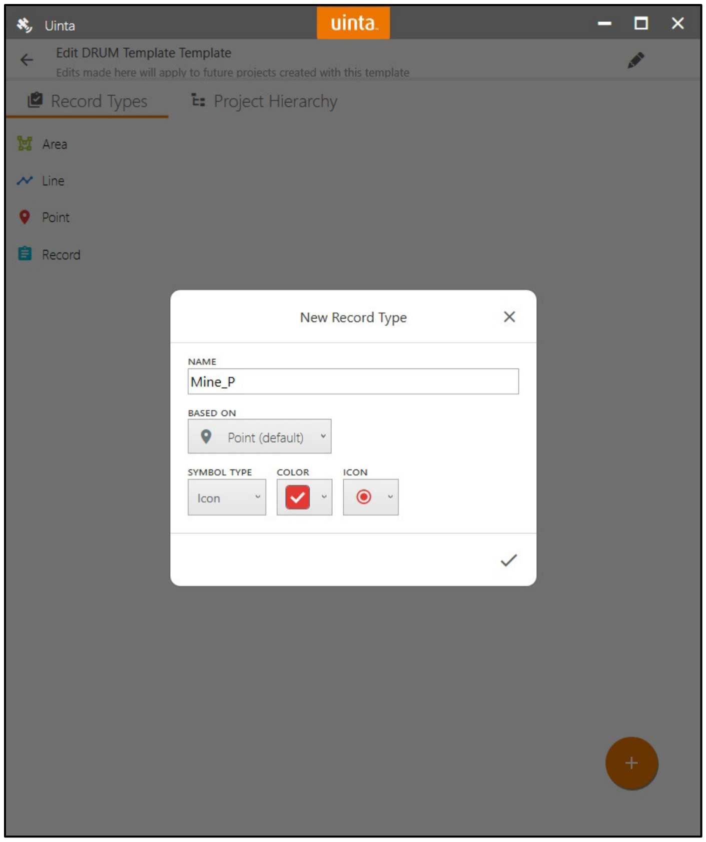


[4] The default sample records of **Area**, **Line**, **Point**, and **Record** can be deleted by selecting each one and then clicking the trash can button on the right.

G1.2 Create a Point Record (_P)

[1] Click the orange plus button.

[2] In the **Name** field, enter the first point feature name. This is the name that appears when collecting data in the field. The names of point features should have "_P" in the suffix to alert the GPS operator that the feature is a point feature.



[3] From the **Based On** dropdown menu, select **Point (default)**.

[4] The **Symbol Type**, **Color**, and **Icon** can be customized to easily distinguish features in the map view of Uinta.

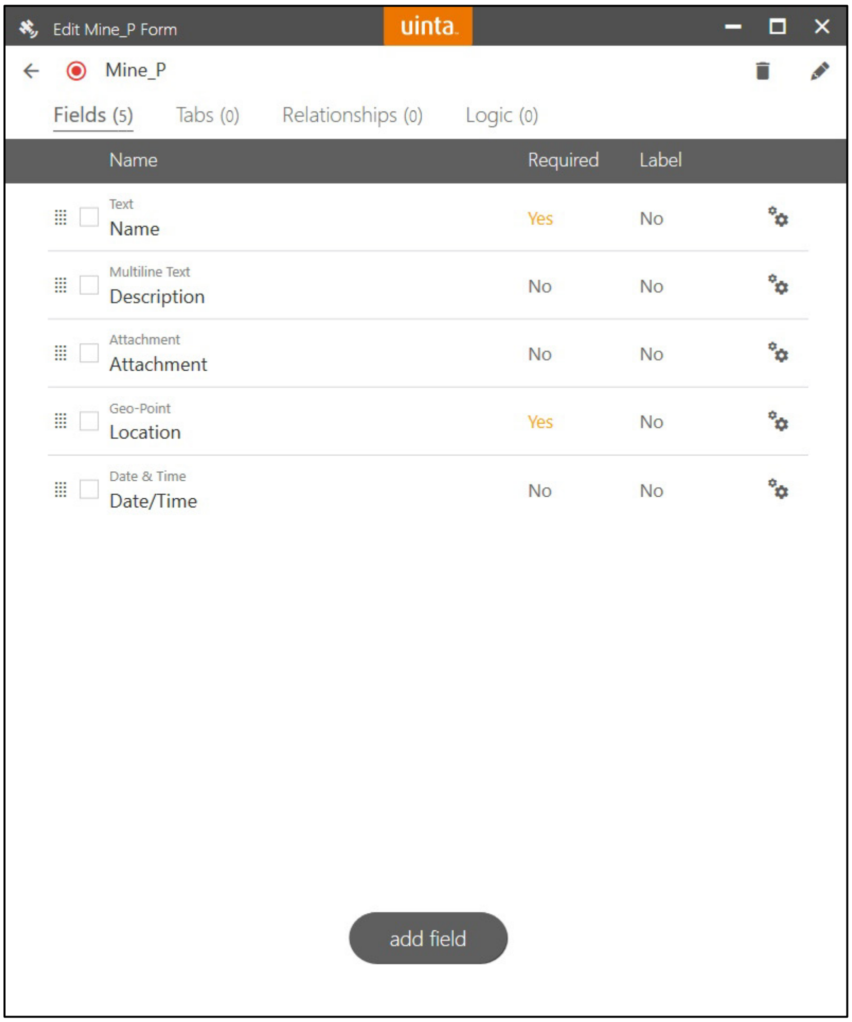
[5] Click the check mark button to complete.

G1.3 Create and Edit Fields

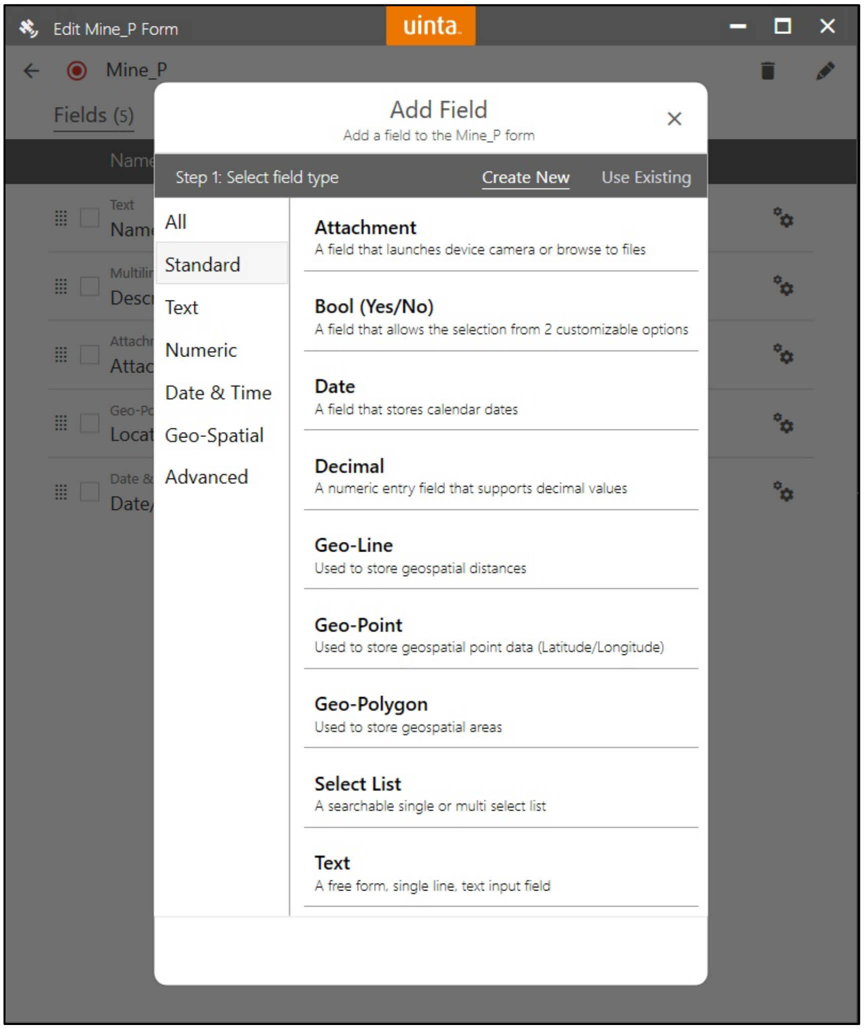
Once a record is created, fields can be added to quantify the record. A single field can be used for many records (e.g., LM ID and Mine_Name).

[1] Select the record to add attributes and then click the pencil  button on the right. The **Edit Record Form** dialog will appear.

[2] Click the **add field** button to create a new field.



[3] The **Add Field** dialog box appears:



[4] To edit a field, click the gear button to the right of the field name and then select **edit**.

G1.3.1 Select List Field

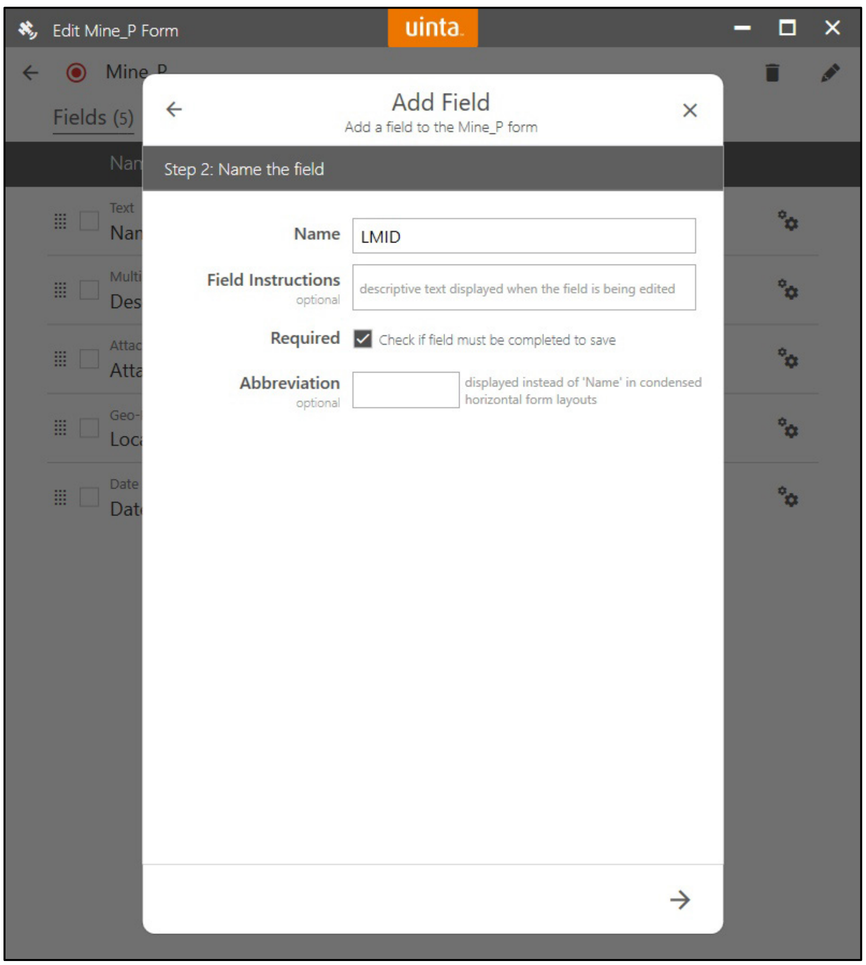
The **Select List** field is useful when the information being recorded is a defined set of options. This standardizes the entry of information and makes it easier to enter values in the field quickly.

[1] In the **Add Field** dialog box (see step [3] of Section G1.3), choose the **Standard** option from the left, choose **Select List**, and then click the right arrow button.

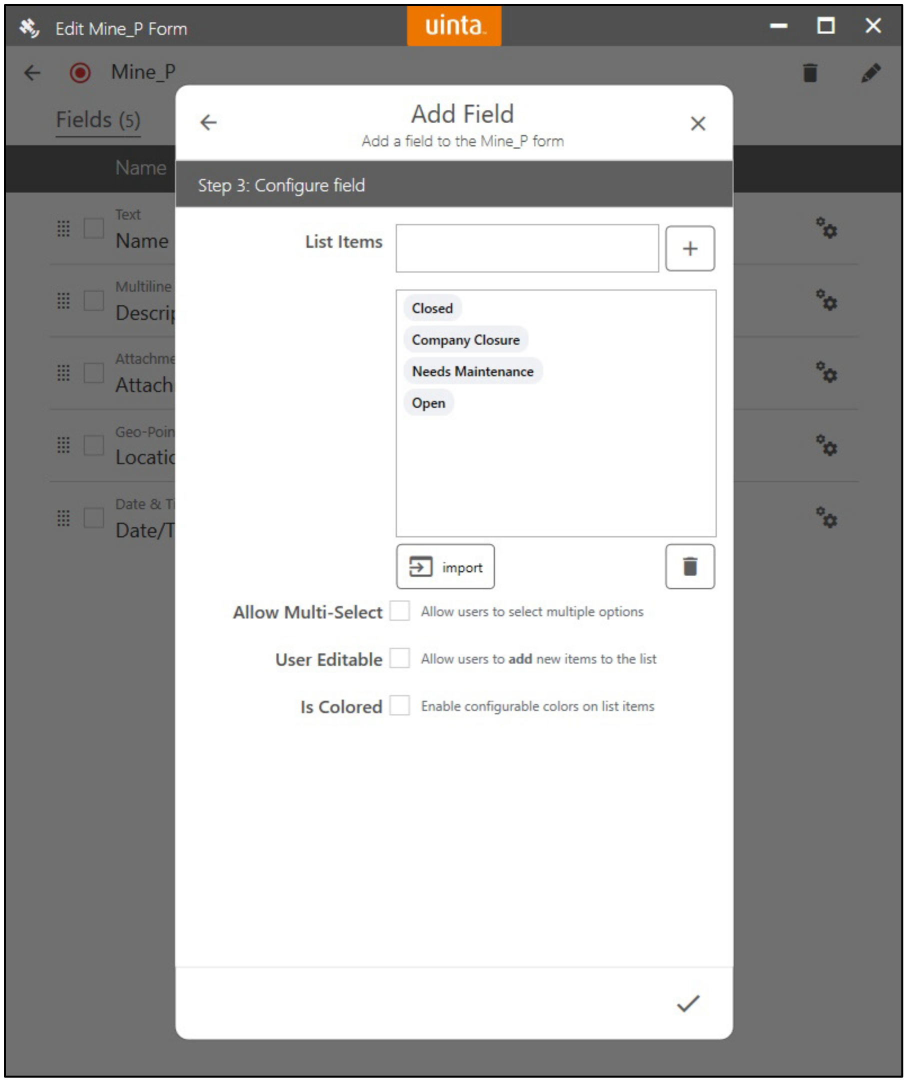
[2] Enter the *field name* next to **Name**. Any descriptive text can be entered in **Field Instructions**.

[3] If this field will be required for every record collected (usually the mine name and LM ID are required), then select the checkbox next to **Required**.

[4] Click the right arrow button.



[5] Next to **List Items**, enter the first field option and click the plus button. Continue to enter field options until all options are shown.



[6] Click the check mark button to return to the **Edit Record Form** dialog box. It should display the new field.

[7] Click the left arrow  button near the top left to close the **Edit Record Form** dialog box.

G1.3.2 Numeric Field

Use a numeric field to enter numeric attribute values while in the field. The minimum and maximum values help prevent incorrect entries, and a sensible default value can save time.

[1] In the **Add Field** dialog (see step [3] of Section G1.3), choose the **Numeric** option from the left then select **Number** for integer values. For decimal values instead, select **Decimal**.

[2] Click the right arrow button.

[3] Enter the *field name* next to **Name**. Any descriptive text can be entered in **Field Instructions**.

[4] If this field will be required for every record collected (usually mine name and LM ID are required) then select the checkbox next to **Required**.

[5] Click the right arrow button.

Optionally:

[6] Enter the *minimum and maximum values* then click the check mark button to return to the **Edit Record Form** dialog. It should display the new field.

[7] Click the left arrow button near the top left to close the **Edit Record Form** dialog.

Note *In the field, if a value outside the range defined by the minimum and maximum values is entered, an error message appears in the Uinta software, and the feature will not be allowed to close.*

G1.3.3 Text Field

Text fields are useful when the information to be stored varies for different occurrences of a record or when a defined select list is impractical. This attribute allows letters, numbers, and punctuation to be used for each field.

[1] In the **Add Field** dialog (see step [3] of Section G1.3), choose the **Standard** option from the left, choose **Text**, and then click the right arrow button.

[2] Enter the *field name* next to **Name**. Any descriptive text can be entered in **Field Instructions**.

[3] If this field will be required for every record collected (usually mine name and LM ID are required) then select the checkbox next to **Required**.

[4] Click the right arrow button.

[5] Optionally, a *default value* can be entered next to **Default Value**. Click the check mark button to return to the **Edit Record Form** dialog. It should display the new field.

[6] Click the left arrow button near the top left to close the **Edit Record Form** dialog.

G1.3.4 Date Field

When a feature is created, the current date is automatically entered in the **Date** field.

[1] In the **Add Field** dialog (see step [3] of Section G1.3), choose the **Standard** option from the left, choose the **Date** option, and then click the right arrow button.

[2] Enter the *field name* next to **Name**. Any descriptive text can be entered in **Field Instructions**.

[3] If this field will be required for every record collected (usually mine name and LM ID are required), then select the checkbox next to **Required**.

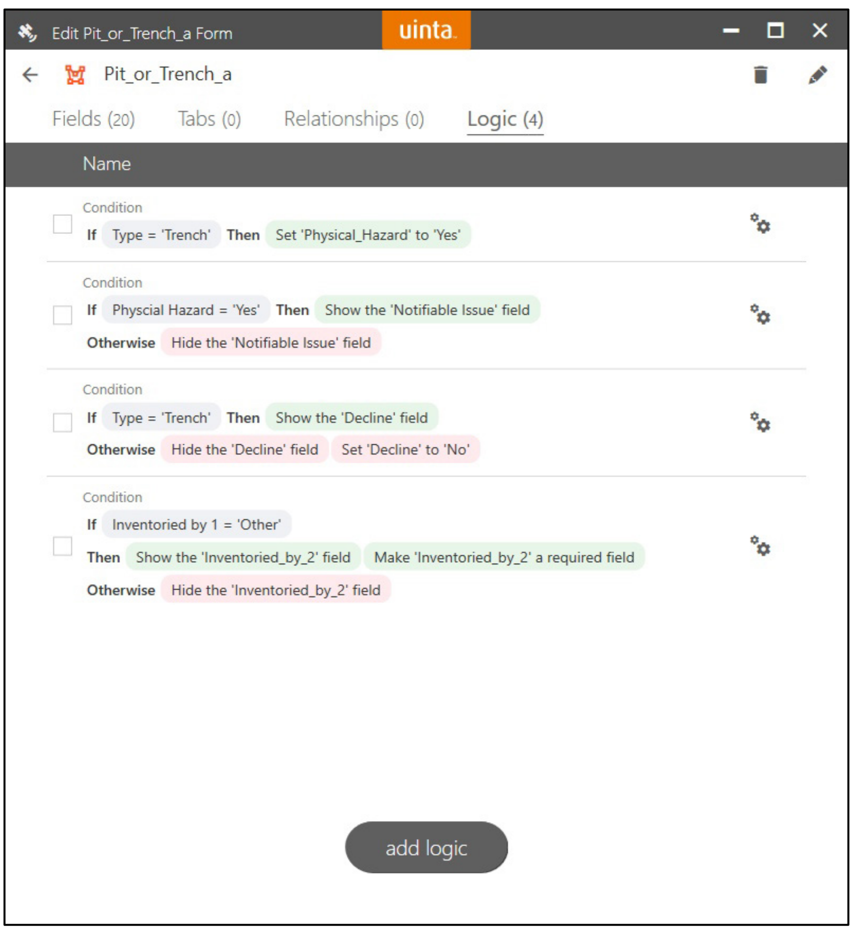
[4] Click the right arrow button.

[5] Configure the options as needed and then click the check mark button to return to the **Edit Record Form** dialog. It should display the new field.

[6] Click the left arrow button near the top left to close the **Edit Record Form** dialog.

G1.3.5 Logic Conditions

All of the fields described above can be modified under a logic condition. Logic conditions work as if-then statements. If a field should only appear when another field meets a certain criterion, add a logic condition under the **Logic** tab of the **Edit Record Form** dialog.

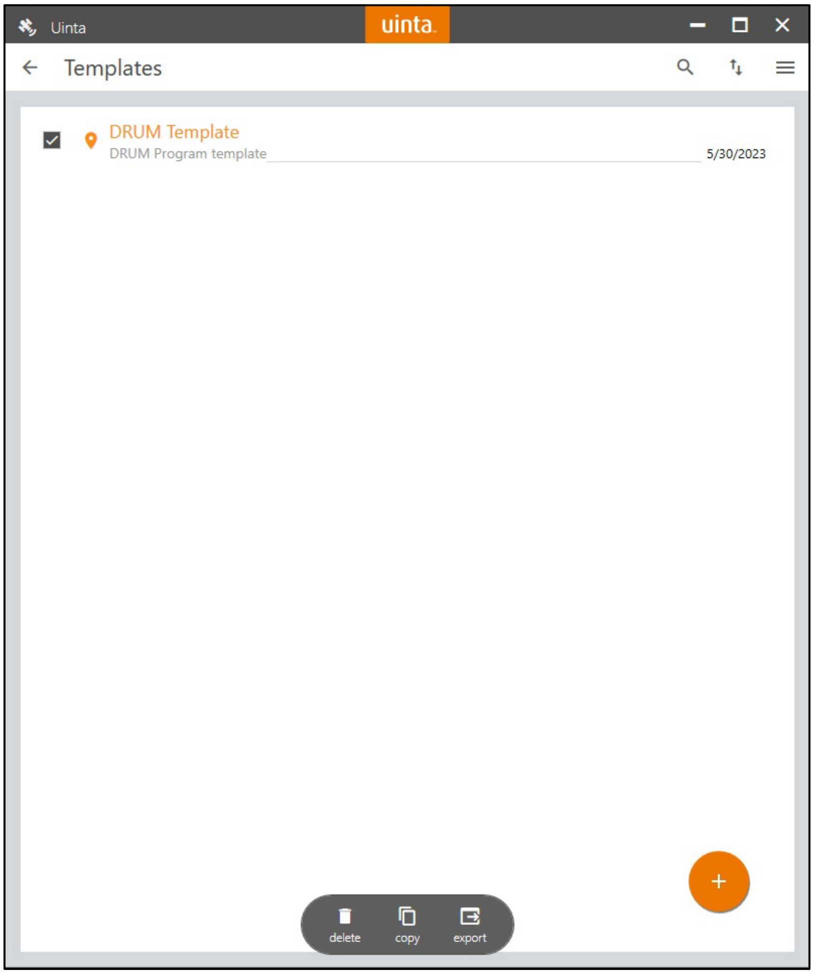


G1.4 Export a Template

[1] Inside Uinta, select the triple bar button and then select **Templates**.

[2] Select the checkbox next to the desired template.

[3] Click the **export** button that appears near the bottom of the window.



[4] Uinta will open a **File Explorer** window at the default save location, which is C:\Users\USERNAME\Documents\Uinta\Templates. Here *USERNAME* is the login name of the current Microsoft Windows user.

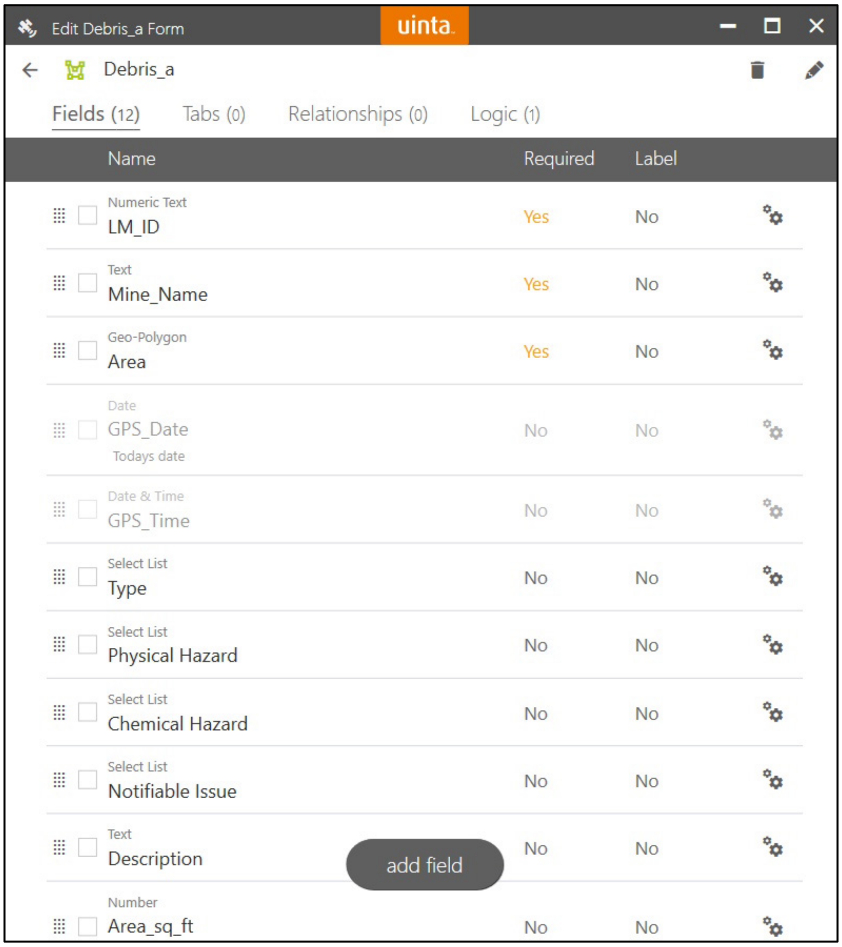
[5] Each template is saved as a .json file in the default save location. Users can copy the desired .json template file to an appropriate location for backup or to transfer to another device.

G1.5 Edit a Template

[1] Inside Uinta, select the triple bar button and then select **Templates**.

[2] Click the name of the template to edit.

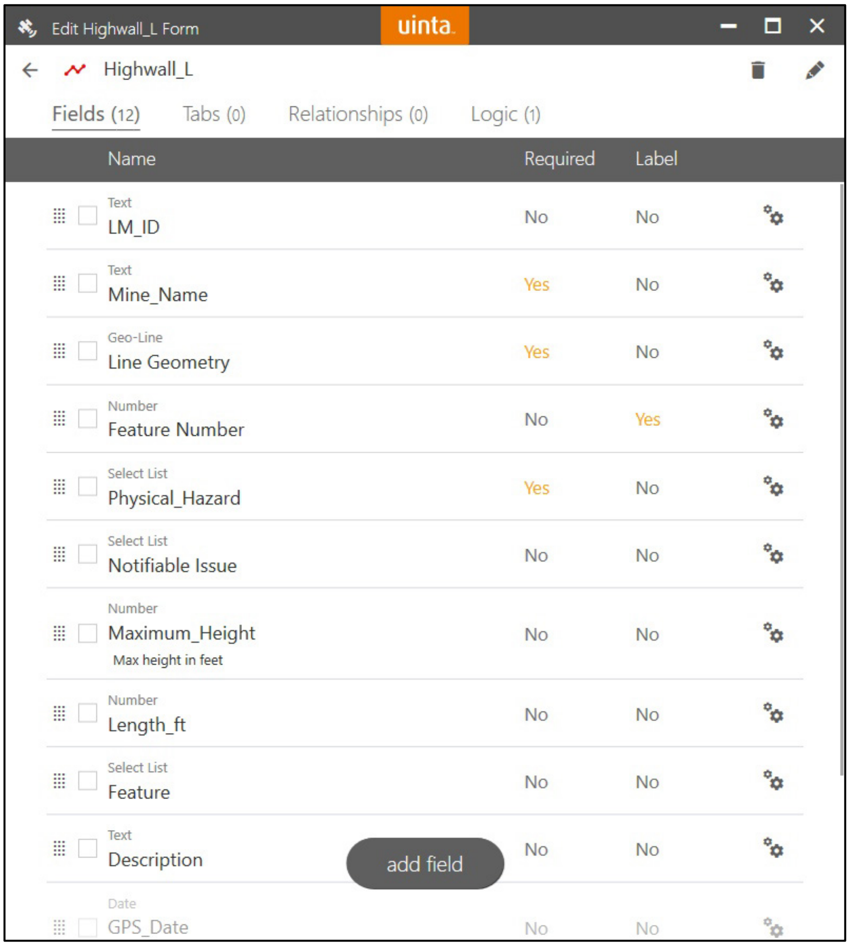
[3] Click a record name and then click the pencil button. The edit form page will appear.



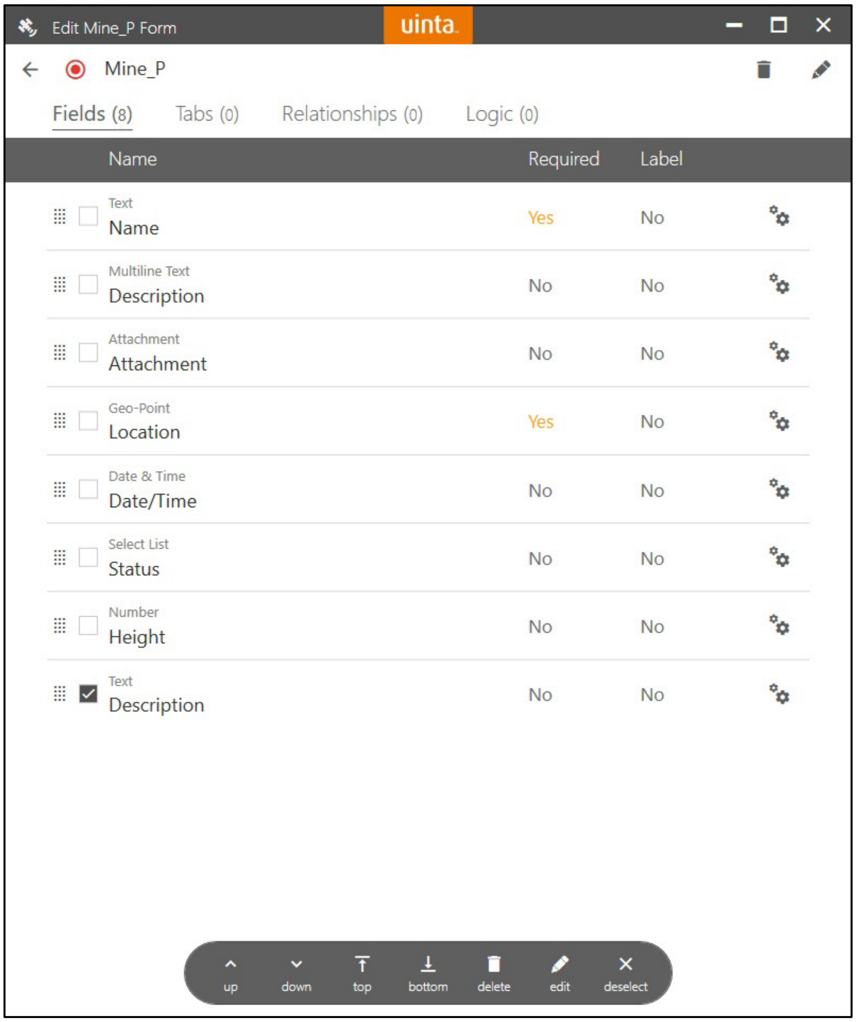
[4] To edit a field, click the gear button to the right of the field name and then select **edit**.

[5] Make the necessary edits and then click **Update**.

[6] To add a new field click **add field** from the edit form page.



[7] To change the order of the fields, select the checkbox to the left of the field you want to move and then click the **up**, **down**, **top**, or **bottom** button on the toolbar at the bottom of the popup.



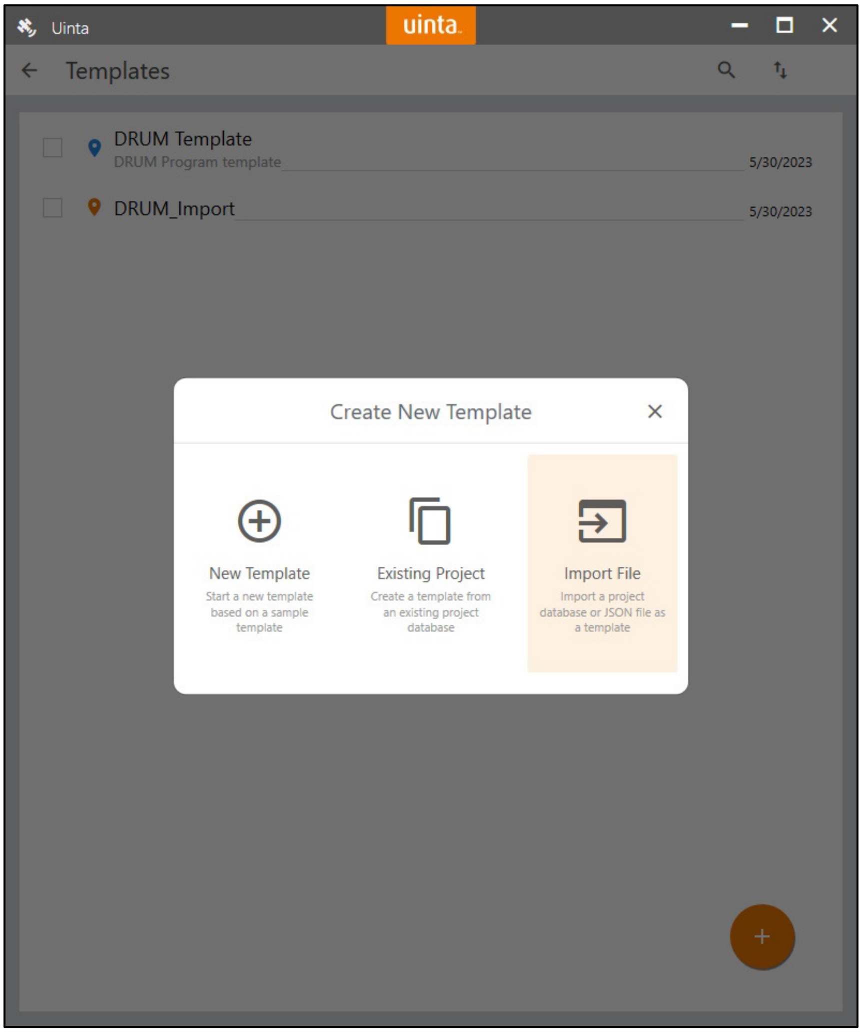
[8] Click the left arrow near the top left to return to the edit template page.

G1.6 Import a Template

[1] Inside Uinta, click the triple bar button and then select **Templates**.

[2] From the **Templates** page, click the orange plus button then click **Import File**.

[3] Navigate to the saved .json file and click **Open**.



[4] Give the template a name and description then click the check mark button.

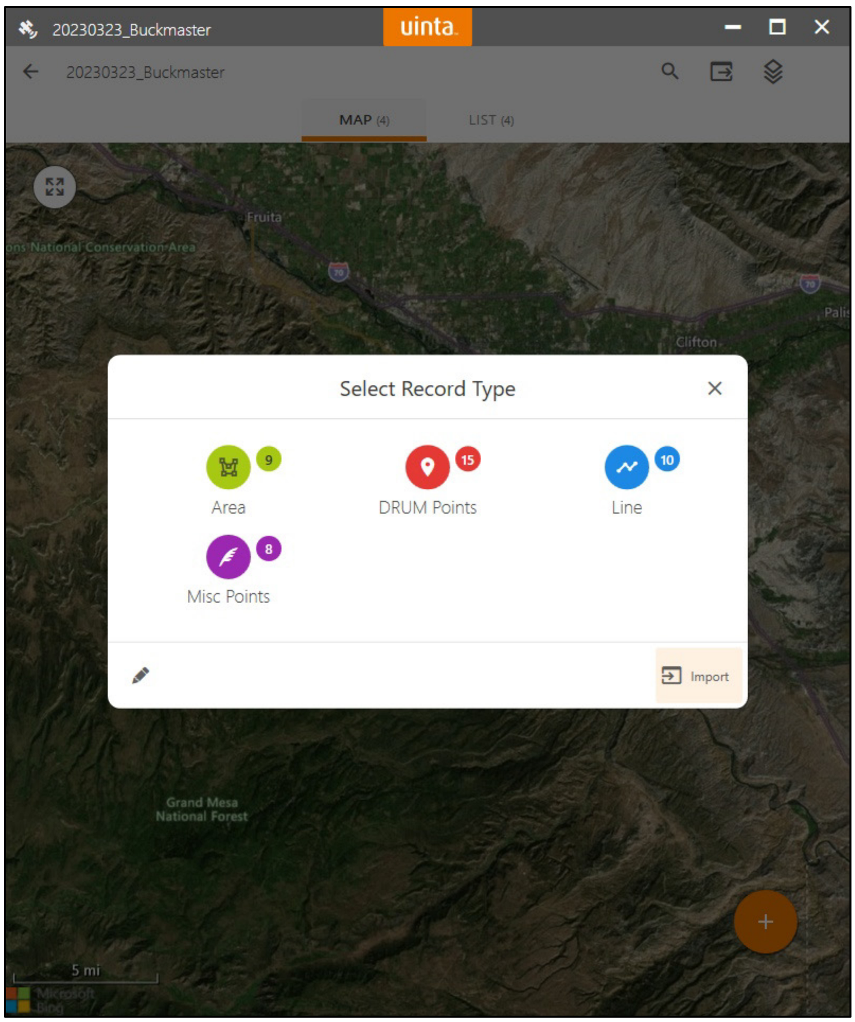
G2.0 Import Data to Uinta

Data can be imported into Uinta using .kml (or .kmz), .shp (zipped), and .csv files. For more information, see the support page titled, "Uinta – Import Options." Background imagery from bing.com can be downloaded for offline use from the Uinta app. For more information, see the support page titled, "Uinta – How to Use Offline Maps."

G2.1 Import Data Files

[1] Open Uinta and either create a new project file or open an existing one.

[2] From the map view, click the orange plus button then click the **Import** button at the bottom right corner of the popup window.



[3] To import the data to a new record type (i.e., one that is not defined in the current template), click **Create New**. Otherwise, click **Map to Existing**.

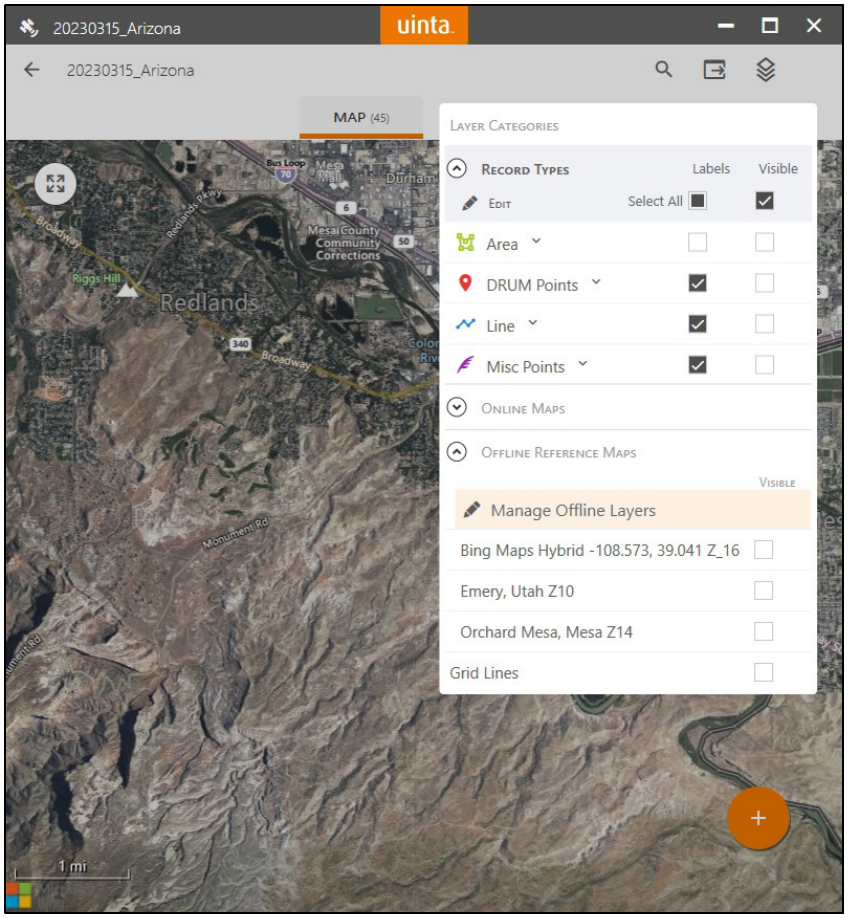
[4] Follow the subsequent prompts to import the data.

G2.2 Download Background Imagery

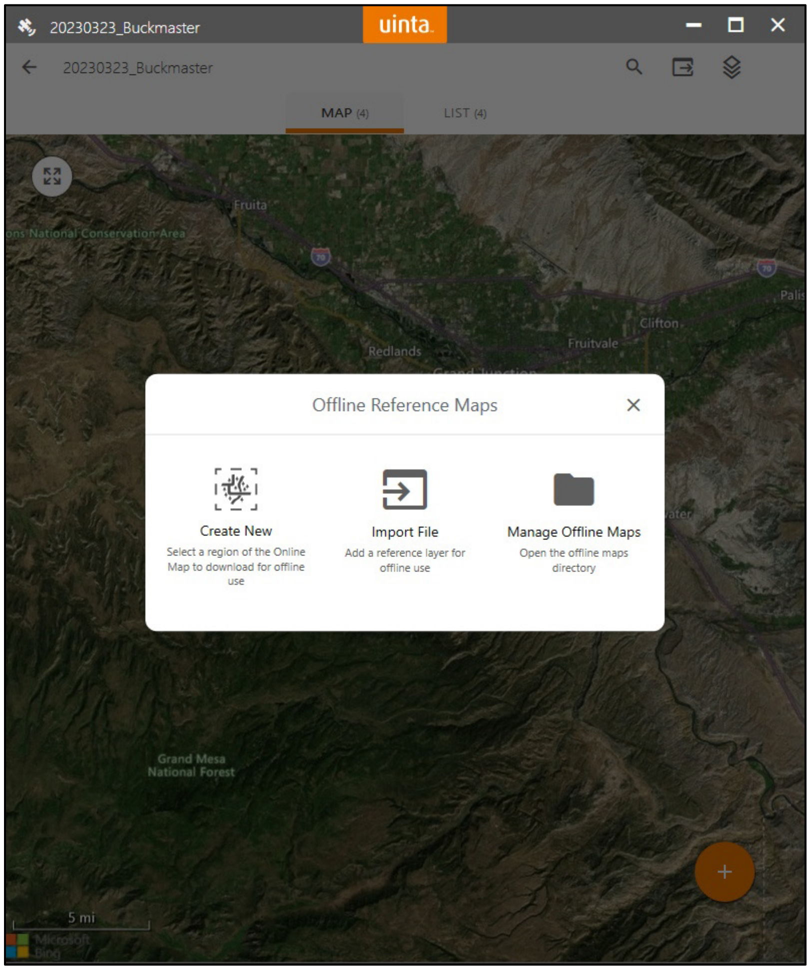
[1] Open Uinta and either create a new project file or open an existing one.

[2] From the map view, click the layers button near the top right.

[3] Expand the **Offline Reference Maps** section then click **Manage Offline Layers**.



[4] Click **Create New**.



[5] An orange box will appear on the map view. Pan and zoom to the location for which you wish to download background imagery, using the **left mouse button** to pan and the **mouse wheel** to zoom.

[6] When ready, click the **Download** button at the bottom of the screen.

G3.0 Uinta Field Reference

For more information on downloading, installing, and licensing, see the Juniper Systems help page titled, "Install Uinta."

G3.1 Activation and Setup

[1] Open Uinta either from the start menu or from a shortcut on the Windows desktop.

[2] Click the triple bar button at the top right then click **About**.

[3] Enter the license key and click **Submit**. Each Uinta license key can only be used on a single hardware device.

[4] Set the coordinate system and datum.

- [a] Click the triple bar button at the top right then click **Settings**.
- [b] Select **Location Settings**.
- [c] Under **Antenna Height**, enter an appropriate *height in ft* that the global navigation satellite system (GNSS) antennae will be carried at. Three to 4 ft is most common.
- [d] Click **Coordinate Systems**.
- [e] Under **Displayed Coordinate System**, select **Other (specify)**.
- [f] Under **Coordinate Reference System ID**, select **4269: NAD83**.
- [g] Click **Save Changes** then click the **X** button to close the location settings window.

Note *Setting the coordinate system affects how Uinta displays coordinates in the application and automatically projects subsequently exported files to the chosen coordinate system.*

G3.2 Collect Data Using a Template

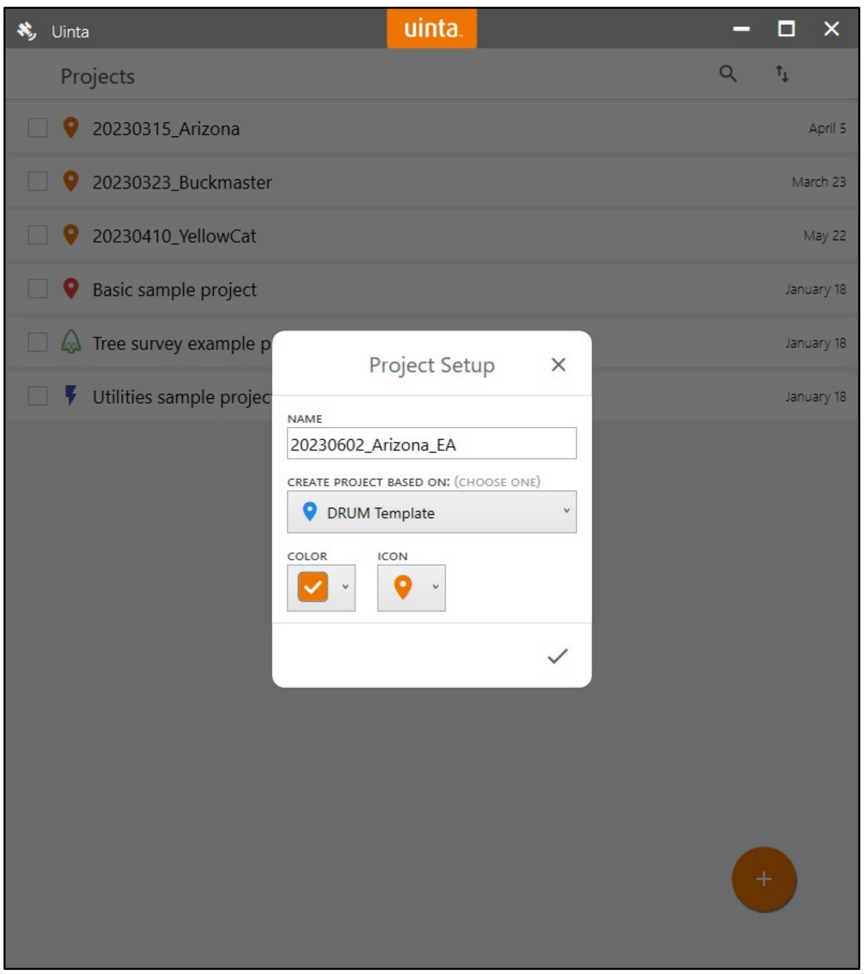
For more information on using local projects in Uinta, see the help page titled, "Overview of Uinta Projects."

[1] Open Uinta either from the start menu or from a shortcut on the Windows desktop.

[2] From the **Projects** page (the first page that appears after opening Uinta, which can be accessed from the triple bar button), click the orange plus button at the bottom right and then click **Local**.

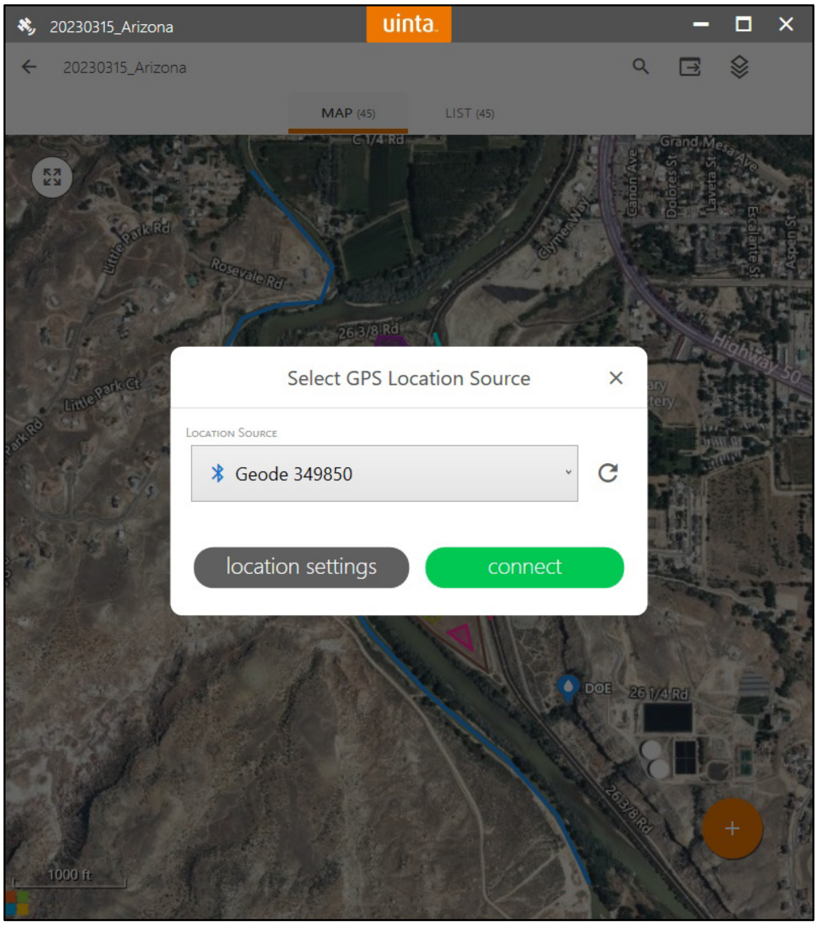
[3] Under **Name**, enter an appropriate *name* for the project (e.g., 20230602_Arizona_EA).

[4] Expand the menu under **Create Project Based On** to find and select the template imported earlier (see Section G1.6). It will be under the submenu **Custom Templates**.



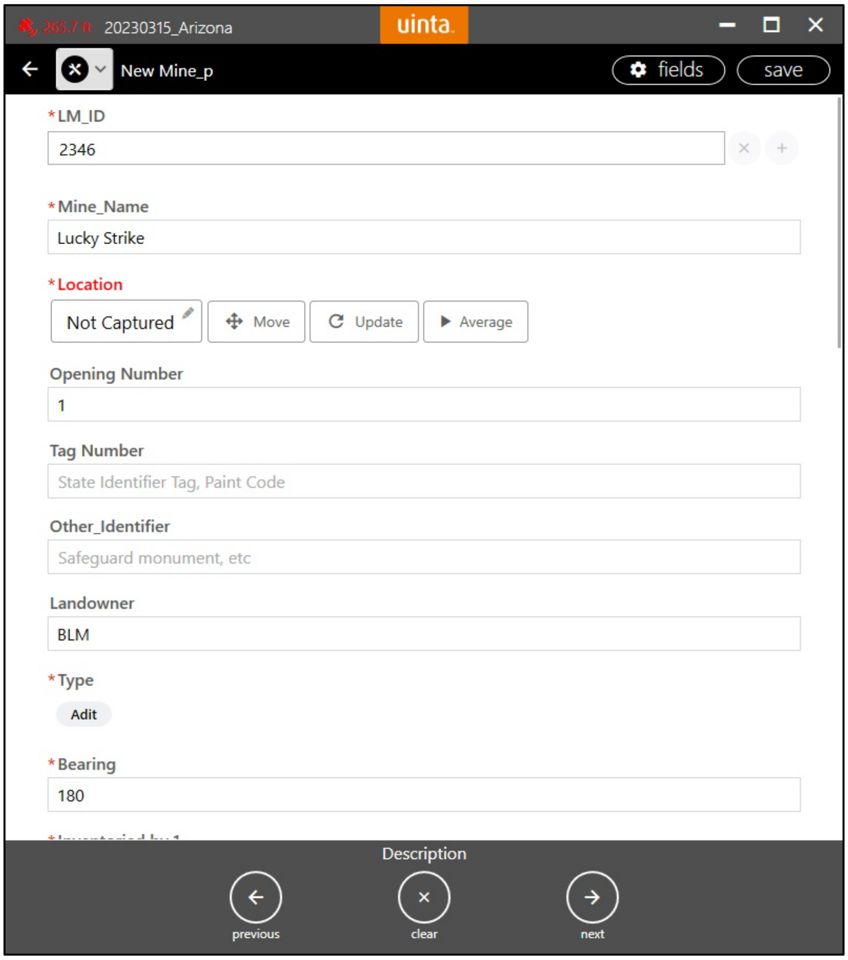
[5] The **Color** and **Icon** selections will not matter unless new record types are added to either the template or the project. Click the check mark button to create the project.

[6] Uinta will automatically switch to the map view and open the **Location Settings** to connect to a GNSS receiver. Choose the correct receiver from the **Location Source** dropdown menu and click **Connect**. To refresh the menu selection, click the circle arrow just to the right of the **Location Source** dropdown menu.

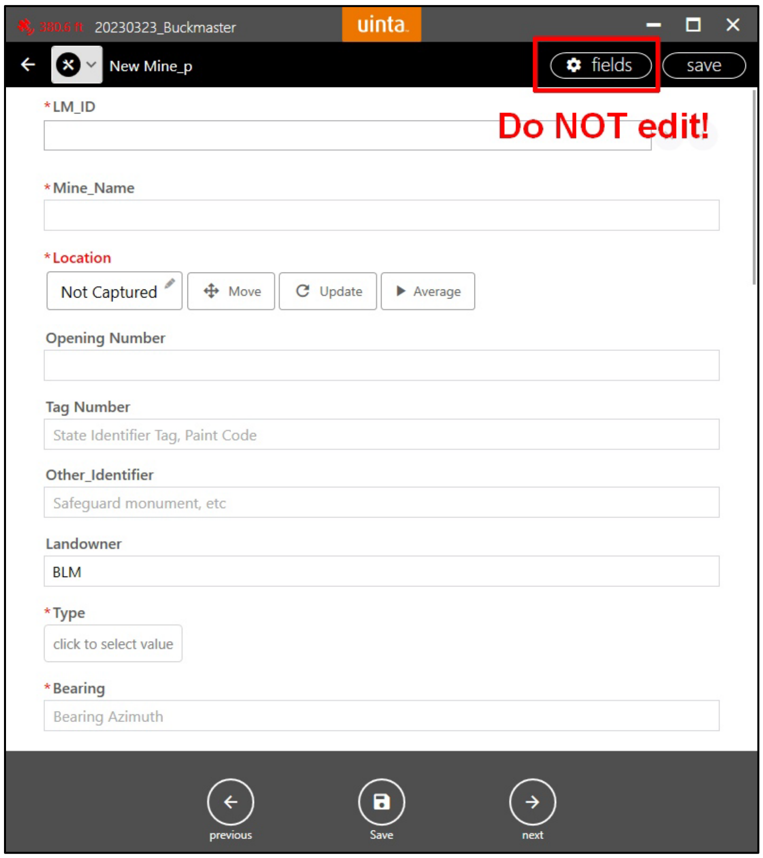


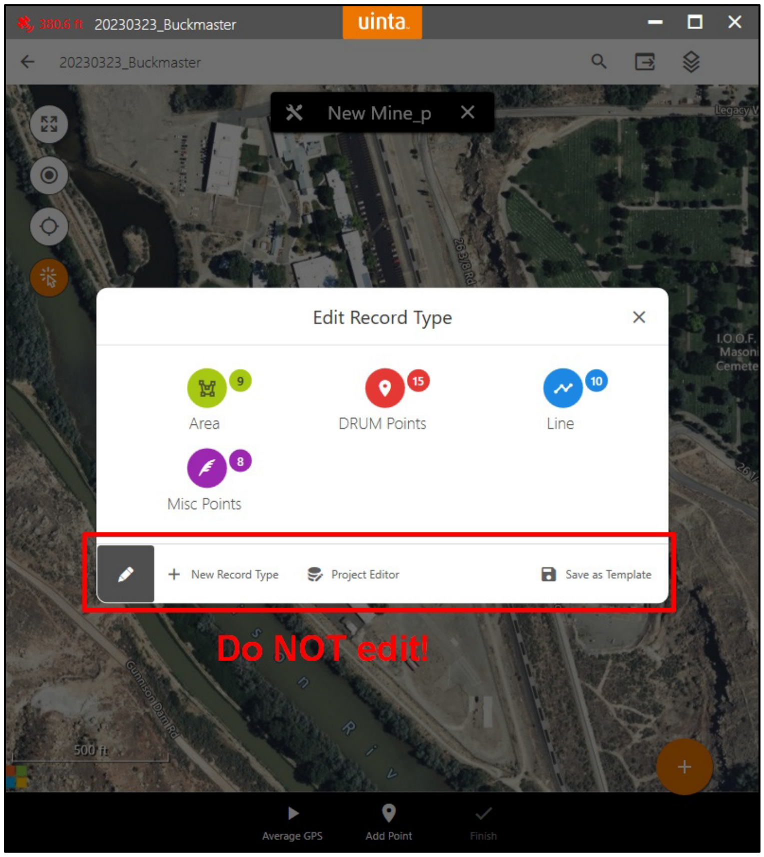
[7] To collect data for a feature, click the orange plus button and select the record type most appropriate (e.g., Mine_P for an adit feature).

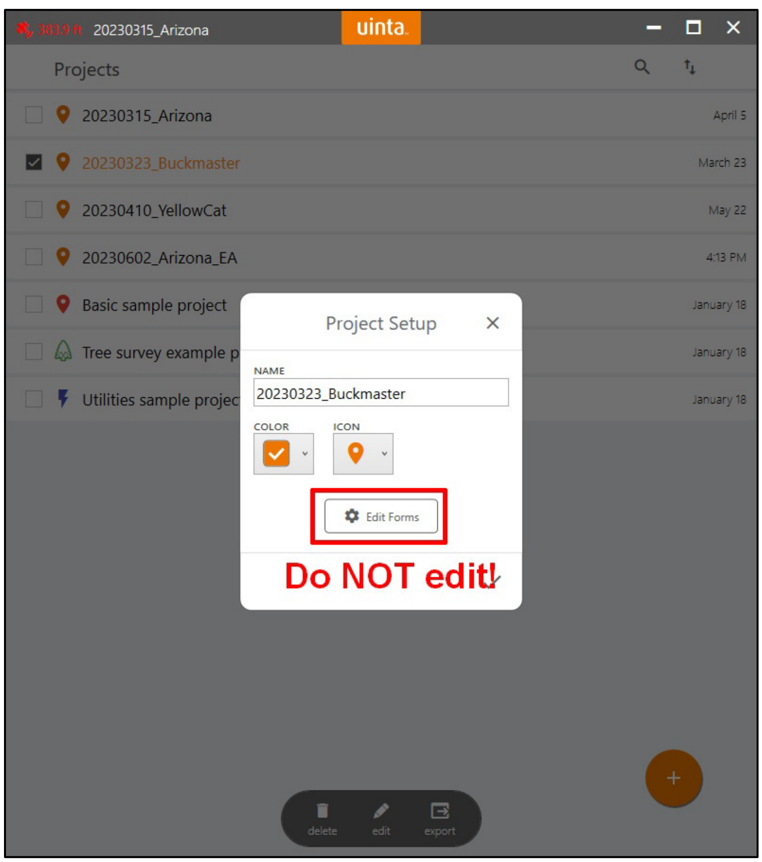
[8] Populate the fields for the chosen record type; when finished, click **Save**. All fields marked with a red asterisk are required. Location data for the feature can be modified using the **Move**, **Update**, and **Average** buttons under **Location**. To cancel saving a record, click the left arrow near the top left.



[9] *Important*: When using a local project file, it is possible to edit or delete any record and the associated field attributes by clicking the **fields** button when collecting data for a record or by clicking the pencil button in the bottom left corner of the popup when recording a new record. The DRUM Program has a standardized template that everyone is expected to use. **DO NOT** click the **fields** button or the pencil button, as this may result in changes to the project file or template field settings. Additionally, do not edit forms from the **Projects** page. This will cause the machine to subsequently collect and record data differently from other machines on the DRUM Program, and the data may not import into the DRUM geodatabase.




20230323_Buckmaster
uinta
20230323_Buckmaster
New Mine_p
Edit Record Type
Area
DRUM Points
Line
Misc Points
New Record Type
Project Editor
Save as Template
Do NOT edit!
Average GPS
Add Point
Finish


20230315_Arizona
uinta
Projects
20230315_Arizona
April 5
20230323_Buckmaster
March 23
20230410_YellowCat
May 22
20230602_Arizona_EA
4:13 PM
Basic sample project
January 18
Tree survey example p
January 18
Utilities sample projec
January 18
Project Setup
NAME
20230323_Buckmaster
COLOR
ICON
Edit Forms
Do NOT edit!
delete
edit
export

G3.3 Manage Background Files

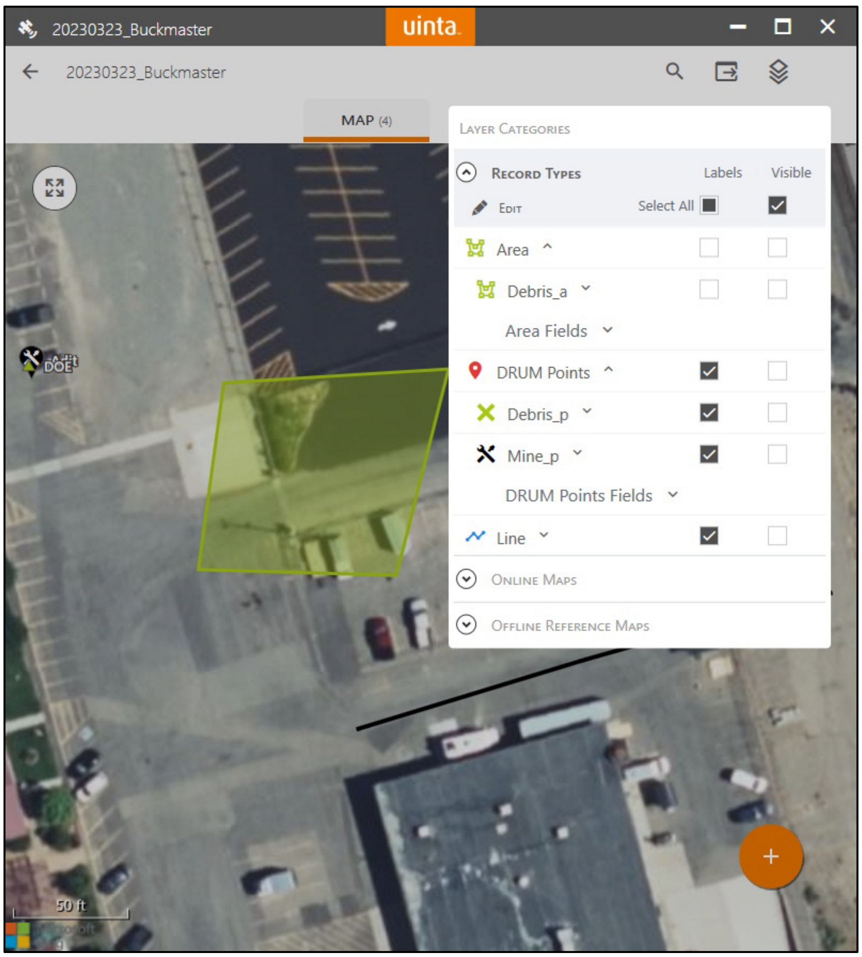
[1] Create or open a project file in Uinta.

[2] Click the layers button near the top right.

[3] From the layers menu, expand the groups of records by clicking the down arrows. Groups can be collapsed by clicking the up arrows.

[4] Layers can be toggled on or off by selecting or clearing the checkboxes under the **Visible** column.

[5] Labels can be toggled on or off for each layer by selecting or clearing the checkboxes under the **Labels** column.



[6] Click the layers button near the top right to return to the map view.

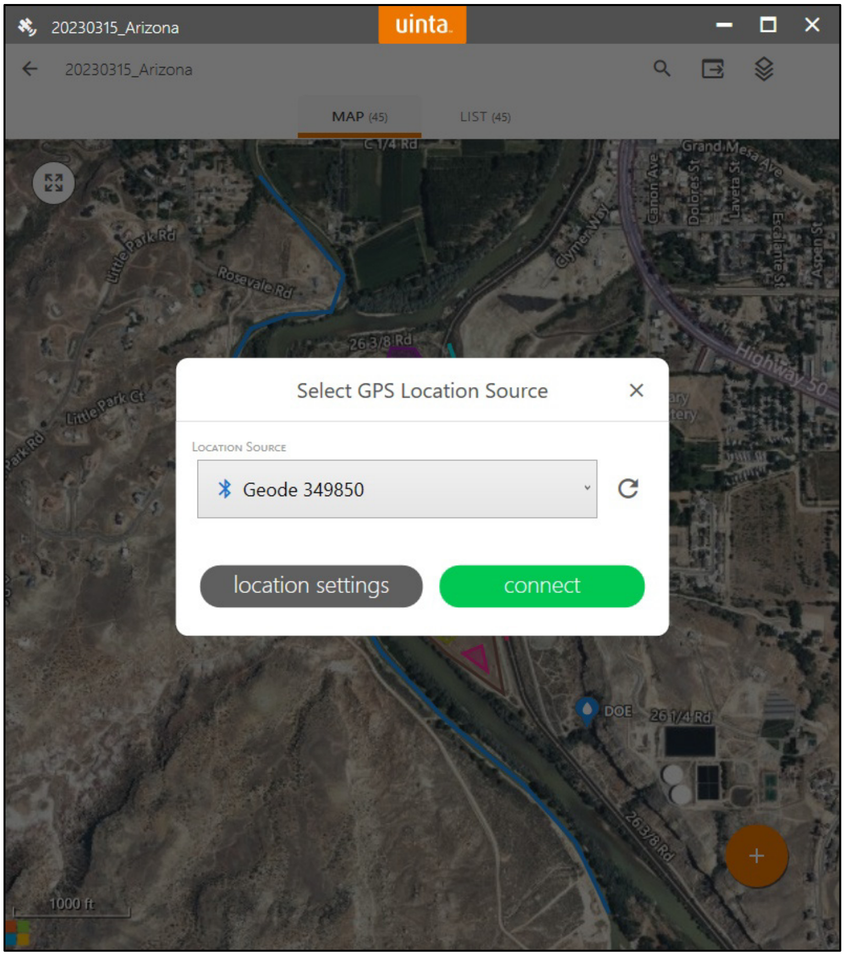
G3.4 Navigation

[1] Open an existing project file in Uinta or import data.

[2] Connect to a GNSS receiver.

[a] In Uinta, click the satellite button at the top left corner.

[b] Select the correct receiver from the **Location Source** dropdown menu.



[c] Click **connect**. The GPS position, accuracy, and satellite information will be displayed.

[d] Close the popup window to return to the project.

[3] From either the map view or the list view, select the record you want to navigate to.

[4] Click **Navigate** in the popup window.

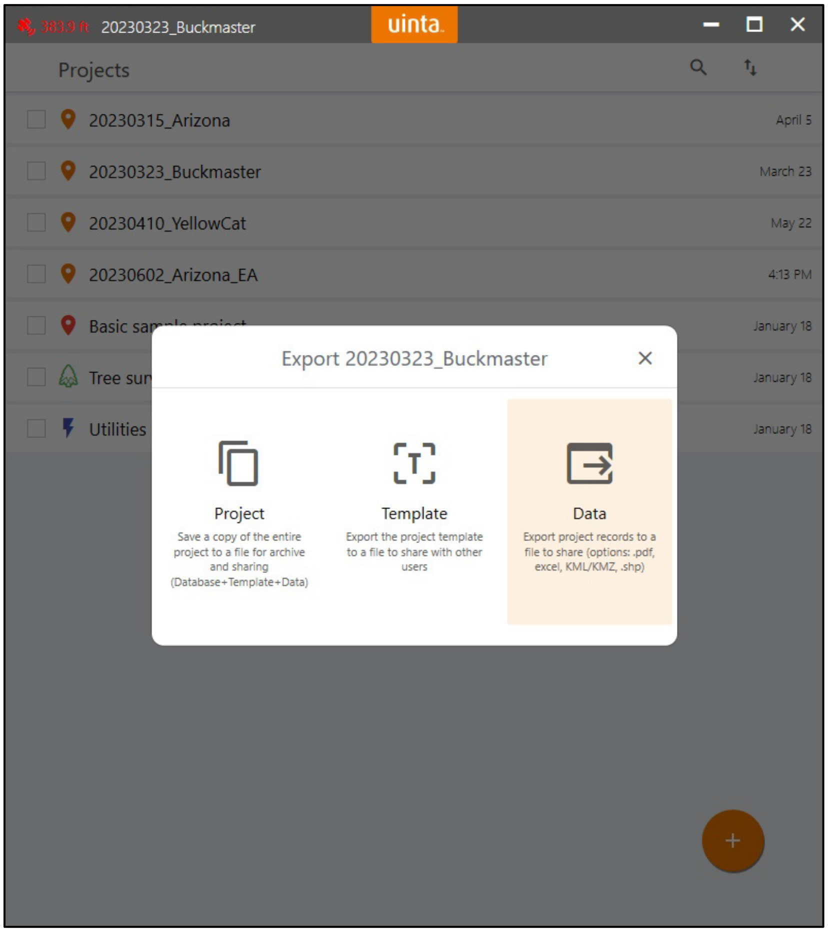
[5] Click the left arrow button near the top left to exit navigation.

G4.0 Uinta Data Export

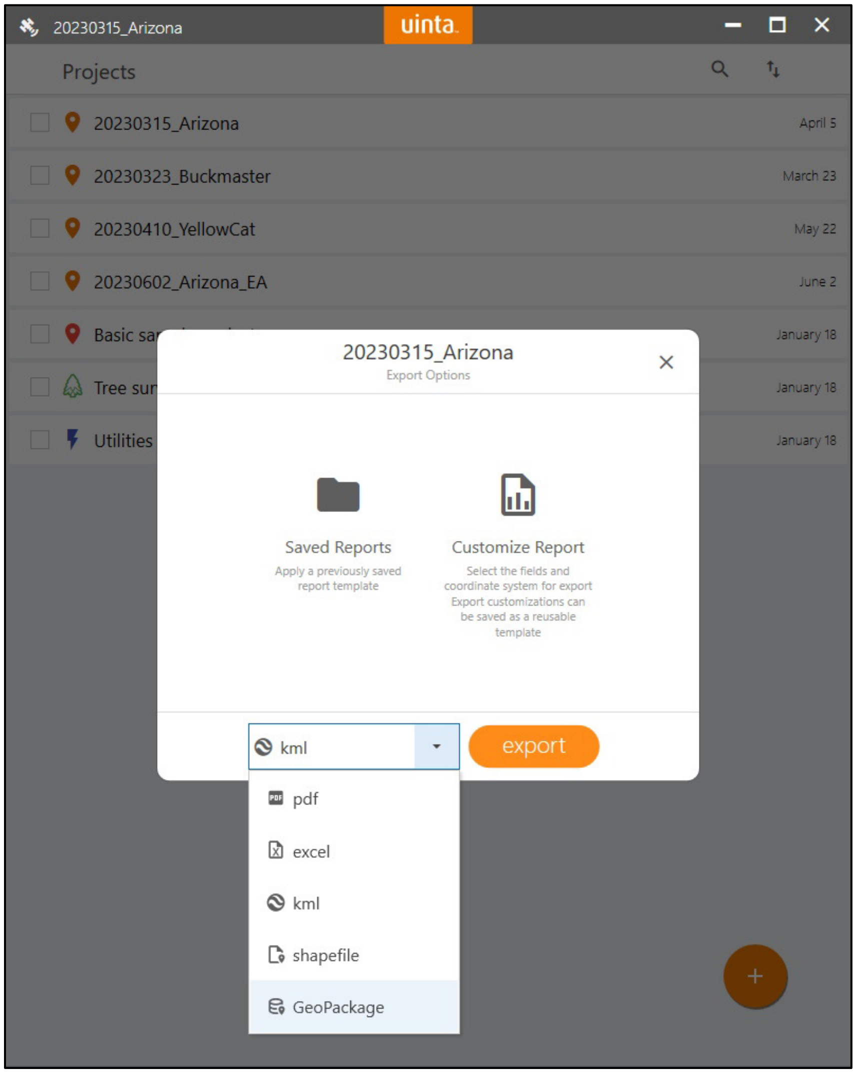
G4.1 Export Data Files

[1] From the **Projects** page, select the project you want to export by selecting the checkbox to the left of the project name.

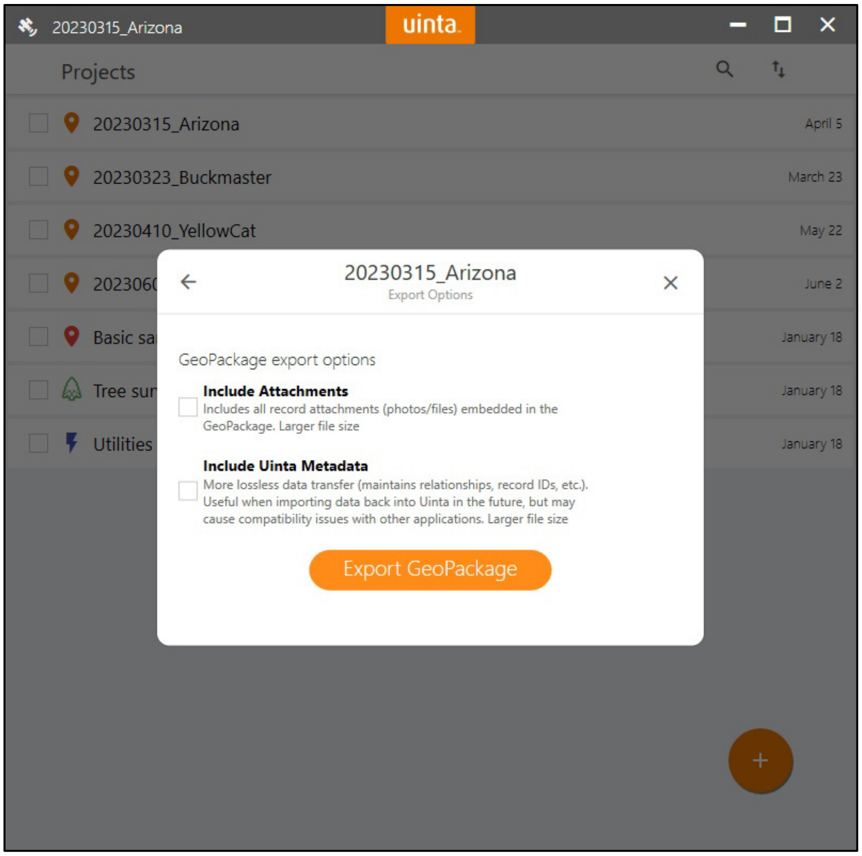
[2] Click **Export** from the bottom menu and then click **Data** on the export popup window.



[3] Select **GeoPackage** from the dropdown menu then click **export**.



[4] Clear the checkboxes next to **Include Attachments** and **Include Uinta Metadata** then click **Export GeoPackage**.



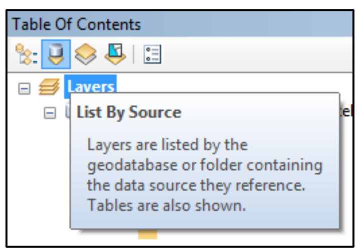
[5] Navigate to an appropriate place to save the GeoPackage file and click **Save**.

G5.0 Versioning in ArcGIS

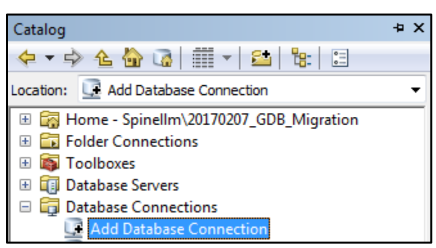
Loading and modifying data in the enterprise geodatabase is controlled by versioning in ArcGIS. Each field team has a version of the geodatabase in which they load data and perform edits (e.g., FT1 for Field Team 1). Every evening, the geodatabase performs a post and reconciliation. This process takes all the edits made in the field team versions and saves them to the default version. The default version cannot be edited and is the version from which the DRUM Program database pulls information. It is important for all field team members to perform edits in the correct version to prevent conflicts in the database. For example, if Team Member 1 changes the geometry of the total disturbed area at the Lucky Strike mine while Team Member 2 is also changing the geometry of the same total disturbed area, there may be a conflict. If both team members are editing the same version of the geodatabase, the first one to save the edits will be successful, while the second one to save the edits will receive a notification that the data have been changed, and ArcGIS will not make the changes in the second save. However, if the two team members are editing the same feature in two different versions of the geodatabase, both will be able to save their edits. When the geodatabase performs the post and reconciliation that evening, the geodatabase will see two different edits made to the same feature and will not be able to determine which edit is correct. This is a conflict, and this conflict is a problem because no edits will be moved to the default version.

G5.1 Introduction

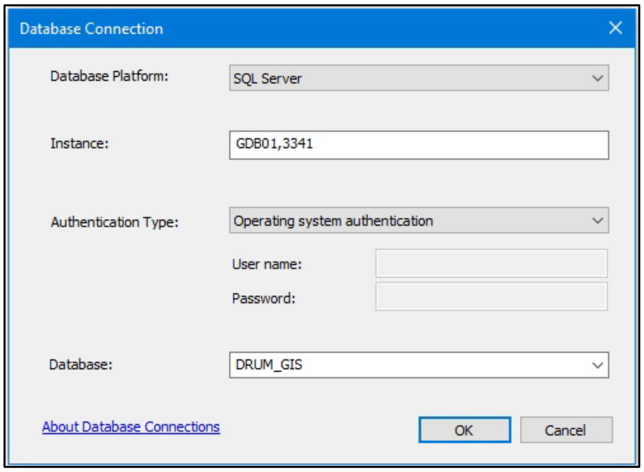
[1] To add features from the enterprise geodatabase, change the ArcMap view to **List By Source**.



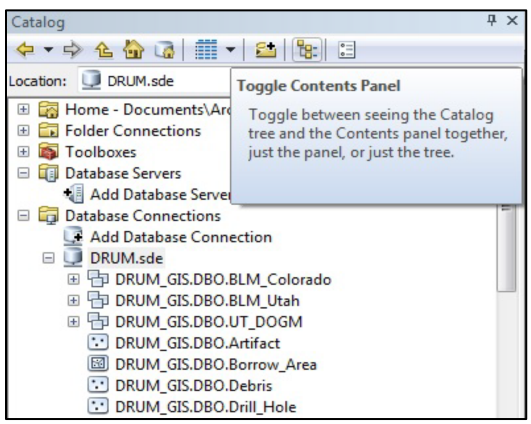
[2] In the ArcCatalog window, use **Add Database Connection** to establish a connection to the enterprise geodatabase.



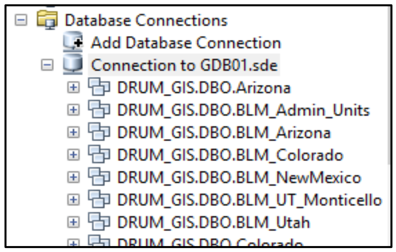
[3] Select **SQL Server** as the **Database Platform**, enter **GDB01,3341** as the **Instance**, select **Operating system authentication** as the **Authentication Type**, and select **DRUM_GIS** as the **Database**. Click **OK**.



[4] Once the connection is made, **Toggle Contents Panel** will show the contents of the enterprise geodatabase. Each .sde feature class is pulled from the schema, with DRUM_GIS.DBO. as a sort of prefix (e.g., DRUM_GIS.DBO.Artifact). The database connection can be renamed for quick reference.

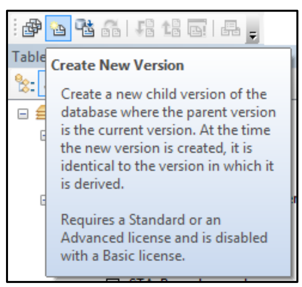


[5] If an .sde feature class needs to be added to the map, the layer is listed by source and should fall under **dbo.DEFAULT** (GDB01). This means the layer is coming from the default version of the enterprise geodatabase.

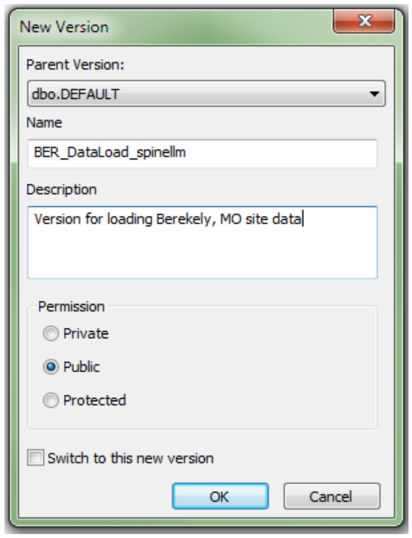


[6] To change this and call the data from the working version, the **Versioning** toolbar from **Customize**: **Toolbars** needs to be added to the **ArcGIS** toolbar.

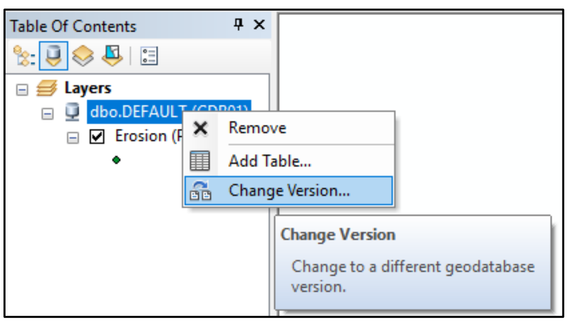
[7] Once the toolbar has been installed, select **Create New Version**. If a current edit version exists, continue to step [9].



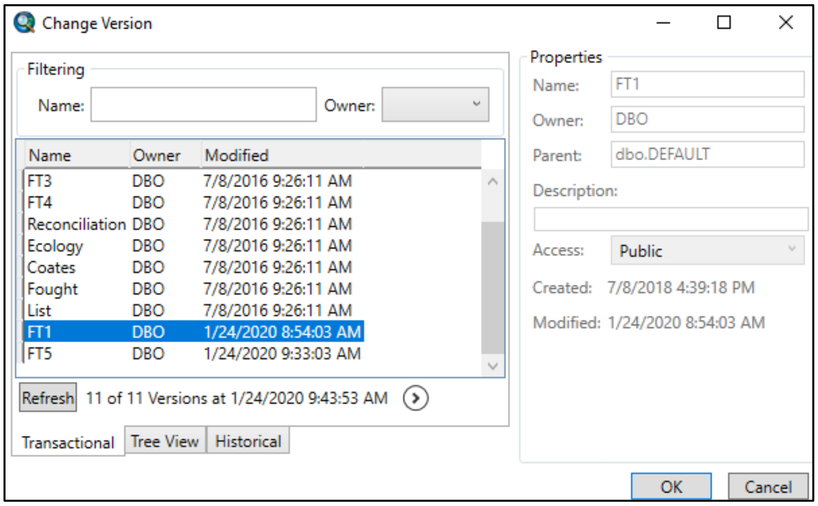
[8] The **Parent Version** will be **dbo.DEFAULT**, and the new edit version will need to be assigned a name (e.g., SRD_DataLoad_Spinelli). Click the **Public** option under **Permission** and describe the version in a meaningful manner. Click **OK**.



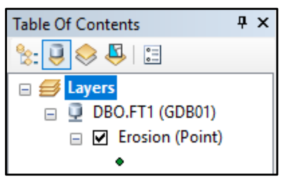
[9] Look at the database connection for the .sde feature class that was added to the map, right click, and select **Change Version**.



[10] Select the edit version established above and click **OK**.



[11] The database connection should update accordingly.

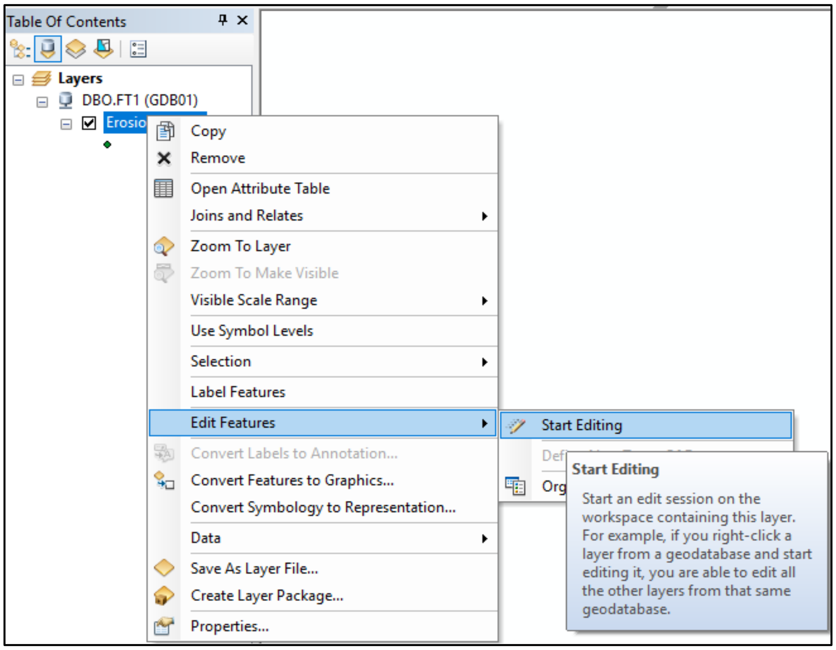


Note *The default version of the map can be kept as a sort of reference or as a reminder of what has already been done. The default version is protected and requires administrator rights to be changed.*

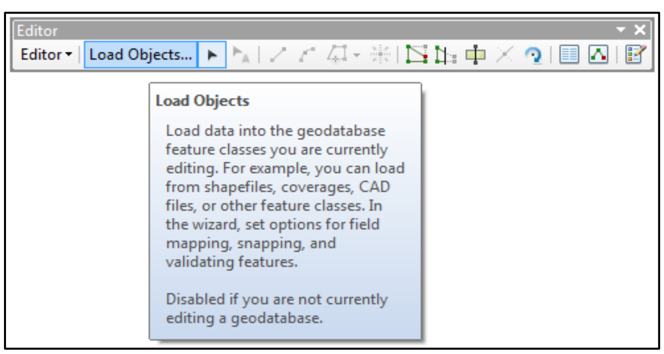
G5.2 Workflow

Data to be added to the enterprise geodatabase will go through versioning. An administrator will reconcile and post the changes to the default version and will delete the current edit version after all changes have been completed and approved. A new edit version will be created for future editing.

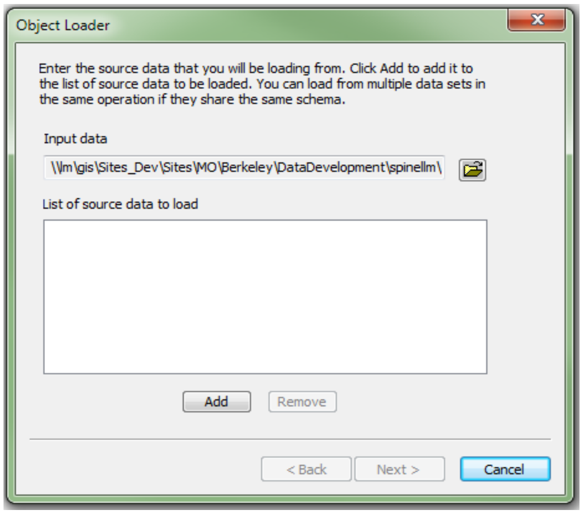
[1] Right click the target (.sde) feature and select **Edit Features** and **Start Editing**.



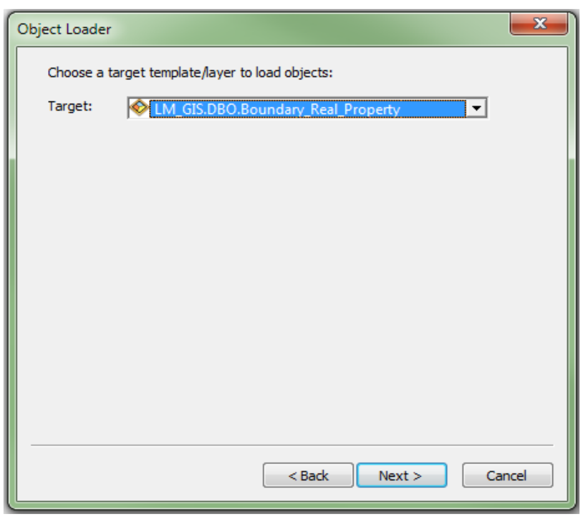
[2] In the **Editor** toolbar, select **Load Objects**.



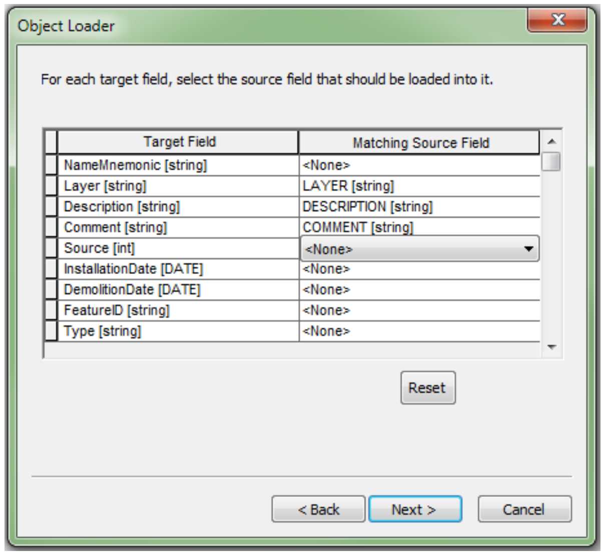
[3] In the **Object Loader** wizard, browse to the source of **Input data** and select **Add**. Multiple sources of data can be selected at once for loading. Click **Next** when all sources have been selected.



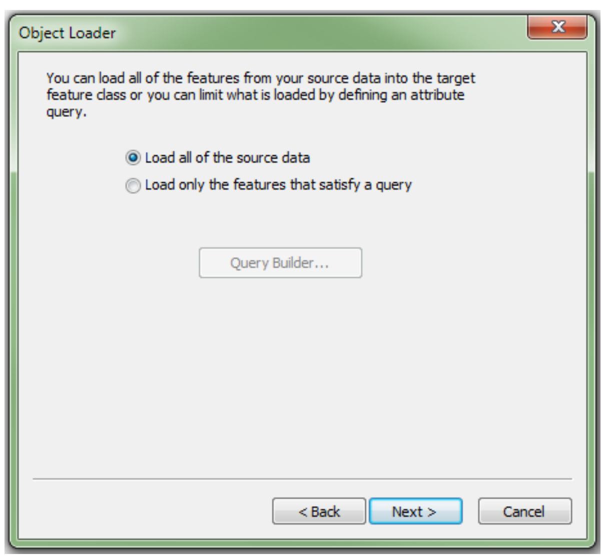
[4] On the following screen, choose the appropriate target layer from **LM_GIS.DBO**. Click **Next**.



[5] Next, transfer attributes from the **Source Field** to a corresponding **Target Field**. The field **Type** (e.g., string, double) must match for the transfer of attributes to process without error. If the source data contain a field (e.g., **Layer**) whose attributes should carry over to the target data, use the dropdown menu on the right to assign that transfer. After making appropriate assignments, select **Next**.

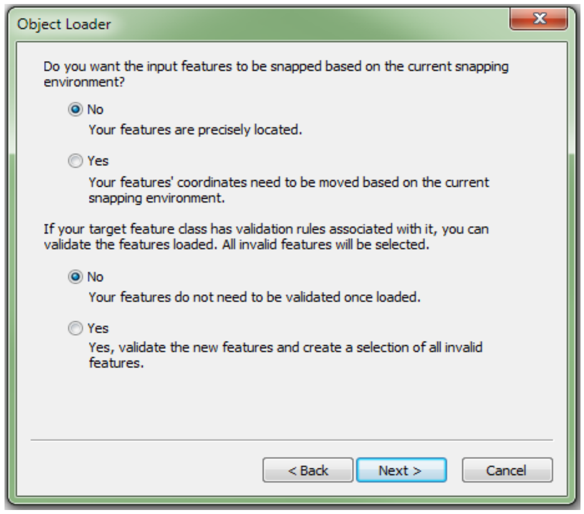


[6] The decision will need to be made whether to load all source data into the target feature class or to load only those features that satisfy certain criteria by means of a query. Once the type of data to load has been established, select **Next**.

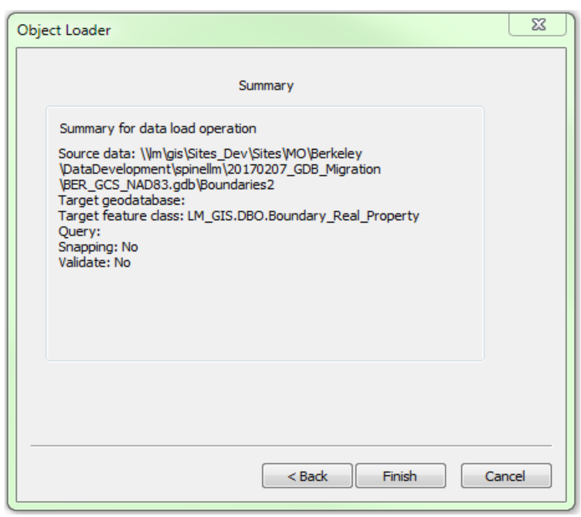


Note *Source data can be parsed out into several target feature classes. Target feature classes can be populated by data from several sources. One source can also populate one target in its entirety.*

[7] The following screen will ask about snapping input features and establishing validation rules. Typically, the default values of **No** will be appropriate for loading. Only change the default values if the features are intended to snap or move the input features or if the intended features are to validate new features. Click **Next**.

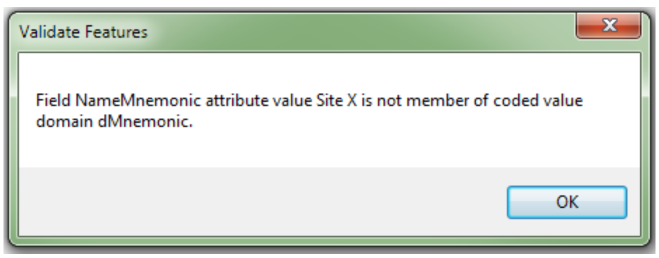


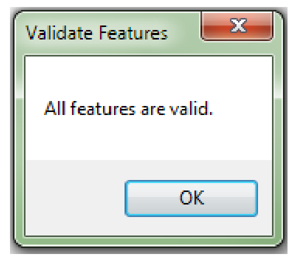
[8] The final screen in the **Object Loader** wizard serves as a summary for the data load operation that has been set up. If all settings are correct, select **Finish**. If not, select **<Back** and make any necessary corrections. (On occasion, fields will not import due to incorrect entries. These will need to be edited in the file before data are loaded. When the error message pops up, it will state the specific fields that did not import correctly. Undo, fix these first, and then load the data again.)



[9] Right click the target layer and select **Open Attributes**. Scroll through the records until those with empty attributes are identified. The features just loaded should be revealed by the absence of **Name Mnemonic** content. Select these and confirm that they are indeed within the mine or map extent. With the mine's newest features selected, select **Show selected records** to add or edit attribute data.

[10] When these data have been edited, return to the **Editor** toolbar and select **Validate Features**. This tool provides an additional QC and will check the new data against the geodatabase configuration to ensure that proper values have been entered and the data fit without error.





If there is a validation error, make the necessary correction, as described. If all features are valid, click **OK**, then **Save Edits**, and **Stop Editing**. When done loading data for the mine, inform the administrator so the edits can be reviewed. The administrator will examine the version and, when satisfied, will reconcile and post the edits so they become part of the default version.

Appendix H

DRUM Surface Water Sampling Procedure

H1.0 Scope

This procedure describes general protocols for obtaining screening level surface water samples and measurements for the DRUM Program. The methods and procedures described in this procedure are adapted from the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2024i).

Surface water will be noted by the field team if it is within the disturbed area or within 300 ft of the disturbed area of a mine. A water sample will be collected when surface water which may be safely accessed is being impacted by the mine (e.g., sediment is migrating into the water body, water draining from or across the mine area is confluent with receiving water resources, water is discharging from an adit, water is in direct contact with waste rock). By contrast, ephemeral water bodies that form due to precipitation and are likely to persist for less than approximately 2 weeks will not be sampled.

The protocols outlined below are considered a screening level effort. Surface water samples are collected for the purpose of providing a “snapshot in time” indication of the quality of the water sampled. The analytic results of the sample are not compared to any water quality standards but are provided for use by land management agencies as they quantify the risks presented by any one particular mine.

There is a possibility the surface water encountered at a mine may be flowing. Generally, these flows will be observed as mine adit discharges or discharges from springs and seeps emanating from slopes within the disturbed area. Discharge measurements will be made from these features when possible, given potentially very small flow rates.

H2.0 Roles and Responsibilities

Personnel participating in surface water monitoring activities will be proficient in the procedures, equipment, and instrumentation used for the work they perform. Individual qualification worksheets for LMS V&V field team members will be used as an initial qualification process to document completion of training.

H3.0 Equipment and Supplies

Refer to the *Water Sampling Field Data* (LMS 1805) form for the list of equipment and supplies that may be required for collection of surface water samples.

H4.0 Instructions

H4.1 Field Measurement and Calibration

Calibrate field instruments before a sampling event begins. Operation, inspection, maintenance, and calibration associated with using field instruments will be conducted according to manufacturers' instructions. Calibration and operational check requirements for field instruments are shown in Table H1. Record the instrument's response. If the acceptance criteria are not met during the operational check, then conduct a primary calibration of the affected probes and instruments. Equipment failing calibration or malfunctioning shall immediately be removed from service and have a "Defective" or "Do Not Use" tag attached to it.

Collect field measurements of pH, specific conductance, temperature, and turbidity, which are indicative of physical and chemical conditions at the time of sampling, at all sample locations. Collect these measurements using a YSI Pro1030 (or equivalent) for pH, specific conductance, and temperature and a Hach 2100Q (or equivalent) for turbidity.

Table H1. Field Parameter Calibration Requirements

Parameter	Requirement	Frequency	Operational Check Criteria
pH	3-point calibration	Before start of sampling event	NA
	1-point check with pH 4, 7, or 10 buffer	Daily	±0.2 pH units
Specific conductance	1-point calibration	Before start of sampling event	NA
	1-point operational check	Daily	±10% of standard
Temperature	Operational check	Before start of sampling event	±1.5 ºC compared to NIST-traceable thermometer
Turbidity	4-point calibration	Every 3 months	NA
	3-point operational check	Daily	±10% of standard

Abbreviations:
NA = not applicable
NIST = National Institute of Standards and Technology

H4.2 Sample Collection

If the field team lead determines that a surface water sample is necessary, collect the sample as follows:

- If possible, before sampling the surface water feature, measure the following field parameter data from the same location where the surface water is to be collected:
  - pH
  - Specific conductance
  - Temperature
  - Turbidity

Note *In some cases, it may not be practical or possible to carry the water sampling equipment to the sample collection location. In these cases, pH, specific conductance, temperature, and turbidity will be measured at the first practical opportunity.*

- For surface water features less than 6 ft wide, collect the sample from the middle of the feature.
- For surface water features greater than 6 ft wide, collect the sample 1 to 3 ft from the water's edge.
- Sample flowing surface water features greater than 6 ft wide (e.g., rivers, streams, ditches) within the main current and not in stagnant or eddy areas.
- If stagnant or eddy areas extend more than 3 ft from the water's edge, collect samples at the nearest downstream location where the main current is within 3 ft of the water's edge.
- Collect the surface water sample by directly immersing the sample container or by using a dip sampler. If the surface water is flowing, approach the sampling location from downstream and point the sample container or dip sampler upstream.
- Filter all samples through a 0.45-micrometer filter, regardless of turbidity.
- Log sample location, sample collection date and time, and field parameter data using a GPS unit and download into the database. If a GPS unit is not available at the time of sampling, record the required information in a field logbook or sample data sheet and transfer the information to the database.

Note *Duplicate surface water samples are not required to be collected as assessment of field and analytical precision is not required of screening level samples.*

H4.3 Sample Preservation

- Field preserve the sample by adding an appropriate amount of acid to the sample in the container. Use a pH strip to determine that the pH is less than 2.
  - Review chemical Safety Data Sheets.
  - Use nitrile gloves and safety glasses when dispensing sample preservatives (acids and bases) or using calibration solutions and field test reagents.
  - Spills of chemicals will be cleaned up as soon as possible, and EC must be notified.
  - Acids must be transported in quantities no greater than 500 milliliters per container; containers must be leak proof and must be secured during transportation to limit spill potential and to qualify as DOT materials of trade.
- Store filled sample containers in a cooler with bagged ice. Analytical parameters, container type, sample volume, analytical method, preservative, and holding times are listed in Table H2.

Table H2. Water Sample Collection Requirements

Parameter	Analytical Method	Sample Container	Preservative	Holding Time	Detection Limits (µg/L)
Metals					
Aluminum	6010	250 mL HDPE[a]	Nitric acid, pH <2	180 days	200
Antimony	6010			180 days	5
Arsenic	6020			180 days	0.1
Barium	6010			180 days	20
Beryllium	6020			180 days	1
Cadmium	6020			180 days	1
Chromium	6020			180 days	2
Cobalt	6020			180 days	50
Copper	6010			180 days	8
Iron	6010			180 days	100
Lead	6020			180 days	2
Manganese	6010			180 days	5
Mercury	7470			28 days	0.1
Molybdenum	6020			180 days	3
Nickel	6020			180 days	10
Selenium	6020			180 days	0.1
Silver	6010			180 days	1
Thallium	6020			180 days	4
Uranium	6020			180 days	0.1
Vanadium	6010			180 days	20
Zinc	6010			180 days	15
Radionuclide					
Radium-226	903.1	1 L HDPE	Nitric acid, pH <2	180 days	1 pCi/L
Major Ions					
Sodium	6010	250mL HDPE[a]	Nitric acid, pH <2	180 days	5000
Potassium	6010				5000
Calcium	6010				5000
Magnesium	6010				5000
Chloride	9056	125 mL HDPE[b]	4 °C	28 days	500
Sulfate	9056				500
Nitrate	353.2	125 mL HDPE	4 °C, sulfuric acid, pH <2	28 days	50
Field Parameters					
The following parameters will be measured in the field: pH, specific conductance, turbidity, temperature, and dissolved oxygen					

Notes:
[a] One 500 mL HDPE bottle needed for Method 6010/6020/7470 analytes.
[b] One 125 mL HDPE bottle needed for Method 9056 analytes.

Abbreviations: HDPE = high-density polyethylene, L = liters, µg/L = micrograms per liter, mL = milliliters, pCi/L = picocuries per liter

H4.4 Sample Documentation

[1] Firmly tighten the lid of the sample container and wipe the container surface.

[2] With a permanent marker, write the mine name, sample ID, analyte, preservative, sampler name, and date and time the sample was collected on the sample container.

[3] Place the sample container in a plastic bag and return to transport vehicle.

[4] Place samples in a cooler with ice for transport back to the LM Field Support Center (LMFSC) at Grand Junction, Colorado.

H5.0 Sample Transfer

- Transfer samples from the transport vehicle to the designated sample storage refrigerator in Building 32 at the LMFSC. Samples must remain in the designated area until they have been surveyed, packaged, and approved for shipment to the analytical lab.
- Before packaging the samples for shipment:

  [1] Apply a label to the side of the sample container and label samples in sequential order (by the sequence in which the samples were collected). Place the initials of the person(s) collecting the sample on the sampler(s) line and document the date and time the sample was collected.

  [2] Complete the following on the COC form: print name(s) in the sampler(s) line and fill in the date and time on the line that corresponds to the label placed on the sample container. Include the mine identification number.

  [3] Keep the COC forms with the samples.

Acids used for water sample preservation are considered materials of trade and will be transported in accordance with Section 2.5 of the *Environmental Instructions Manual*. All drivers will receive the *DOT Hazardous Material Awareness for the General Hazmat Employee* (HM100) training before transporting acids.

Acid containers must be clearly marked with the common name or proper shipping name of the acid and must be leak-tight and securely closed, secured against movement, and protected from damage. Acid will be packaged in containers in the manufacturer’s original packaging or in a package of equal or greater strength and integrity.

H6.0 Sample Shipment

[1] Prepare the individual sample container so that the required sample identification, COC form, and security seal (as deemed necessary by the receiving laboratory or LMS sample custody protocol) are in place. Combine all sample containers (four) from each sample set into individual sample bags.

Note

All ice in the sample shipping container needs to be bagged. Transport companies (e.g., FedEx Corporation) will not accept packages with evidence of leakage.

[2] Prepare the shipping container (DRUM-specific beverage type cooler) by lining the container with two 40-gallon, 2.5-millimeter plastic bags. Place an absorbent pad inside the inner bag. Pack the sample by setting the bags into the cooler and surround them with bagged ice so that they are secure in the container and will not move freely. Tie the inner bag closed and then tie the outer bag closed.

[3] Insert the COC forms inside of a plastic bag and place them inside the cooler. Close the lid of the cooler, but do not seal it permanently. The cooler lid will be reopened before shipment.

[4] Perform a radiation dose rate survey on the cooler exterior in accordance with LMS Radiological Control organization procedures. Record the survey results on an LMS *Radiological Survey Map* form (LMS 1553).

[5] Perform an alpha and beta smear survey (for loose surface contamination) on the exterior of the cooler in accordance with LMS Radiological Control organization procedures. Record the survey results on an LMS *Radiological Survey Map* form.

Note: *As these samples are being transported to a laboratory for testing, they are not subject to DOT surface contamination survey limits or the requirement to survey a surface area of 300 square centimeters (cm^2). Use 100 cm^2 as the area to sample.*

[6] Once the *Radiological Survey Map* is complete (excluding the reviewer signature), insert a copy of the completed *Radiological Survey Map* in the bag with the COC forms inside the cooler.

[7] Store samples in the radioactive materials area until authorization for shipment is received from the LMS laboratory coordinator.

[8] Provide the completed *Radiological Survey Map* to the LMS Radiological Control manager for review within 5 working days of survey completion.

[9] Once the LMS laboratory coordinator gives authorization for sample shipment, complete a *Shipping Request* form (LMS 1051) and take the shipping container(s) to Building 2, Shipping and Receiving.

[10] Close and seal the cooler lid in accordance with other shipping and transportation procedures. Place a custody seal on the shipment container.

H7.0 Surface Water Discharge Measurements

Discharge measurements will be made when surface water is observed to be flowing. Generally, these flows will be observed as mine adit discharges or discharges from springs and seeps emanating from slopes within the disturbed area. Install a portable, collapsible stainless steel flume according to the manufacturer's specifications to collect flow measurements. Set the flume into the channel floor in a manner that ensures the entirety of the flow passes through the flume. Level the flume in the channel and read and record upstream and downstream staff gauges. Consult the rating curve specific to the flume throat width to determine discharge. If flowing water is too slow, shallow, or otherwise not able to be measured using the flume, use a graduated container and timer to measure discharge. Log discharge measurement location, date and time, and results (staff gauge readings and resulting rating curve discharge) using a GPS unit and download into the database. If a GPS unit is not available at the time of measurement, record the required information in a field logbook or sample data sheet and transfer the information to the database.

If a large stream is encountered, its discharge rate can be calculated using the float method (or cross-sectional method). This method measures the amount of water passing a point on the stream channel during a given time and is a function of the velocity and cross-sectional area of the flowing water. This method will be incorporated by the field team's geologist.

Water Sampling Field Data

Location ____________________

Sampling Event Date __________ **RIN** __________

Equipment List
Monitoring Equipment Current meter GPS unit Stainless steel flume Turbidity meter YSI with pH, conductivity, and temperature probes **Pumps and Accessories** Dipper arm Hose barbs Hose reel with weight Inverter Reel of tubing Small peristaltic pump and pump-head tubing, power cords **Chemicals** Conductivity calibration solutions (1000 micromhos per centimeter [µmhos/cm]) Deionized (DI) water H_2SO_4 HNO_3 Laboratory-grade detergent such as Alconox or equivalent pH buffer solutions (4, 7, 10) pH paper Primary turbidity calibration solutions **Paperwork** Chain of custody (COC) forms Custody seals DRUM Safety Plan (DSP) Pens or permanent markers Safety Data Sheets (SDS) Sample labels Shipping requests Water Sampling Field Data forms **Miscellaneous** 0.45-micrometer (µm) filters Absorbent pads Disposable nitrile gloves Disposable pipettes and tips Duct/strapping tape Eyewash solution Garbage bags Ice chests and ice Paper towels, Kimwipes Rain gear Safety eyewear Sample bottles (1 L, 500 mL, 125 mL) Scrub brush Sealable plastic bags (e.g., Ziploc) Squirt bottles Tape measure Wash and rinse container (e.g., 5-gallon bucket)

DRUM YSI Pre-Trip Calibration

Date ______ Time ______ Project Location (FOP) ______

YSI No. ______ Cell Constant (should be within 4-6) ______

pH Buffers

4	Manufacturer	______	Lot No.	______	Expiration Date	______
7	Manufacturer	______	Lot No.	______	Expiration Date	______
10	Manufacturer	______	Lot No.	______	Expiration Date	______

Nitric Acid

Mnf. ______ Exp. Date ______ Lot No. ______

Sulfuric Acid

Mnf. ______ Exp. Date ______ Lot No. ______

Specific Conductance Calibration

Standard used: ______ µS/cm Pre Cal. Reading: ______ µS/cm Exp. Date ______

pH 3 Point Calibration

Buffer	mV	Range		Pre Cal. pH Reading	Temp. (°C)	pH Cal. Value
pH 4	______	______	+180 ± 50 mV	______	______	______
pH 7	______	______	0 ± 50 mV	______	______	______
pH 10	______	______	−180 ± 50 mV	______	______	______

HACH 2100Q Turbidity Meter

Instrument Number: ______

Primary Calibration Standards Expiration Date: ______

Date of Primary Calibration (within 3 mths of sampling event): ______

Temperature Check (Compare YSI temperature with NIST reference thermometer.)

NIST Temp. (±1.5 °C) ______ YSI Temp. ______ NIST Cal Due Date ______

Calibrator Name ______

DRUM Water Sampling Daily Operational Checks

Project Location (FOP) ______

Name ______

Date ______ Time ______

YSI # ______ Hach 2100Q Turbidity Meter Instrument # ______

Operational Check Recalibration Required/Conducted? Yes ☐ No ☐

	Standard	Reading	
pH (4/7/10)	______	______	+/-0.2 pH units
Sp Cond (µS/cm)	______	______	+/-10% of standard

Gelex Standards (NTU)

Standard	Reading	P/F (±10%)
______	______	______
______	______	______
______	______	______

Note: see YSI Pre-Trip Calibration sheet for recalibration information

Water Sampling Field Data **Task 113**

Date ______ Project (FOP) Location ______ Mine Name/LMID ______

Surface Water/Flow Information (Choose appropriate units)

Water Depth Cross Section Area ______ Flow Rate ______

Instrument Used to Measure: Flume ☐ Graduated Container ☐ Float ☐ Other (explain) ☐ ______

Sampling Equipment

Dipper Arm ☐ Container Immersion ☐ Other: ☐ ______

Measurement Equipment YSI No. ______ Turbidimeter Type/No. ______ Other: ______

Op Check Time ______ Measurement(s) made: Open container ☐ In-situ ☐

Date	Time	Turbidity (NTU)	Temp. (°C)	Specific Conductance (µS/cm)	pH

Sample Time ______ Weather ______

Filtration: Yes ☐ No ☐ Number of .45 µm filters used ______

Sample Storage: Ice in cooler? Yes ☐ No ☐

Preservation: 1L - Nitric ☐ 500 mL – Nitric ☐ 125 mL - Sulfuric ☐

Comments: ______

Signature of Sampler ______ Date Signed ______

Checked by ______ Date Checked ______

Water Sampling Field Data **Quality Assurance Sample Log**

Date ______ Project Location ______ Location Name ______

Sample Number ______ False Identification Location ______

Sample Type ______

Comment: ______