Grand Canyon National Park

2019 Safety and Health

Review Report

July 19, 2019

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Table of Contents

Executive Summary

The Grand Canyon Safety and Health Review Team (Team) received a delegation of authority from the National Park Service Acting Associate Director, Visitor and Resource Protection to review three distinct areas of the Grand Canyon National Park (GRCA) occupational safety and health program. Those areas were: determining if radiation levels—at the time uranium ore samples were stored in the Park's Museum Collection Facility—posed a health hazard to employees and visitors; a review of the Park's Automated External Defibrillator (AED) program to determine strengths and areas for improvement; and a review of an employee on-duty injury to determine if it was investigated per Department of the Interior and National Park Service policies and if the Park routinely used Job Hazard Analysis (JHA) to identify hazards associated with the operation that led to the injury.

Uranium ore samples were collected and stored in various locations within the park since the 1950s with plans to conduct research on the materials. In 2001, the ore samples were collected from multiple locations in the Park and moved to the Museum Collection Facility. In June 2018, the samples were removed from the Museum Collection facility and placed in the Orphan Mine located in GRCA. Following the removal, the Occupational Safety and Health Administration (OSHA) conducted sampling and determined only background levels of radiation existed in the facility. The term background level is a determination that the radiation level is consistent with what would exist in the environment in that location.

A contract Certified Health Physicist (CHP) accompanied the Team and determined: (1) radiation levels reported in the Intermountain Region's 2018 [GRCA] Trip Report were severely overstated, falsely indicating a serious health hazard existed; (2) levels in the Museum Collection Facility at the time of the review were deemed not to pose a health hazard to employees and visitors; and (3) the CHP's "dose reconstruction" determined the radiation levels in the facility, and elsewhere on the Park where uranium ore was previously stored, were at levels below what would be considered a health hazard when the materials were present in those locations. The CHP's "Ore Dose Assessment Report" received favorable peer review by the National Institute for Occupational Safety and Health.

The Team's review of the Automated External Defibrillator (AED) Program revealed areas for improvement, particularly in the AEDs maintained outside of the Law Enforcement/Emergency Medical Technician (EMT) program. The Team found that the Park's standard operating procedure on the management of the AED program did not conform to the requirements of the National Park Service AED policy outlined in Reference Manual 51, Emergency Medical Services. A Park employee alleged a visitor died of sudden cardiac arrest as a result of AEDs not being positioned per Codes of Federal Regulation. That allegation was not substantiated by the Team. The visitor had been in cardiac arrest for an unknown length of time when a Park employee discovered the visitor already in duress and was very likely beyond the time limits of successful defibrillation. When applied, the AED issued a "No Shock" instruction.

In March 2018, a maintenance supervisor operating a demolition saw to cut aluminum pipe on the Trans Canyon Water Pipeline, was injured when the saw kicked back, resulting in a laceration to the employee's forehead. The Park Safety and Health Manager responded to the incident to initiate an investigation, but stated he was not allowed to access the accident site.

However, Park leadership asserts that they believed the Safety and Health Manager was actively investigating the accident and was unaware he was not granted access to the site. The Team's review of the accident revealed no comprehensive accident report was generated or entered into the accident investigation database or elsewhere that indicated a thorough investigation was ever conducted. The Team was unable to make a firm determination if the Safety and Health Manager was in fact prevented or discouraged from conducting an accident investigation. Upon learning of the incident and the potential seriousness of the injury that could have occurred, the Intermountain Region offered to dispatch a regional Serious Accident Investigation Team, but the Park did not accept the offer indicating it could conduct an investigation with its resources.

The review of the Job Hazard Analysis (JHA) program, particularly focused on the JHAs used by Facility Maintenance personnel in conducting maintenance on the Park's Trans Canyon Pipeline, found that a JHA was developed in 2007 and contained over 80 lines, which is extremely comprehensive. However, the JHA had not been reviewed annually and updated as required. Due to extremely short staffing in the Facility Management Division to include those trained, experienced, and available to conduct maintenance repairs on the Trans Canyon Pipeline, Facility Management Division leadership were often forced to assign untrained and inexperienced personnel from other maintenance functions to work on the pipeline, which supplies water to both the North and South rims of the Park. The Team found that these employees did not receive training in emergency situations to include a review of the specific JHA.

During the Team's short visit to the Park, it observed a culture where employees and supervisors exhibited immense passion to work safely. The greatest issue noted was a sense that communication seemed to fail at multiple levels and a lack of role clarity existed. For instance, the Park's Safety Committee was extremely passionate about serving as an advocate and champion for the safety and health issues Park employees wanted changed. However, the Safety Committee's approach was in total opposition to the work the Park Safety and Health Manager wanted the Safety Committee to conduct, which led to a complete severing of productive communication whatsoever. Here, a simple charter outlining the Safety Committee's roles and responsibilities and reporting structure would have alleviated the issue, but had not been accomplished, allowing the issue to continue unresolved.

The Team noted a general lack of implementation of basic safety and health programs; however, it would be unfair to attribute this observation to Grand Canyon National Park in isolation. This is a continuing issue across the National Park Service and one that the organization is trying to correct through its National Safety, Health, and Wellness Strategy and its implementation mechanism, the *eTool*. The work to build fully implemented, sustainable safety and health programs is an ongoing effort across the National Park Service.

Abbreviations

AED – Automated External Defibrillator
DOI – Department of the Interior
GRCA – Grand Canyon National Park
IMR – Intermountain Region
JHA – Job Hazard Analysis
NIOSH – National Institute Occupational Safety and Health
NPS – National Park Service
OSHA – Occupational Safety and Health Administration
WASO – Washington Area Support Office

Grand Canyon National Park History and Overview

Grand Canyon National Park (GRCA) was established as a National Monument in 1908 by President Theodore Roosevelt under Presidential Proclamation #794 and designated as a National Park by an act of Congress on February 26, 1919. The Park was designated as a World Heritage Site in 1979. The Park measures 1,217,403.32 acres, 1,904 square miles, and 277 river miles. The Park's South Rim rises to 7,000 feet elevation while the North Rim rises to 8,000 feet above sea level.

The Park preserves an iconic geologic landscape and resources ranging from 1,840 to 270 million years old, including diverse paleontological resources; unconsolidated surface deposits; a complex tectonic and erosion history; and Pliocene to Holocene volcanic deposits. The Colorado River established its course through the canyon about six million years ago, and likely evolved from pre-existing drainages to its current course. Geologic processes, including erosion of tributaries and slopes, and active tectonics continue to shape the canyon today. The geologic record in Grand Canyon is an important scientific chronicle and is largely responsible for its inspirational scenery.

The oldest human artifacts found date to the Paleoindian period and are nearly 12,000 years old. There has been continuous use and occupation of the park since that time. Archaeological evidence from the following prehistoric culture groups is found in GRCA: Paleoindian, Archaic, Basketmaker, Ancestral Puebloan (Kayenta and Virgin branches), Cohonina, Cerbat, Pai, and Southern Paiute. Historical-period cultural groups the Hopi, Navajo, Pai, Southern Pauite, Zuni and Euro-American. The Park has recorded more than 4,403 archaeological resources with intensive survey of approximately six percent of the park area. The Park's Traditionally Associated Tribes and historic ethnic groups view management of archaeological resources as preservation of their heritage.

The park is home to an array of wildlife including 373 species of birds, 91 species of animals, 18 species of fish, 58 species of reptiles and amphibians, 8,480 species of invertebrates, 23 non-native animal species, 20 endemic animal species, seven endangered species including the California condor, three Threatened species, and 10 Extirpated species including Grizzly Bears. The Park also possesses 1,750 species of vascular plants, four Endemic species, and 205 Exotic species.

The Park's 2018 recreation visitation was 6,380,495, the second consecutive year recreation visitation exceeded six million.

I. Review of Potential Radiation Exposure from Uranium Ore Samples Stored at Grand Canyon National Park

Executive Summary

An investigation was initiated by the National Park Service, with assistance from the Department of the Interior and Federal Occupational Health, to assess concerns regarding potential employee and visitor exposure to ionizing radiation resulting from uranium-containing ore specimens previously maintained within the museum collection at Grand Canyon National Park (GRCA). The investigation included a site visit, document review, employee interviews, field radiation measurements, and an exposure evaluation based on historical information. The investigation results indicate that health risks are low and that employees and members of the visiting public were not exposed to unsafe levels of radiation.

The investigation team documented the time line and identified several findings related to how the ore specimens were historically stored and the process utilized to remove them from the Museum Collections Building. These findings indicate that the radiation survey conducted by the NPS Intermountain Radiation Safety Officer was inaccurate and overstated the radiation levels associated with the ore specimens. The findings also suggest that several opportunities for improvement exist regarding how GRCA manages its safety program.

Introduction

The U.S. Department of the Interior (DOI) Office of Occupational Safety and Health (OSH) conducted an investigation to evaluate possible radiation exposures resulting from the storage of uranium ore specimens in the museum collection at Grand Canyon National Park (GRCA). This investigation was initiated at the request of the National Park Service (NPS) Acting Associate Director for Visitor and Resource Protection in response to concerns raised by park officials regarding the safety of the ore specimens and their previous storage and display within park buildings. Specifically, the review team was tasked with investigating *the exposure of park employees or visitors to radioactivity from uranium ore stored in the park's collection, [providing] a determination if the health and safety of any park staff or visitors may have been materially impacted, and recommending next steps.*

This report summarizes the investigation on process and relevant findings. The accompanying technical report – **Evaluation of Exposures to Uranium Ore Specimens** – provides a historical evaluation of employee and visitor risk resulting from the storage and display of the uranium ore specimens and recommendations for controlling additional exposures. The technical report and this summary do not address actions taken by park management or staff beyond the historical management of the specimens and their removal from park buildings in June 2018.

Background

A total of 25 ore samples were held by GRCA beginning in the late 1950s. The ore specimens were managed as part of the park's museum collection until they were removed from the Museum Collections Building (i.e. Building 2C) and relocated to the Orphan Mine Site within the park on June 18, 2018. Subsequently, the GRCA Safety Manager raised concerns regarding the radiation measurements taken by the Intermountain Regional Radiation Safety Officer (RSO) once the "Trip Report" was provided to the park. As a result, investigations were initiated by regulatory and health authorities including the Occupational Safety and Health Administration (OSHA) and the Arizona Department of Health Services (ADHS) Bureau of Radiation Control.

Investigative Process

An investigation team composed of representatives from the DOI Office of Occupational Safety and Health, NPS Office of Risk Management, NPS Office of Public Health, NPS Environmental Quality Division, and NPS Geological Resources Division was assembled and assigned with assessing the health and safety risks that the ore specimens may have presented to park staff and visitors. A consulting Certified Health Physicist (CHP) was engaged via an interagency agreement with Federal Occupational Health (FOH) to provide radiation health expertise and conduct the exposure evaluation. The investigation team, including the CHP, visited GRCA during the week of March 4, 2019 to collect field radiation measurements, inspect locations where the ore samples were previously stored, verify the current location of the specimens at the Orphan Mine site, conduct interviews, and gather documentation to support the exposure evaluation process.

Chronological Narrative

Based on a review of relevant records, email correspondence, and interviews, the investigation team assembled the following timeline related to how the ore specimens were managed by GRCA including storage locations and movements. This information was used to support the historical dose estimates provided in the technical report.

Late 1950s

A total of 25 uranium ore samples, primarily from the Orphan Mine site, were obtained by GRCA and logged into the park's museum collection. The specimens were stored and displayed in the current Community Library space (formerly the Naturalist Building).

1966

The ore specimens were relocated to the newly constructed Visitor Center, now the GRCA Park Headquarters Building. Most of the specimens were stored in the basement boiler room or in the Museum Collections room. Two specimens were displayed in the Visitor Center display area from 1966-2000.

2000

The 25 ore specimens were removed from the Visitor Center and transferred to the new Museum Collections Building. The majority of the specimens (20) were placed within storage cabinets within the Natural History Room. One larger specimen was stored on an open shelf within the same room near six (6) additional small uranium ore samples that were not cataloged as part of the museum collection. Four specimens were placed in three marked plastic buckets and placed on the floor in the Natural History Room adjacent to a taxidermy cabinet.

2000-2017

A total of 31 ore samples remained stored in the Natural History Room within the Museum Collections Building. During this time, NPS staff, part-time interns (minors), visiting researchers, and members of the general public (adults and children) accessed the area for varying lengths of time.

June 20-22, 2000

Rocky Mountain Consultants, Inc. conducted a radiation assessment of the ore specimens including radioactivity levels. A report of their findings and recommendations was provided to GRCA in July 2000.

November 2017

A visitor entered the Museum Collections Building with a personal radiation detection instrument (i.e. a Geiger counter). The instrument reacted to the uranium ore samples and other areas of the building. Due to concerns that radiation exposures may be occurring, the museum staff moved the three buckets from the Natural Collections Room to a hallway near the south exit door.

June 11, 2018

The GRCA Safety Manager, accompanied by contractors conducting a safety, health, and environmental audit, entered the Museum Collections Building to conduct a routine inspection. Museum staff raised concerns regarding the safety of the three buckets and specimens stored in the cabinets within the building. As a result, the GRCA Safety Manager contacted the NPS Intermountain Regional (IMR) Office to request assistance. The IMR Safety, Health, and Wellness Manager (Regional Safety Manager) determined that assistance was necessary and dispatched the IMR Radiation Safety Officer (RSO) to GRCA to evaluate the issue. GRCA management instructed all employees to vacate the building pending the RSO's evaluation.

June 12, 2018

A copy of the 2000 Rocky Mountain Consultants, Inc assessment report was provided to the Regional Safety Manager and RSO.

June 13, 2018

The RSO departed from Lakewood, CO for GRCA. He stopped enroute at the NPS Southeastern Utah Group (SEUG) Headquarters in Moab, UT to pick up a Ludlum Model 3001 Multi - Detector Digital Radiation Survey Meter. This RSO determined that the instrument was necessary for measuring the radioactive activity of the uranium ore specimens.

June 14, 2018
The RSO arrived at GRCA to meet with the museum collections staff and the GRCA Safety Manager. The RSO and his wife - a reportedly trained radiation safety technician who accompanied him throughout the trip and assisted with his work tasks - subsequently conducted a self-described “hasty survey” of the Museum Collections Building taking several radiation readings inside and outside the building while noting the values. The GRCA Safety Manager and two museum staff members were present during the survey. The RSO determined that radiation readings from the ore specimens were above background levels. The RSO recommended that the park remove the ore specimens from the building.

June 15, 2018
The RSO returned to the Museum Collections Building in the morning to conduct a more focused radiation survey of the ore specimens and to segregate those producing higher than background levels of radiation. Measurements were taken, but the survey focused on identifying areas/objects with higher radioactivity levels (i.e. above background). The RSO moved the three buckets of uranium ore from the hallway near the south exit door to an isolated shelving unit near the back of the Large Objects Room pending additional instructions. The other ore specimens, which were in small cardboard boxes, were transferred into a plastic tote. The RSO wore rubber gloves while handling the ore. Collections staff and the GRCA Safety Manager observed this process.

The RSO next conducted surveys of the Park Headquarters Building basement, Grand Canyon Power House, and the exterior of a storage container (i.e. Conex Box) located near the Fee Building. All areas were negative for increased radioactivity (i.e. above background) except near the storage container. The RSO later met with the GRCA Superintendent to provide an update and discuss options for the transfer and/or disposal of the ore specimens.

June 16, 2018
The RSO conducted an additional radiation survey along the Trail of Time walking path near the Canyon’s south rim. The survey did not indicate radiation above background levels.

June 18, 2018
The GRCA Superintendent, in consultation with NPS Environmental Compliance and Cleanup Branch (ECCB), authorized the RSO to remove the ore samples from the Museum Collections Building and place them in sealed and labeled containers inside of the fence enclosing the Orphan Mine Site until arrangements for proper disposal could be made. The RSO loaded the buckets and tote into the back of the GRCA Safety Manager’s government-owned pickup truck. The RSO wore rubber gloves covered with cotton utility gloves while handling the specimens and used a mop handle to place the buckets in the bed of the pickup. The RSO, his wife, and the Grand Canyon Safety Manager then drove to the Orphan Mine Site (approximately 3 miles) and all proceeded to enter the locked, fenced enclosure.

Once on site, the RSO became concerned that the buckets would be conspicuous to park visitors and employees, and that the buckets might be pilfered if left in plain sight. The RSO then proceeded, without further consultation or direction, to remove the ore specimens from the buckets and boxes/tote and bury them in the ground using a shovel and covering them with 1-2 inches of soil. The RSO and GRCA Safety Manager then departed the mine site. The RSO conducted a radiation scan on the pickup prior to leaving the enclosure area. They then proceeded to the vehicle maintenance yard to rinse off the vehicle, buckets, and shovels. The RSO returned the buckets and shovels to the Museum Collections Building Large Objects Room. The RSO then departed the park.

July 9, 2018
The Regional Safety Manager responded to a request for information from the NPS Office of Risk Management regarding the removal of the ore specimens including field radiation levels recorded by the RSO. The Regional Safety Manager discussed the request with the RSO who provided him a draft trip report. The draft report did not contain any radiation measurements.

July 10, 2018
The Regional Safety Manager discussed the radiation measurements with the RSO via phone. The Regional Safety Manager then added the measurement information to the draft trip report provided by the RSO. The RSO reported that most of the values were "based on memory". The Regional Safety Manager then emailed the requested information, including radiation levels, to the NPS Office of Risk Management.

August 13, 2018
The Regional Safety Manager provided a copy of the trip report, including radiation values, to GRCA management including the GRCA Safety Manager.

Findings

Based on a review of pertinent records, information provided during interviews, site observations, and conclusions presented in the technical report, the investigation team identified 13 findings. Each finding represents a single event or condition based on factual information as determined by the investigation team. Findings are essential steps in the incident sequence based on the weight of evidence, professional knowledge, and judgment.

1. The radiation measurements provided in the RSO's August 23, 2018 Trip Report were inaccurate and indicate radiation levels approximately 200 times higher than expected based on background levels and historical survey data.

2. Past radiation exposures from the uranium ore specimens stored at GRCA were approximately 3.5% of the OSHA quarterly dose limit of 1.25 rem and were within permissible exposure limits for employees.

3. Past exposures to uranium ore specimens at GRCA for visitors are a small fraction of the natural background radiation the average American receives annually and well within (<5%) of the Nuclear Regulatory Commission's dose limits for members of the public.

4. Exposure modeling indicated that past exposures to uranium ore specimens at GRCA are a small fraction of the natural background radiation and do not not represent a health risk.

5. The RSO was unfamiliar with the operation of the Ludlum Model 3001 Multi-Detector Digital Survey Meter and did not have prior experience or specific training related to the instrument.

6. The Ludlum Model 3001 instrument was within its annual calibration guidelines at the time of the survey with a most recent manufacturer's calibration date of October 6, 2017.

7. The Ludlum Model 3001 rate meters and detector were more than likely improperly configured during the June 2018 survey conducted by the RSO.

8. The RSO used the radiation meter in a qualitative manner and did not take adequate field notes to document the radiation readings.

9. The GRCA Safety Manager was present for a portion of the radiation survey but did not document any of the radiation readings taken by the RSO.

10. The RSO's wife (not an NPS employee) participated in the radiation survey and removal of the ore specimens from the Museum Collections Building and transfer to the Orphan Mine site.

11. The GRCA Safety Manager had limited contact with the Regional Safety Manager and RSO after the specimens were transferred to the Orphan Mine Site and did not seek additional information or clarification when he suspected that the radiation measurements in the RSO's trip report were inaccurate.

12. Current radiological conditions within the Museum Collections Building and the Park Headquarters Building did not exceed established limits and did not pose a significant health hazard.

13. Low levels of residual alpha and beta particle contamination were present within three mineral specimen storage cabinets in the Natural History Room. This low-level radiological contamination is not a routine exposure hazard because the cabinets are kept shut and are not opened on a routine basis.

Other Findings

The investigation team identified six other findings, which while not directly related to the incident, may result in unsafe or unhealthful work conditions if left uncorrected.

1. GRCA personnel had not received safety and health training regarding the chemical, physical, and biological hazards associated with museum objects.

2. GRCA had not completed job hazard analyses (JHAs) or developed standard operating procedures (SOPs) for museum operations.

3. GRCA had not documented a personal protective equipment (PPE) hazard assessment for museum operations.

4. GRCA had not conducted a comprehensive exposure assessment to identify potential health and safety hazards within the Museum Collections Building or objects contained within the park's collection.

5. The Museum Collections Building had not been subject to required annual safety inspections since 2014.

6. The GRCA Safety Manager had not received any formal training in radiation safety and health.

7. The GRCA Safety Manager released the three buckets that previously contained ore specimens to the Arizona Department of Health Services.

Recommendations

The investigation team recommends that the following actions be taken by NPS and GRCA based on the identified findings to reduce organizational and employee risk, and to further determine the appropriateness of the response to this incident.

1. Develop written policies and procedures to ensure that employees and managers are aware of potential hazards within their workplace and take appropriate actions to mitigate risk. This includes, but is not limited to: completion of JHAs for all job tasks; conducting formal exposure assessments to determine the types of hazards present, potential routes of exposure, and appropriate protective measures; development of SOPs for routine work tasks; and, completion of a written PPE hazard assessment.

2. Provide appropriate safety and health training for regional/park staff and managers based on their workplace exposures and potential exposures. For the museum collection staff, training should include the chemical, physical, and biological hazards associated with their work arising from museum objects. For the GRCA Safety Manager, provide formal training in radiation safety and control methods. For the RSO, ensure that training regarding the use and limitations of instruments is provided.

3. Implement an ongoing facility inspection program to identify, document, and correct hazards in the workplace. These inspections should be conducted on a periodic basis, but not less than annually.

4. Decontaminate the interior of cabinets N.B16, N.B17, and N.B18 and N.E01 within the Natural History Room. Although this condition is not an immediate health concern, museum collections staff should wear disposable nitrile gloves to prevent cross-contamination when accessing these areas.

Review of Automated External Defibrillation Program
Grand Canyon National Park
2019

Summary

This review was conducted to evaluate the current automated external defibrillation (AED) program at Grand Canyon National Park (GRCA). Concerns had been raised by GRCA staff regarding insufficient maintenance of AED units, unclear procedures, and general lack of awareness and understanding of the GRCA AED program. Further, a park employee alleged that a visitor died of sudden cardiac arrest as a result of AEDs not being positioned per Codes of Federal Regulation and/or inadequate AED maintenance. An assessment of the GRCA AED program, which included a review of documentation, an evaluation of current procedures, and interviews with key staff, revealed that this allegation was not substantiated, and there is insufficient information to conclude that the health and safety of any park employee or visitor had recently been materially impacted by the AED program. However, the investigation did reveal that there are several significant programmatic gaps that need to be addressed. Per National Park Service (NPS) policy documents and best practices documents, AED programs require compliance with several elements that include:

- Support of the program by leadership
- Understanding legal aspects for EMS and non-EMS responders
- Needs Assessment of AED program that is evaluated on a periodic basis
- Medical oversight
- On-going Training of responders in CPR and the use of the AED and accessories
- Routine evaluation of placement and number of AEDs
- Maintaining hardware and support equipment on a regular basis and after each use
- Development and regular review of the program and standard operational protocols (SOPs)
- Development of an emergency response plan and protocols
- Educating all employees regarding the existence and activation of the AED program
- Development of quality assurance plans
- Development of measurable performance criteria, documentation and periodic program review

The current GRCA AED program does not sufficiently address each of these elements in a systematic, programmatic manner. Recommendations are presented in this review that incorporate the above essential (and required) program components; and guidance is provided on how to fill the identified gaps, which if addressed, will lead to improved outcomes and decreased liability for GRCA, the NPS, and the US Department of the Interior.

Introduction

An AED is a device designed to improve the survival rate for victims of cardiac arrest. AEDs enable minimally trained personnel to safely restore a victim's heart from ventricular fibrillation (completely disorganized electrical activity, and its consequent absence of effective pumping activity) to the victim's previous electrical and pumping activity. Early defibrillation and cardiopulmonary resuscitation (CPR) can dramatically improve survival after cardiac arrest. Successful resuscitation depends on the rapid response of bystanders – both trained and untrained – to initiate CPR and locate the nearest AED before the arrival of emergency medical services.[1] Because the effectiveness of these devices used in conjunction with CPR has been demonstrated, it is common to observe AEDs in public locations.

The importance of providing access to AEDs is illustrated by the following facts:

- Sudden cardiac arrest (SCA) is a leading cause of death in the U.S., accounting for more than 356,000 deaths outside the hospital each year[2]
- Traditional first aid, including cardiopulmonary resuscitation (CPR), isn't enough if the victim is suffering a SCA.[3]
- Without intervention, such as CPR/AED, less than 10% of SCA victims survive[4]
- It is unlikely that a SCA victim will recover without defibrillation within a ten-minute window; for each minute that a person is in cardiac arrest, their chance of survival decreases by 10%[5]
- When CPR and AEDs are used within three to five minutes from the onset of collapse, the survival rate of a sudden cardiac arrest victim is as high as 50 to 70 percent.[6]
- Less than half of SCA victims get the immediate help they need before emergency responders arrive, in part because emergency medical services take, on average, between 4 and 10 minutes to reach someone in cardiac arrest[7]
- Waiting for the arrival of emergency medical system personnel results in only a 5-7% survival rate[8]

[1] Kilaru, Austin, et al. Use of Automated External Defibrillators in US Federal Buildings, Journal of Occupational and Environmental Medicine, 2014; 56: 86-91.
[2] Benjamin et al.
[3] AED State Laws, https://www.aedbrands.com/resource-center/choose/aed-state-laws/
[4] Weisfeldt ML, Sitlani CM, Ornato JP, et al. Survival after application of automatic external defibrillators before arrival of the emergency medical system: evaluation in the resuscitation outcomes consortium population of 21 million. J Am Coll Cardiol. 2010;55(16):1713–1720.
[5] Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: a graphic model. Ann EmergMed. 1993;22:1652–1658..
[6] Ibrahim WH. Recent advances and controversies in adult cardiopulmonary resuscitation. *Postgrad Med J*. 2007;83(984):649–654.
[7] Benjamin et al.
[8] OSHA publication 3185-09N (2003), https://www.osha.gov/Publications/3185.html

- Survival from cardiac arrest doubled when a bystander stepped in to apply an AED before emergency responders arrived.[9]

While there is no legal requirement to have an AED program in Federal facilities, it is often recommended that employers consider the use of AEDs in public areas and in the workplace to respond to a SCA. All fifty states have enacted various laws and/or regulations requiring that certain public gathering places have AEDs available.[10]

The National Park Service (NPS) is committed to the existence of an AED program in the park. The NPS Reference Manual– 51 (RM-51), Chapter 10 Automated External Defibrillators states, "The goal of an AED program is to increase the rate of survival of people suffering from sudden cardiac arrest. The key is to minimize the time from the onset of cardiac arrest to defibrillation. This can only be accomplished when the site has an appropriate number of AEDs placed in strategic and easily accessible locations and the appropriate number of people trained to use them." The document adds "AEDs are designed to be used by both medical and non-medical personnel who have been properly trained." [11]

Per the Grand Canyon National Park EMS Plan, "The goal of an AED program is to increase the survival rate for people suffering from sudden cardiac arrests. Grand Canyon National Park will continue to work through the park's AED Program to increase the number and availability of AEDs park-wide. This will include placement in areas where the necessity is highest (e.g., visitor centers, administration buildings, campgrounds, etc)." Additionally, the GRCA EMS Plan notes: "To maintain the current level of service and to continue to strive for efficiency and safety within the park EMS program there are some factors which need to be addressed, including;

- Install automatic external defibrillators (AEDs) in all park office building and establish an AED program for Grand Canyon National Park. Some work units have taken the initiative to purchase an AED for the workspace, however it would be beneficial to have uniform coverage throughout park office buildings. Without rapid access to an AED, the chance of survival in a cardiac arrest patient decreases dramatically by delaying critical, lifesaving defibrillation.. Having an AED in all major park offices and/or large concession facilities will increase survival rates of patients with cardiac arrest."[12]

These two documents clearly demonstrate that GRCA appreciates the need for rapid access to AEDs, and is dedicated to the existence of an AED program that is utilized not solely by EMS

[9] Weisfeld et al.
[10] Laws on Cardiac Arrest and Defibrillators, http://www.ncsl.org/research/health/laws-on-cardiac-arrest-and-defibrillators-aeds.aspx
[11] National Park Service Emergency Medical Services Reference Manual RM-51, 2009, https://docs.google.com/a/nps.gov/viewer?a=v&pid=sites&srcid=bnBzLmdvdnxsZXNlc3xneDo2OWZkNTNhOTNjZGZmNzZi
[12] Grand Canyon National Park EMS Plan, March 2012

but is also accessible by lay responders. This latter type of program is referred to in RM-51 as "Open Accessibility," but is more commonly called a Public Access Defibrillation (PAD) program.

PAD Program:

RM-51 touches on --but does not clearly delineate-- the difference of utilizing AEDs by EMS versus having a Public Access Defibrillation (PAD) program in which AEDs are used by trained lay responders. The concept of a PAD program is to decrease time to defibrillation, before EMS arrives to the scene--because with sudden cardiac arrest, every minute counts and defibrillation should occur within 3-5 minutes of collapse. A PAD program relies on lay responders (non-EMS) who have been trained in CPR and the appropriate use of AEDs. If a federal entity chooses to have a PAD program, the program should be developed so that the lay responders have the training as well as properly maintained devices to successfully react to an event, and that liability for the lay responder and the federal facility is limited. For this reason, the Department of Health and Human Services and General Services Administration published a best practices document entitled "Guidelines for Public Access Defibrillation Programs in Federal Facilities." [13]

Leadership/Program Management

Currently, the Grand Canyon National Park's AED program is coordinated and managed by Emergency Medical Services (EMS) under policies outlined in the National Park Service Director's Order #51: Emergency Medical Services[14] (DO), in conjunction with RM-51.[15] These policy documents establish and define standards and procedures for the National Park Service Emergency Medical Services program. Per the DO, "The policies, procedures, and standards in this document are to be implemented uniformly throughout the NPS." [16]

According to RM-51, "It is the responsibility of each Park Superintendent to ensure that the Park EMS Program is in compliance with DO-51 and RM-51." Program accountability lies within the individual Park Superintendent, and the GRCA EMS Plan is administered by the Division of Visitor and Resource Protection, with the Branch Chief of Emergency Services designated as the EMS program manager. GRCA has an EMS coordinator who is responsible for managing the GRCA AED program.

[13] Guidelines for Public Access Defibrillation Programs in Federal Facilities, https://www.govinfo.gov/content/pkg/FR-2009-08-14/pdf/E9-19555.pdf
[14] NPS Director's Order #51: Emergency Medical Services, https://www.nps.gov/policy/DOrders/DO-51.html
[15] Ibid
[16] Ibid

Governing/Guidance Documents, Legal considerations

As noted within the NPS Director's Order #51 (NPS DO) in reference to RM-51, "The policies, procedures, and standards in this document are to be implemented uniformly throughout the NPS." [17] Thus, it is expected that GRCA's AED program would be in line with the AED chapter in RM-51. *(Note: The AED program document outlined in the GRCA EMS Plan dated March 2012 is not equivalent/insufficient to the requirements of RM-51).* Additionally, because the GRCA AED program encompasses not only AEDs specifically for EMS providers, but also includes a public access component, it is recommended that GRCA leadership become familiar with applicable laws and best practices surrounding AED programs to better understand how liability can be minimized. The references below are not an exhaustive list of applicable AED laws and best practices, and are provided solely to illustrate the importance of understanding and implementing essential components of an AED program. It is recommended that GRCA consult a solicitor to address any legal questions.

Federal Statute:

- For lay responders ("Good Samaritans"): The Cardiac Arrest Survival Act (CASA) was passed by Congress in 2000. Congress found that "limiting the liability of Good Samaritans and acquirers of AED devices in emergency situations may encourage the use of AED devices in emergency situations, and result in saved lives."[18] CASA grants civil immunity to any person who uses or acquires an AED, provided that any resulting harm was not due to the failure of an acquirer to (1) notify emergency response personnel of the device's placement, (2) properly maintain and test the device, or (3) to provide appropriate AED training to an employee, unless the AED user was not an employee or expected user of the device. Immunity does not attach if the harm was caused by willful, grossly negligent, reckless misconduct, or flagrant indifference to the victim's safety, or if the AED user is a licensed health care professional or provider acting in the scope of employment.[19]

- For EMS: EMS providers are not covered by CASA as they have a duty to act as health care providers acting in the scope of employment, but they would likely be covered by the Federal Tort Claims Act (FTCA) provided they meet certain criteria. RM-51, Chapter 16 outlines legal aspects as they related to EMS providers.

State of Arizona laws:

[17] Ibid
[18] Cardiac Arrest Survival Act of 2000, https://www.govinfo.gov/content/pkg/FR-2009-08-14/pdf/E9-19555.pdf
[19] Ibid

According to RM-51, the state may not impose its regulatory power upon the NPS without specific congressional consent. However, in the CASA act, there could be some action for civil liability in a state where there is no applicable Federal law. Therefore it is recommended that GRCA consult with a solicitor to determine if GRCA must adhere to the following state of Arizona laws regarding the use of AEDs:

> <u>Arizona Revised Statutes § 36-2262</u>
> Except as provided in section 36-2264, a person or entity that acquires an automated external defibrillator shall:
>
> 1. Enter into an agreement with a physician who shall oversee the aspects of public access to defibrillation.
>
> 2. Require each trained user who uses an automated external defibrillator on a person in cardiac arrest to call telephone number 911 as soon as possible.
>
> 3. Submit a written report to the bureau of emergency medical services and trauma systems in the department of health services within five working days after its use.
>
> 4. Ensure that the automated external defibrillator is maintained in good working order and tested according to the manufacturer's guidelines.[20]

Best Practices:

CASA also delegated the Secretary of Health and Human Services (HHS) to establish guidelines for implementation of AEDs in Federal buildings. These guidelines are contained in the document *Guidelines for Public Access Defibrillation Programs in Federal Facilities*,[21] (hereafter referred to as *HHS Guidelines for Federal PAD programs*) and serve as a general framework for Public Access Defibrillation (PAD) programs in Federal facilities. In parallel with RM-51 for EMS providers, this document is widely considered “good and accepted practice” or the “Standard of Care” for PAD programs.

This document notes that each PAD program should include the following major elements:

- *Support of the program by each of the facility's occupant agencies*
- *Training and retraining personnel in CPR and the use of the AED and accessories*
- *Obtaining medical direction and medical oversight from nationally recognized institutions or agencies*

[20] Arizona Revised Statutes Automated External Defibrillators, https://www.azleg.gov/ars/36/02262.htm
[21] HHS Guidelines for Federal PAD Programs

- *Understanding legal aspects*
- *Development and regular review of the PAD program and standard operational protocols (SOPs)*
- *Development of an emergency response plan and protocols, including a notification system to activate responders*
- *Integration with facility security and EMS systems*
- *Maintaining hardware and support equipment on a regular basis and after each use (Note: AEDs are not building equipment and, as such, are not inventoried or maintained by GSA or property management personnel)*
- *Educating all employees regarding the existence and activation of the PAD program*
- *Development of quality assurance and data/information management plans*
- *Development of measurable performance criteria, documentation and periodic program review*
- *Review of new technologies*[22]

[22] Ibid

Discussion/Recommendations:

Based on a review of documents and interviews with key personnel, it is clear that there are gaps in the GRCA AED program that need to be addressed in order to bring the program into compliance with RM-51 and in order to reduce liability for GRCA. It is understood that the RM-51 policy requires all NPS AED programs to be implemented uniformly, thus this review will focus heavily on how the GRCA AED program can better align with RM-51. The *HHS Guidelines for Federal PAD programs*, albeit a guideline document, serves as best practices for PAD programs within the federal government, thus this document will also be referred to in this review, where applicable, to address gaps in the GRCA AED program.

Starting with key points outlined in RM-51, essential AED program components, findings, and recommendations include:

1. **AED Needs Assessment/Update GRCA EMS Plan chapter on AED program:**

Per the NPS DO, "The EMS Needs Assessment is the fundamental tool used in the development of a park's EMS program. Each superintendent must assess the emergency medical resources available to them, and ensure that their EMS program has been developed and maintained so that all persons have access to emergency medical care as per current standards. It is important that each park's EMS program be evaluated on a continuous basis and to make adjustments as necessary. The EMS Needs Assessment will be completed or updated by the Park EMS Coordinator and submitted every three years to the superintendent or designee."

RM-51 adds, "Each park manager will complete an EMS Needs Assessment and develop and implement a program to meet identified needs, in accordance with this Reference Manual."

RM-51 outlines the criteria that should be considered in a Needs Assessment:

> *"As part of the overall EMS Needs Assessment, the following criteria should be considered in determining the need for an AED program:*
>
> > *• Probability of use of an AED due to cardiac arrest is at least one use in 5 years.*
> > *• Is the EMS call-to-shock time interval of less than 5 minutes reliably achieved with conventional EMS services and if not, can NPS AEDs be brought to the same location within that time frame?*
> > *• Do large numbers of people frequent the area?*
> > *• Does this location have an at-risk workforce and/or visitor population?*
> > *Risk factors include:*

1. Men age 40 or older
2. Post-menopausal women
3. High blood pressure
4. High cholesterol
5. Sedentary lifestyle
6. Diabetes
7. Personal history of heart disease
8. Family history of heart disease

• Is this location considered a high-risk location? High-risk locations include:

1. High activity/recreation area
2. Areas where people experience high levels of stress
3. Areas where people spend long periods of time

• Hazardous materials/conditions (chlorine, electrical, etc).

• Physical layout of the facility.

1. Multiple floors
2. Size of office space or number of rooms"[23]

Grand Canyon National Park conducted a needs assessment and established its own EMS plan (GRCA EMS Plan), dated March 2012. [24] As noted previously, Page 12 of the GRCA EMS Plan states:

> *"To maintain the current level of service and to continue to strive for efficiency and safety within the park EMS program there are some factors which need to be addressed, including;*
>
> - *Install automatic external defibrillators (AEDs) in all park office building and establish an AED program for Grand Canyon National Park. Some work units have taken the initiative to purchase an AED for the workspace, however it would be beneficial to have uniform coverage throughout park office buildings. Without rapid access to an AED, the chance of survival in a cardiac arrest patient decreases dramatically by delaying critical, lifesaving defibrillation.. Having an AED in all major park offices and/or large concession facilities will increase survival rates of patients with cardiac arrest."*[25]

RECOMMENDATIONS:

- Per the NPS DO, the EMS Needs Assessment is to be updated every three years, however, it is unclear if a more recent Needs Assessment has been conducted. It is recommended that GRCA conduct an updated Needs Assessment for the AED

[23] RM-51
[24] GRCA EMS Plan
[25] Ibid

program using the criteria in RM-51 for consideration. GRCA should determine if the goal continues to exist for uniform coverage throughout park office buildings, and determine if there is a need for additional AEDs in the park. The criteria in RM-51 is not limited to dense visitor areas—other areas for consideration include high-risk areas, locations with hazardous materials/conditions, and physical layout. GRCA should also analyze EMS response times from dispatch to arrival at patient, and consider areas where EMS would be unable to arrive within about 5 minutes. As part of conducting this assessment, it is recommended that the needs assessment evaluation includes consultation with personnel from Safety, Visitor and Resource Protection, Concessions, Interpretation, Facilities Management, and other key operational programs to ensure a thorough understanding of park-wide AED needs, and to assure the most efficient use of resources and the best outcomes possible.

- After conducting a Needs Assessment, it is recommended that GRCA create an updated AED Program document (within the GRCA EMS Plan) to be in line with the requirements of RM-51. Currently, the AED Program document within the GRCA EMS Plan is not uniform with RM-51, it provides insufficient detail on necessary AED program components, it is incomplete as it does not address necessary AED program components, and continued use of this document as currently written is not recommended.

2. **Medical Oversight:**

RM-51 states, *"All park units that have an AED will have a Medical Advisor that provides oversight to the AED program. The Medical Advisor's duties are as follows:*

• Provide medical direction for determining equipment selection and use of the AED.
• Write a prescription for new AED purchases. The Food and Drug Administration has classified the AED as restricted, prescription devices.
• Provide and review guidelines for emergency procedures related to the use of the AED.
• Evaluate and review all AED patient encounters"

Medical direction for the GRCA EMS program as well as the GRCA PAD program is provided by Drew Harrell, MD, a board certified physician in Emergency Medicine. Dr. Harrell acknowledged his participation in and support of this program in a letter dated 25 March 2019. The GRCA AED program manager noted that Dr. Harrell is required to review every event in which an AED is used. While several EMS patient care records and general reports were provided for review, medical oversight reports were not provided; thus it is unclear if this is occurring.

RECOMMENDATIONS:

- Ensure that the Medical Advisor is consulted and involved in all of the duties listed above.

- RM-51 outlines cardiac arrest protocols for EMS; however the Medical Advisor should also review protocols and emergency procedures related to the use of the publicly accessible AEDs, as these are different from EMS.

3. **Training**:

According to RM-51, CPR/AED training is recommended for all park employees. The GRCA EMS Plan similarly notes, "All park employees are encouraged to participate in CPR classes. It is the park's goal to have all permanent employees certified in basic life support."[26]

The AED program manager at GRCA noted that almost all training is conducted at the park, and separate courses are offered to different types of employees. The GRCA EMS Plan indicates that non-uniformed employees take the Heartsaver AED course, and uniformed employees take Heartsaver AED/First aid course. Visitor protection or other certified primary care EMS providers take the Basic Life Support for Healthcare Providers course.

All EMS providers at GRCA receive their training at regular intervals (every two years). According to the AED program manager, lay responders do not have a formal training schedule. The AED program manager noted that due to low staffing/hiring vacancies not being filled, the number of classes offered to lay responders has diminished significantly in the past few years. The AED program manager did not have a list of trained lay responders.

RECOMMENDATIONS:

- Determine if the goal still exists to have all permanent employees certified in basic life support. If not, determine which category of employees and how many employees should be trained.

- Develop a formal training program and recertification schedule for lay responders. The greater the number of well-trained lay responders that are available, the more effective a PAD program will be. Training for lay responders should be conducted at the frequency as recommended by nationally recognized training organizations, at least every two years. If the park is unable to conduct the training due to low staffing

[26] Ibid

levels, it is recommended that training be outsourced to an outside entity to ensure adequate numbers of employees are certified in basic life support.

- AED program manager should maintain a list of all trained responders (not just EMS providers), their expiration dates, and their contact information.

- Training should include general information about the GRCA AED program, and ensure that responders are aware of locations of all AEDs throughout the park.

4. Placement and Number of AEDs

A park employee alleged that a visitor died of sudden cardiac arrest as a result of AEDs not being positioned per Codes of Federal Regulation. Specifically, the allegation to the Office of Special Council noted, "The GCNP Desert View Ranger's Office and Waste Water Treatment Facility do not have automated external defibrillators located and accessible within three to five minutes in the event of an emergency, as required by 29 CFR § 1915.87 App. (A)(4)(a)."[27] This allegation is inaccurate. The regulation described in 29 CFR Part 1915 is a shipyard standard and therefore does not apply to general industry operations in the park. Further, this regulation does not state that AEDs must be located and accessible within three to five minutes in the event of an emergency. This maritime regulation states that a first aid provider must be able to reach an injured/ill employee within five minutes of a report of a serious injury, illness, or accident such as one involving cardiac arrest, acute breathing problems, uncontrolled bleeding, suffocation, electrocution, or amputation.[28] Appendix A of this same document does state, "Ensure that AEDs are located so they can be utilized within three to five minutes of a report of an accident or injury," however this is a non-mandatory Appendix entitled "First Aid Kits and Automated External Defibrillators (Non-Mandatory)."[29] The general industry standards for medical first aid that would apply to the operations at GRCA are contained in 29 CFR 1910.151, *Medical Services and First Aid*,[30] and in this regulation, there is no mention of AEDs.

Despite the lack of regulatory backing for the park employee's allegation, further investigation also revealed a concern among other GRCA employees regarding inadequate placement of AEDs. Placement is a critical aspect of an AED program. As noted previously, chances of survival for a victim of sudden cardiac arrest decreases by 10% for each minute that a person is in cardiac arrest, and when an AED is used within 3-5 minutes of an event, survival rates increase dramatically.

RM-51 states,

[27] McMullen, Catherine. "Informal resolution of OSC reported safety violations at Grand Canyon." Email received by Michael May, February 26, 2019.
[28] https://www.osha.gov/laws-regs/regulations/standardnumber/1915/1915.87
[29] https://www.osha.gov/laws-regs/regulations/standardnumber/1915/1915.87AppA
[30] https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=9806&p_table=STANDARDS

"Optimal locations and numbers of AEDs are such that trained individuals can access them and reach the patient within a target response time of three to five minutes (3 minutes is optimal, 5 minutes is considered acceptable). This is defined as the time it takes a responder to go from his/her work area to retrieve an AED and then, walking at a rapid pace, to reach the victim. When locating an AED, the responder should consider placing them in areas where the risk assessment is highest (i.e., visitor centers, administration buildings, campgrounds, etc). Consider equipping all EMS first response vehicles and ambulances with an AED that are not already equipped with an ALS defibrillator."

RM-51 notes that the optimal locations and numbers of AEDs are such that an AED can be applied within 3-5 minutes. RM-51 also points out that areas of high risk should be considered. The *HHS Guidelines for Federal PAD programs* notes that "there is no single 'formula' to determine the appropriate number, placement, and access system for AEDs," but "there are several major elements that should be considered"[32] that include the items listed in RM-51. One element that should be stressed for consideration of AED placement is EMS response times. In the three patient care reports provided for review, the time from dispatch to EMS arrival to the patient was 32, 35, and 39 minutes. While this may not be a representative average of all GRCA EMS response times, it is clear that GRCA should fortify the PAD AED program to ensure a more timely AED placement by lay responders to victims of sudden cardiac arrest. As noted previously, updated Needs Assessment is essential in determining adequate placement and number AEDs.

Other considerations for placement include:

- The defibrillator should be easy to reach in a location free of obstacles. This could include a location near existing emergency equipment, such as fire extinguishers and first-aid kits. When considering location, avoid areas that expose the defibrillator to moisture, dust, or extreme temperatures. Recommended storage temperature is 15° to 35° C (59° to 95° F). Storage at higher temperatures will shorten the life of the battery and electrodes."[33]

- *HHS Guidelines for Federal PAD programs* has similar recommendations, and adds the criteria of placing AEDs in a secure location to minimize the potential for tampering, theft, and misuse. An additional important consideration for AED placement is one that is well marked, publicized and known among trained staff.

Number of AEDs:

[32] HHS Guidelines for Federal PAD Programs

[33] Operating Instructions for Physio Control Lifepak CR Plus Defibrillator, https://www.physio-control.com/uploadedFiles/Physio85/Contents/Workplace_and_Community/Products/CRPlus_OI_3201686-011.pdf

The document "GRCA AED Inventory," indicates that there are a total of 60 AEDs at the park; 32 of these are EMS AEDs located in law enforcement patrol vehicles, and 28 are placed throughout the park in publicly accessible locations such as headquarters building, maintenance building, clinic, and information desk. *[Note: Additionally, the three concessionaires who operate in Grand Canyon National park have a contractual obligation to provide and maintain a number of AEDs in public access locations in places such as lodges, general store, and trading post. The concessionaire AED programs have not been reviewed as part of this evaluation.]*

According to the AED Inventory spreadsheet, all of the AEDs in the inventory are the Lifepak CR Plus (CR+) model, manufactured by Physio Control, with the exception of one unit at the Albright Training Center, which is manufactured by Zoll. All of the CR+ AEDs are relatively new as they replaced the older Physio Control model, the Lifepak 500 (LP500), which was discontinued in 2007. According to the AED program manager, the replacement of LP500 AEDs was phased out between 2006 and 2018. At the time of this review, however, a photograph dated March 24, 2019 of a deployed AED was an LP500, thus it is unclear if the inventory spreadsheet is current and accurate.

RECOMMENDATIONS:

- Based on results of updated Needs Assessment, determine if additional AEDs need to be added or moved to a new location, and ensure all AEDs are placed in optimal locations.
- Analyze EMS response times from dispatch to arrival at patient, and consider placing AEDs in high risk areas where EMS would be unable to arrive within about 5 minutes.
- Consider creating and widely distributing a map where all AEDs are located within the park to educate GRCA staff on locations of all AEDs.
- Ensure AEDs are clearly marked and known among trained staff
- Update AED inventory spreadsheet on a monthly basis and expand spreadsheet to incorporate all items in RM-51 Exhibit 5, "Sample Monthly AED Check and Maintenance Log" into the spreadsheet

5. <u>Supplies</u>

According to RM-51, the following supplies should be stored with each device: A razor, barrier device, spare battery, disposable gloves, and two sets of electrodes. RM-51 adds additional supplies for consideration: a biohazard bag, small towel, and a set of concise instructions for performing CPR, and pen and paper.

The *HHS Guidelines for Federal PAD programs* recommends all of the above items and recommends the addition of 4x4 gauze pads to clear and dry skin to assure proper electrode-to-skin contact, and a pair of medium size bandage or blunt end scissors if clothing needs to be cut.

To clarify the language of "spare battery": The Physio Control Lifepak CR+ AED uses an internal rechargeable lithium battery that can be recharged by connecting the AED to the Physio-Control CHARGE-PAK battery charger; therefore, the spare battery referred to in RM-51 is, in this situation, a CHARGE-PAK battery charger. The battery charger provides a trickle charge for the internal battery and can provide a charge for approximately two years, as long as the defibrillator is not used. The battery charger should always remain connected to the Physio Control AED to ensure that the battery is fully charged and prepared for sudden cardiac arrest medical emergency. Per the manufacturer's recommendations, "It is important to keep a fresh CHARGE-PAK battery charger in the defibrillator, even when the defibrillator is stored."[34]

RECOMMENDATIONS:

- Ensure all AEDs contain all supplies listed in RM-51 and consider adding the additional items recommended in the *HHS Guidelines for Federal PAD programs.*
- Ensure that these supplies are checked (and replenished if needed) each time the AED is inspected.

6. Maintenance Procedures

Survival from cardiac arrest depends on the reliable operation of automated external defibrillators; and regular maintenance of the AED is a critical indicator of its reliability. In a 2011 analysis of over 1,000 AED device failures, low batteries and other instances of the machine powering off unexpectedly (attributed to batteries), contributed to nearly one quarter of all AED failures, resulting in hundreds of deaths. [35] Having an AED program can have the unintended consequence of introducing liabilities based on an employee's failure to use the AED when someone suffers a sudden cardiac arrest, or failure to administer aid with the AED properly. From a liability standpoint, the Cardiac Arrest Survival Act of 2000 stresses the importance of properly maintaining and testing the AED,[36] thus immunity may not apply if harm to the victim arises due to failure to properly maintain the AED. Further, while there is no law requiring AEDs in federal facilities, if the entity chooses to have an AED program, the program would be exposed to liability for not ensuring that there are comprehensive policies and procedures in place, responders are properly trained, and the AED is properly maintained. Trends in AED legislation and civil litigation are generally for the failure of a premises owner to have an AED when required (under state statute or municipal/county ordinance), the negligent failure to

[34] Operating Instructions for Physio Control Lifepak CR Plus Defibrillator
[35] DeLuca LA, Simpson A, Beskind D, et al. Analysis of Automated External Defibrillator Device Failures Reported to the Food and Drug Administration. doi:10.1016/jannemergmed.2011.07.022. https://www.annemergmed.com/article/S0196-0644(11)01338-2/pdf
[36] Cardiac Arrest Survival Act of 2000

properly find or use an AED when it is already present on the premises, or for a defect or malfunction in the device itself.

Issues around routine maintenance contributed to the largest number of complaints by GRCA interviewees. Further, it was suggested by several employees that a visitor died of sudden cardiac arrest not only as a result of inadequate placement of AEDs, but also possibly due to expired AED batteries and/or pads. A review of this particular event revealed that when the AED was applied, the cardiac rhythm was not shockable, and the AED did not advise a shock to the victim. There is no evidence that the batteries or pads were expired at the time, no evidence that there was a malfunction of the AED, and no evidence that this visitor or any other visitor or park employee had recently been materially impacted by the GRCA AED program.

There is evidence, however, of insufficiently maintained AEDs throughout the park. While a thorough check of each AED at GRCA was not conducted as part of this review, documentation of inadequately maintained AEDs was provided. For example, in 2018, an employee found an AED at GRCA headquarters building that had not been inspected in four years (since 2014), and the battery had expired in 2015. After that was discovered, documentation on 5 additional AEDs was provided that demonstrated lack of maintenance (no routine inspections; and four out of five had expired pads, and three out of four had an expired battery). Additional documentation showed expired pads and batteries found on an AED as recently as March 16, 2019 at the Back Country office.

It is not clear that the monthly inspections are being conducted in a uniform and consistent manner. There does not appear to be a formal "checklist" for an AED inspection. The current GRCA AED Inventory spreadsheet is insufficient to meet the requirements of RM-51, nor the manufacturer's recommendations. Per this spreadsheet, the AEDs are currently checked once per year, and there are many empty boxes under this section indicating thatsome AEDs had not been checked in 2018. Further, some of the AEDs which had expired components (per the documentation provided), had been listed as "checked in 2018." This appears to be inaccurate data collection.

RM-51 clearly identifies the process for maintaining the AED:

> *"Maintenance and performance checks of all AEDs and associated equipment are to be performed per manufacturer's recommendations. Each NPS area will designate a person(s) responsible for this task.*
> *Each AED should have a written checklist to assess the preparedness of the AED and supplies. Per the NPS Records Schedule, A7615 Health and Safety, completed checklists should be kept on file in the park for a minimum of 15 years.*
> *(See Exhibit 5 for a sample AED Log). This checklist may be used as a supplement to regularly scheduled, more detailed maintenance check recommended by the manufacturer.*

At minimum, the checklist should include the following:
• Date of inspection
• Verification of placement
• Verification of battery installation
• Checking status/service indicator light
• Inspecting exterior components and sockets for damage
• Inventory of supplies
• Name of the person who inspected the unit"

Maintenance recommendations from the manufacturer states:

On a regular basis, you should do the following:
• Check to make sure that the OK symbol is visible in the readiness display.
• Check the Use By date on the electrode packet (visible through the defibrillator lid in the upper right corner) and all other electrode packets. If the date has passed, replace the electrode packet and the battery charger.
• Check other emergency supplies stored with your defibrillator.

When establishing your local inspection schedule, consider how often your defibrillator will be used and how familiar the operators are with using a defibrillator. For example, if the defibrillator is used only rarely, monthly inspections may be appropriate. [37]
(A sample Lifepak CR+ inspection checklist can be found in the manufacturer's operating instructions)

Physio-Control also notes: "All AED batteries and pads have an expiration date. CR+ AED pads last for 2 years. The CHARGE-PAK battery charger and pads should be replaced after each use of the defibrillator."[38]

A thorough maintenance program also includes the responsibility of handling recalls and potential software updates or upgrades

A common concern among interviewed employees was a lack of understanding who is responsible for checking and maintaining the AED units. Per the sample AED policy in RM-51, "AED Coordinators will be responsible for ensuring that monthly inspections of AEDs are made and that the AED is fully functional." . However, it does not appear that the AED Coordinator currently has a reliable method for ensuring AED units are checked on a routine basis, and the AED Coordinator has no authority to task NPS staff to provide monthly inspection results.

[37] Operating Instructions for Physio Control Lifepak CR Plus Defibrillator
[38] Ibid

RECOMMENDATIONS:

- Establish a formal plan for systematic, routine maintenance, monitoring, and reporting inspection results of all AEDs (PAD and EMS) on a periodic basis, but no less than once per month.
- The same maintenance checklist should be adopted for use for all AEDs (PAD and EMS) incorporating all of the items listed in RM-51 and the manufacturer's User's Checklist.
- Identify who will be checking each AEDs every month at every location, and develop a back-up plan for handling issues such as absences, vacations, and job turnover. This individual would be responsible for providing maintenance checklists to the AED Coordinator, and would also notify the AED Coordinator in the event of any issues related to the AED.
- The AED Coordinator is responsible for ensuring that monthly inspections of AEDs are made and that the AED is fully functional. Create a method to make certain that maintenance checklists are provided to the AED Program Manager on a monthly basis, or consider an alternate method such having the data entered at the site on a shared spreadsheet that would be reviewed by the AED Program Manager
- Ensure there is a formal process for reordering and replacing expired equipment in a timely manner (and that each site is aware of the process)
- Develop a plan for handling recalls and software updates
- Maintain a log of any deficiencies and actions taken to repair them

7. **<u>AED Policy and Protocols</u>**

Concerns related to roles and responsibilities of the AED program were commonly voiced by GRCA staff as part of this review. Both non-EMS employees and EMS personnel noted a significant lack of communication about response procedures, a lack of authority to task others with AED responsibilities, and a lack of understanding regarding procedures related to AEDs that are considered "public facing."

A clear AED policy and protocol for all types of responders will assist in alleviating these issues. AED policy and protocol documents set the criteria for the operation of the AED program and all of its components. RM-51 states, *"Each NPS area must have a current written policy available to all participants that contains the protocols and procedures for their AED program. This policy should address roles and responsibilities, protocols, and procedures for program. (See sample AED Policy in Exhibit 6.)"*[39]

[39] RM-51

(Note: there is a chapter within the GRCA EMS Plan entitled "Automated External Defibrillator (AED) Program," however this document does not appear to be a policy, does not include a protocol, and it does not sufficiently address all essential aspects of an AED program.)

The sample AED policy provided in RM-51 provides an example of roles and responsibilities of the program. This sample AED policy also refers to using an AED per "attached protocols." RM-51 has cardiac arrest protocols for EMTs, Parkmedics, and Paramedics, but there is no protocol in this document for lay responders. An example of a protocol for a lay responder can be found in the *HHS Guidelines for Federal PAD programs* document, which outlines the need for AED policies and protocols, provides a sample AED protocol for lay responders, and addresses the use of an AED treatment algorithm until EMS arrives and assumes care of the patient. The *HHS Guidelines for Federal PAD programs* document adds the following essential information regarding protocols:

- *Protocols should clearly address procedures for activating local EMS personnel as well as a notification system to activate lay responders.*
- *Responders must be familiar with and trained in the context of the approved procedures in the facility and strictly adhere to these procedures when an emergency occurs.*
- *Responsibility for each aspect of the program should be clearly articulated in protocols.*
- *Emergency response and AED usage protocols signed by a physician constitute legal authorization for properly trained and certified individuals to use AEDs in a particular manner as outlined in the protocol.*
- *Protocols should be reassessed periodically in accordance with a regular schedule of reviews as determined in consultation with the PAD's supervising physician. A current protocol that takes into consideration both new treatment recommendations and any changes in the FDA labeling of the AED should be integrated into the PAD training and education and re-training programs.*

RECOMMENDATIONS:

- Develop GRCA specific AED policy that contains the protocols and procedures for the AED program. This policy should also address roles and responsibilities of all personnel involved in the program (see sample AED policy in RM-51)
- Review the *HHS Guidelines for Federal PAD programs* document for lay responder protocols and develop protocols for lay responders (EMS personnel will be following cardiac arrest protocols outlined in RM-51). Verify that protocols are current per the American Heart Association Guidelines for CPR and Emergency Cardiovascular Care (updates can be found at https://eccguidelines.heart.org/index.php/circulation/cpr-ecc-guidelines-2/, and an example of an algorithm can be found on page 12 at

https://eccguidelines.heart.org/wp-content/uploads/2015/10/2015-AHA-Guidelines-Highlights-English.pdf)

- Review protocols periodically to ensure they continue to accurately reflect emergency response procedures at GRCA.
- Ensure the physician who provides medical oversight reviews and approves all policy, protocols, and emergency procedures related to the use of the AED.

8. Post-Event Considerations

RM-51 outlines necessary steps after an event in which the AED is used:

> *The following measures are to be taken:*
> *• Return the AED to a state of readiness as soon as possible with the replacement of the pads, pocket mask, and other peripheral supplies as necessary.*
> *• Provide the data to the Park EMS Medical Advisor.*
> *• Review the case with the AED Medical Advisor, Park EMS Coordinator and involved rescuers within 30 days of the incident. The information gathered from the incident review process is intended to be used to help improve the AED program. At a minimum, the review should include protocol and procedure implementation, scene safety, and a review of the AED recorded data.*

As noted earlier, the AED manufacturer recommends that the battery charger and pads should be replaced after each use of the defibrillator.

In addition to these steps, an important post-event consideration is the psychological effect on all responders (EMS and lay responders). While RM-51 outlines the procedures for Critical Incident Stress Debriefing for EMS, it is unclear if all lay responders involved in use of CPR/AED, or other emergency situations, are included in the Critical Incident Stress Management process.

RECOMMENDATIONS:

- Include RM-51 post-event considerations in GRCA AED protocols
- Address options for psychological services for all responders and include this information in the AED protocol

9. Quality Assurance/Continuing Quality Improvement

Per the DO, 4.3.8 Continuous Quality Improvement:

“The continuous quality improvement (CQI) process is essential to the success of the Service's EMS program. Ongoing program evaluation will help to ensure that EMS program management and patient care are being provided at an optimal level. Accountability for quality assurance lies with the superintendents and the Chief, U.S. Park Police. These responsibilities are detailed in RM-51, Chapter 8, 3.11 "Quality Assurance/Continuous Quality Improvement."

While this particular requirement is for the training and provider aspects of an EMS Program, and is intended for EMS in general, there is a need for some type of quality assurance/continuing quality improvement specifically for the AED program.

The *HHS Guidelines for Federal PAD programs* recommend the development of quality assurance plans as a major element of a PAD program that involves the development of measurable performance criteria, documentation and periodic program review. PAD programs should be reviewed on a regular basis and improved, where possible.

RECOMMENDATIONS:

- Develop and implement a quality assurance program specific to the GRCA AED program
- Establish a periodic review (consider a review by an external source) of the AED program on a routine basis and implement changes as necessary

III. Employee Accident and Job Hazard Analysis Program Review

A job hazard analysis (JHA) is a hazard assessment tool that focuses on job tasks as a way to identify hazards before they result in an injury or occupational illness (Fig 1). A JHA centers on the relationship between the worker, the task, the tools, and the work environment. Ideally, after uncontrolled hazards are identified, employers and employees will take the necessary steps to eliminate or reduce the hazards to an acceptable risk level.

The Occupational Safety and Health Administration (OSHA) provides the following list of job factors that determine the need for JHAs in priority order:

1. Jobs with the highest injury or illness rates;
2. Jobs with the potential to cause severe or disabling injuries or illness,
3. Jobs in which one simple human error could lead to a severe accident or injury;
4. Jobs that are new to your operation or have undergone process changes in; and
5. Jobs complex enough to require written instructions.

The review of the GRCA Job Hazard Analysis, a component of the Park's overall hazard assessment program, included a review of a workplace injury that occurred on March 13, 2018 where a water utility crew member suffered a head laceration when the power demolition saw he was operating "kicked back" during a water pipe cutting operation and contacted his forehead. Speculation arose that maintenance employees were not conducting job hazard analysis prior to performing hazardous work, as required by 29 CFR § 1910.132(d)(2). There was also speculation/allegations that the Park did not adequately investigate the incident.

In order to accomplish this review, interviews were conducted with individuals directly involved with the incident, division supervisors, and the park's management team. These interviews included both past and present staff. Additionally, documentation was collected and analyzed and included witness statements, the June 2018 Intermountain Region's Environmental, Health, and Safety Audit Report for GRCA, videos and photographs of the incident scene, the injured employee's accident report, the injured employee's Form CA-1, *Federal Employee's Notice of Traumatic Injury and Claim for Continuation of Pay/Compensation,* Trans Canyon Pipeline waterline break data, and the Trans Canyon Pipeline repair JHA.

Background

At approximately 3:15 PM on March 13, 2018, a supervisor, operating a demo saw, sustained a 1.5-inch laceration to his forehead when the demolition saw kicked back while making a final through-cut on an unpressurized, six-inch aluminum water pipe. The supervisor's three crew members immediately administered first aid measures and called for an emergency helicopter evacuation out of the canyon. The injured supervisor was then transferred to a mobile ambulance and transported to a local emergency department for further evaluation and treatment. The employee returned to work a few days later. *Note: The demolition saw was not available for inspection during the evaluation.*

JOB HAZARD ANALYSIS – FORM 2.1

JOB HAZARD ANALYSIS (JHA)		Date: February 28, 2003	New JHA Revised JHA
Park Unit: Best National Park	Division: Maintenance Division	Branch: Auto Shop	Location: Headquarters area
JOB TITLE: Changing flat tire on 2000 Dodge Durango		JHA Number: 1	Page ___1___of ___2___
Job Performed By: Motor Vehicle Operator	Analysis By: Safety Committee	Supervisor: Auto Shop Foreman	Approved By: Auto Shop Foreman

Required Standards and General Notes:	Read the owners manual pages 166 to 172. Study diagram and instructions on the bottom of the cover for the jack and tool storage area showing proper jack placement and the way to use the jack extension and handle.
Required Personal Protective Equipment:	(Summer conditions) Gloves and coveralls
Tools and Equipment:	(Summer conditions) Spare tire, jack, jack handle and extension, lug wrench, emergency markers

Sequence of Job Steps	Potential Hazards/Injury Sources	Safe Action or Procedure
1. Parking car	1. SB – worker struck by passing car	1. Park car as far from the edge of roadway as possible. Park vehicle on a firm level surface. Turn on flashers. Set the parking brake and place the gear selector in PARK. Set out emergency markers. Chock both the front and rear of the tire diagonally opposite the jacking position.
2. Getting equipment	2. none	2. The jack and the tire changing tools are stowed in the floor compartment behind the rear seat, just forward of the lift gate opening. Jack usage instructions are shown on a label mounted on the underside of the cover. Put on gloves and coveralls.
3. Getting the spare tire	3. CI – fingers caught between car body & winch knob. O – while operating winch	3. Use the jack wrench extension on the winch nut to lower the spare tire. Turn the wrench in a counterclockwise direction to lower the tire. Continue to turn the wrench until the spare tire is on the ground and can be pulled out from under the car.
4. Properly place jack and remove wheel cover	4. CB – fingers can be caught between the wheel and the spade end of the wheel wrench O – force needed to loosen wheel nuts	4. Keep the fingers and hands clear of the pinch points between the tire and the spade end of the wheel wrench when prying off the wheel cover. Using the wheel wrench, loosen, but do not remove, the wheel nuts by turning them counterclockwise one turn while the wheel is still on the ground. Always place jack on a firm level surface. When changing a front tire, place the jack under the frame rail as close as possible behind the tire. When changing a rear tire, place the jack under the axle as close as possible to the shock bracket.

Findings:

Finding 1: The Trans Canyon Pipeline Repair JHA was developed in 2007.

Finding 2: The Trans Canyon Pipeline Repair JHA—which contained over 80 steps—did not address the specific "kick back" hazard that resulted in the supervisor's injury.

Finding 3: The minimum required personal protective equipment (PPE) in the Trans Canyon Pipeline Repair JHA includes: gloves, a hard hat, full body clothing, steel toe boots, eye protection, and ear protection.

Finding 4: Due to excessively short personal staffing (> 40% vacant positions), the Facility Management Division (FMD) was limited in qualified and trained demolition saw users.

Finding 5: This was the seventh water line break since January 1, 2018 and those interviewed from the crew complained of fatigue.

Finding 6: Facility Management Division leadership often resorted to assigning untrained employees to assist in conducting pipeline repair.

Finding 7: Weather Underground's historical data for March 13, 2018 indicated the temperatures to be in the high 50s to low 60s °F.

Finding 8: On the day of the incident, the injured supervisor was the only qualified demolition saw operator, pipe fabricator, and welder on duty.

Finding 9: The injured supervisor was wearing safety glasses at the time of the incident, but was not wearing a hard hat or face shield.

Finding 10: The supervisor was injured when the demolition saw he was operating to cut aluminum water pipe kicked-back, causing the rotating blade to contact his forehead.

Finding 11: The supervisor received immediate first aid from other crew members and was safely extricated from the canyon via a short-haul helicopter evacuation operation.

Finding 12: The pipeline repair crew was provided critical incident stress management.

Finding 13: GRCA Superintendent's office declined the Intermountain Region's (IMR) offer to conduct a regional serious accident investigation because IMR's investigation process had not been finalized and GRCA believed it could handle the incident review internally.

Finding 14: The injured supervisor was able to return to work two days later after receiving seven stitches.

<u>Finding 15</u>: The June 2018 Intermountain Region Environmental, Health, and Safety Audit Report for GRCA indicated that most safety programs were not implemented and in draft form, while some needed developed and/or updating.

<u>Finding 16</u>: Interviewees stated that JHAs were often not reviewed by the pipeline repair crew members before emergency repairs, even though team members may have been selected at random to assist.

Contributing Factors and Recommendations

<u>Contributing Factor 1</u>: Although steps were taken to ensure that the pipeline was not pressurized with water, the pipeline still contained stored potential energy due to a bend in the pipeline section being cut. This energy is believed to have been released and transferred through the demolition saw on the final cut that resulted in the saw's "kick back" resulting in the saw blade contacting the supervisor's forehead. The Trans Canyon Pipeline Repair JHA did not address the kick back as a potential hazard during this operation and thus, did not contain a mitigation measure for prevention.

<u>Recommendation 1a</u>: The Facility Management Division (FMD) should consult with an outside party or sister park to reevaluate the pipeline repair operation to determine if there are alternatives or best practices for cutting this type of pipeline under specific conditions. This may include the use of different cutting tools, cutting techniques, and/or methods to reduce the release of potentially stored energy.

<u>Recommendation 1b</u>: At the time of this report, the 2007 JHA for this operation included over 80 steps, primarily addressing the helicopter short haul operation. Very little information was provided for the actual process for finding a damaged pipeline, accessing the pipeline, and using a cutting tool on the pipeline. FMD and the park aviation manager should look at separating these two operations in to separate JHAs, but maintaining the separate JHAs together for quick review, training, updating, and reference. Additionally, FMD and the Park safety and health manager should ensure that training on the JHA process and its use is provided to FMD and its personnel involved in this operation so they can update this specific JHA to ensure appropriate steps are documented, hazards identified, and appropriate mitigations included.

<u>Contributing Factor 2</u>: An impact resistant face shield was not required to be worn as part of the personal protective equipment ensemble while using the demolition saw.

<u>Recommendation 2</u>: Until this operation can be eliminated and/or engineering controls established to protect individuals from potential hazards, personal protective equipment will be required. The Team believes that the use of a hard hat with an impact resistant face shield at the time of the accident may have prevented the injuries to this employee. It should be noted that the JHA for this operation did require the use of a hard hat, but was normally not worn due to it being cumbersome and potentially increasing the effects of heat illness. If it has been determined in a documented personal protective equipment assessment that a hat hard is cumbersome and/or not needed as part of a protective ensemble during this operation, then there may be options available on the market for a standalone impact resistance face shield that fits directly to an

individual's head. Weather Underground's historical data for March 13, 2018 indicated the temperatures to be in the high 50s to low 60s °F.

<u>Contributing Factor 3:</u> Complacency and fatigue may have played a role in this employee's injury.

<u>Recommendation 3a</u>: FMD, with the assistance of the Park Safety and Health Manager, should ensure workplace hazard and/or risk assessments are conducted, documented, and reviewed regularly. Training may also need to be provided to FMD personnel to ensure they understand the process and options for conducting a hazard and/or risk assessment. FMD should consider using risk assessment tools such as a Green/Amber/Red or Severity/Probability/Exposure assessment.

<u>Recommendation 3b</u>: Park management team and FMD should develop a priority list for backfilling positions within FMD and work with their SHRO on getting the positions filled within FMD.

<u>Recommendation 3c</u>: FMD should not utilize untrained staff to support repair work on the Trans Canyon pipeline. FMD, with assistance from the Park Safety and Health Manager, should develop and/or outsource a training program to provide qualified and/or competent person training to individuals assigned to repair work on the Trans Canyon pipeline. This will include specialties such as welding, pipe fabrication, and use of mechanized cutting tools.

<u>Recommendation 3d</u>: FMD should ensure crews frequently responding to waterline breaks have an adequate rest/work cycle to reduce the likelihood of fatigue and an increased probability of injury.

Response to Delegation of Authority Scope of Work

Based on interviews conducted, the Team believes that GRCA personnel responded appropriately to the injured employee by providing first aid measures, extrication from the canyon, and transport to a local emergency department for further medical care. Additionally, steps were taken to preserve the incident scene, provide critical incident stress debriefing and wellbeing checks, and a safety stand down was initiated by Park leadership.

Although, initial steps were taken to secure and document the incident scene and collect witness statements from the pipeline crew, a formal "after action and/or lessons learned process" was not conducted. The Safety Management Information System (SMIS) accident report contained minimal information and/or recommendations on how to prevent similar incidents from occurring in the future. The Team could not confirm why the Park Safety and Health Manager believed his initial steps to conduct an investigation were met with resistance. Information obtained from management interviews indicated that leadership believed that an investigation was being conducted; however, there appeared to be no follow-up on the status of this investigation. Additionally, the Intermountain Region offered to deploy a regional Serious Accident Investigation Team to GRCA to conduct a formal accident investigation; however, this offer was declined by GRCA leadership.

Recommendation: The GRCA Safety and Health Manager, in conjunction with the GRCA Management Team, should develop an accident/incident reporting and investigation process as outlined in RM-50B *Occupational Safety and Health Program*. The process should be communicated to all staff, systematically implemented, and reviewed. When conducted properly, the investigation process reveals the chain of events that may have led to an accident, analyzes the direct and indirect causes of the event, and identifies correctable opportunities. The investigation process also provides information to park management to help prioritize park, regional and/or nationally implemented corrective actions and program activities.

The reporting phase of this process will support the park's safety management programs by providing notification of previously unrecognized hazards to park management for evaluation and development of corrective actions, identification of trends in workplace accidents, and communication of hazards and recommended corrective actions to employees and supervisors in the park and within the rest of the National Park Service.

Response to OSC Informal Resolution

Per the Safety and Health Manager, most divisions developed and used JHAs in a very efficient manner; however, the Safety and Health Manager believed the FMD did not perform this risk assessment process well during the time this incident occurred. Since the time of the incident and following the transition of a new acting FMD Chief, the Safety and Health Manager stated the safety culture within the maintenance division had improved dramatically and JHAs were in the process of being developed, updated, and used for training and refreshers in a far more efficient and effective manner than at any point in his two years in the park. However, it should be noted that the Team identified that the specific JHA developed in 2007 for Trans Canyon Pipeline repair was in need of a thorough review and update and at the time of our review still did not address the specific "kick back" hazard that resulted in the employee's injury.

The Team believes the FMD would benefit from a JHA training focused on the review of current jobs and potential hazards, the written JHA development process, and the importance of employee involvement.

Appendices

Appendix I - Letter of Delegation

United States Department of the Interior
NATIONAL PARK SERVICE
1849 C St NW
Washington, DC 20240

FEB 21 2019

VIA ELECTRONIC MAIL: NO HARD COPY TO FOLLOW

Memorandum

To: Michael May, Chief, Office of Risk Management, National Park Service
Tim Radtke, Director, Office of Occupational Safety and Health, Department of Interior

From: Louis Rowe, Associate Director (A) Visitor and Resource Protection

Subject: Delegation of Authority (DOA) — Grand Canyon Safety Incidents Review

Note: This DOA was originally drafted January 31, edited Feb 7 for clarity and Feb 20, the skills needed and the level of independence were refined.

This memorandum formalizes your appointments as Co-Team Leaders for the Safety Issue Review Team assigned to the Grand Canyon. The issues you are assigned to review are as follows, and in the following order of priority:

Tim Radtke – Department of Interior

- The exposure of park employees or visitors to radioactivity from uranium ore stored in the park's collection, a determination if the health and safety of any park staff or visitors may have been materially impacted, and recommended next steps.

Michael May – National Park Service

- A workplace injury incident that occurred on March 13, 2018 where the forehead of a member of the water utility crew was lacerated when utilizing a power saw and whether the park took appropriate action in responding to the incident, including conducting after action and lessons learned reviews.
- The program for deploying and maintaining automated external defibrillators (AED) and if the program is adequate, if the health and safety of any park employee or visitor has recently been materially impacted by that program, and recommended next steps.
- Other general Safety program observations and recommendations.

Your and your team's duties include but are not limited to:

1. Organizing, managing, and conducting the review in accordance with Departmental Manual 485 Chapter 7 and National Park Service Reference Manual 50B, when applicable.
2. Providing in-briefings and out-briefings with affected personnel and agency officials including the Park Superintendent and the Intermountain Region's Associate Regional Director for Facilities and Lands.
3. Conducting on-site interviews with relevant staff that have knowledge of the situation, and coordinating an information exchange between team members and other entities, notably, the Occupational Safety and Health Administration (OSHA) investigator Patti Downs, Industrial Hygienist assigned the uranium incident; the Arizona Department of Health Services (ADHS) Bureau of Radiation Control Chief, Brian Goretzki; Grand Canyon Facility Management Division; Visitor and Resource Protection Division; and Grand Canyon Safety Officer; and the Intermountain Region Safety Office and other parties previously charged with investigating the incidents.
4. Collecting and analyzing any documentation including previous reports, previous recommendations, and previous actions taken by park management and employees.
5. Coordinating with Grand Canyon's Superintendent's Office to address an employee town hall meeting to provide employees with a synopsis of the situation and answer questions.
6. Maintaining liaison with the affected park and regional office, including the public information officers working with the media and public on these matters.
7. Approving requests and allocating funding for resources to assist with the investigation.
8. Requesting technical, logistical, or other support to conduct the investigation as required.
9. Providing briefings to myself and others.
10. Providing the following formal briefings/reports to myself and the Intermountain Region's Associate Regional Director for Facilities and Lands within 30 days of the site visit, although sooner is desirable. Brevity and timeliness is expected in any deliverables provided it does not compromise the quality and comprehensiveness of the review.
    - For the Uranium Ore Exposure Incident – Incident Review Report – Uranium Exposure - with findings, and recommendations to abate or mitigate those findings appended. The Review Team will identify multiple alternatives in the recommendations where possible. The exposure analysis and similar technical portions will be in a standalone appendix of the report and will be prepared by a qualified independent contractor, then peer-reviewed by an agency outside of the National Park Service.
    - For the Other Incidents – Incident Review Report – Other Issues - with findings, and recommendations to abate or mitigate those findings appended. The Review Team will identify multiple alternatives in the recommendations where possible.
11. Meeting with the park superintendent and regional representatives to discuss the merits of different alternatives, and provide technical expertise to support implementation of alternatives that are complex or require coordination with external agencies. Conduct additional investigations and performing additional follow-up actions as requested by me, the Park Superintendent, or Regional Director.

Your team, at a minimum, should include an Industrial Hygienist from DOI, an Occupational Safety and Health Manager from another region or agency, and a Radiation Safety Specialist and/or Health Physicist from another Federal Agency. You may also request a mining engineer with experience in uranium ores from the NPS Geological Resources Division.

Requests for time extensions on report submittals must be made through me. All reports will be considered draft until they are accepted by the agency DASHO in consultation with the Regional Director of the Intermountain Region.

You will be provided with an accounting code to pay for all travel and associated costs.

cc: NPS Designated Agency Safety and Health Official (DASHO)
Chief, Office of Risk Management, WASO
Regional Director, Intermountain Region
Associate Regional Director, Facilities and Lands, Intermountain Region
Regional Safety Manager, Intermountain Region
Park Superintendent, Grand Canyon National Park

AECOM

Evaluation of Exposures to Uranium Ore Specimens

Historical evaluation of potential radiation exposures and health and safety recommendations for controlling additional exposures to uranium ore samples maintained in the Grand Canyon Museum Collections

Grand Canyon National Park

May 2019

Requesting Agency:

National Park Service
Grand Canyon National Park
1576 Shuttle Bus Road
Grand Canyon AZ 86023

Supporting Entity:

US Department of the Interior
Office of Occupational Safety and Health
1 Denver Federal Center
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Denver, CO

Servicing Agency:

Federal Occupational Health
Environmental Health and Safety Services
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Table of Contents

Tables

Figures

Appendices

Acronyms

AECOM	AECOM Technical Services, Inc.
ALARA	As Low As Reasonably Achievable
AOC	Area of Concern
Bq	Becquerel
CFR	Code of Federal Regulations
Contractor	AECOM Technical Services, Inc.
DAC	derived air concentrations
dpm/100cm^2	disintegrations per minute per 100 square centimeters
EPA	U.S. Environmental Protection Agency
FOH	Federal Occupational Health
GRCA	Grand Canyon National Park
ICRP	International Council on Radiological Protection
µCi	Microcuries
µCi/ml	Microcuries per milliliter
µR/hr	MicroRoentgen per hour
mR	milliRoentgen (units for exposure)
mR/hr	milliRoentgen per hour
mrem	Millirem (units for dose equivalent)
mrem/hr	Millirem per hour
NCRP	National Council on Radiation Protection
NORM	Naturally occurring radioactive material
NPS	National Park Service
NRC	U.S. Nuclear Regulatory Commission
OEL	Occupational Exposure Limits
OSHA	U.S. Occupational Safety and Health Administration
pCi/L	Picocuries per liter
PEL	Permissible Exposure Limit
PPE	Personal protective equipment
U_3O_8	Uranium oxide
URS	URS Group, Inc.
WHO	World Health Organization
WL	Working Levels
WLM	Working Levels Months

Glossary of Terms

- **ALARA**: As defined in Title 10, Section 20.1003, of the 10 CFR 20.1003, ALARA is an acronym for "as low as (is) reasonably achievable," which means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations.
- **Alpha particle (α):** Two protons and two neutrons bound together into a particle identical to a helium-4 nucleus emitted during the decay of some radioactive substances.
- **Beta particle (β):** A fast-moving electron or positron emitted during the decay of some radioactive substances.
- **Dose limits:** The Federal regulations in the United States that specify the maximum dose of radiation than an employee may be exposed to. These regulations are legally enforceable. Dose limits are established by the Occupational Safety and Health Administration (OSHA) and the Nuclear Regulatory Commission (NRC).
- **Equilibrium Factor (f)**: A simplified factor describing the degree of radioactive equilibrium between radon and its short-lived daughters. Equilibrium Factor often ranges approximately from 0.2 to 0.8. International agencies commonly apply use of 0.4 as a default indoor equilibrium factor.
- **External exposure:** Ionizing radiation exposure received from sources outside the body.
- **Gamma radiation (γ):** Electromagnetic radiation of the shortest wavelength and highest energy, resulting from the radioactive decay of atomic nuclei.
- **Ionizing radiation (radiation):** Refers to alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. An ion (an electrically charged particle) is produced when an electron is removed from an atom or molecule, leaving that atom or molecule electrically charged.
- **Isotopes:** Isotopes of an element all have the same chemical properties but have different atomic weights. Radioactive isotopes (radioisotopes) of an element have different rates of radioactive decay, different decay series (decay chains) and different emissions. Two isotopes of uranium, U-238 and U-234, are shown in Figure 2-1.
- **Licensed radioactive material:** Source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Nuclear Regulatory Commission (NRC) or an NRC Agreement State.
- **Naturally Occurring radioactive Material (NORM):** Materials containing non-enhanced (depleted or concentration) level of natural radioactive isotopes such as soil and rocks.
- **Non-licensed radioactive material:** Any type of radioactive material not licensed by the US NRC or an NRC Agreement State.
- **Objective data:** The term “objective data” is apparently used to differentiate the exposure data developed in this study from the safety data as reflected in OSHA Safety Data Sheets.
- **Progeny:** products of radioactive decay (formerly called “daughters”).
- **Radioactive Half-life**: The time required for a quantity of radioactive material to reduce to half its initial value through radioactive decay.
- **Radon:** A naturally occurring element with symbol Rn and atomic number 86; it is a radioactive, colorless, odorless, tasteless noble gas.

- **Radon exposure:** Is the portion of the internal dose equivalent that is attributable to radon and its progeny. Radon is a radioactive noble gas and exposure occurs when air containing radon and its progeny are inhaled.
- **Secular equilibrium:** Exists between a "parent" radionuclide and a progeny radionuclide. The progeny radioactivity will decay at its own radioactive decay rate but will build up as the "parent" decays. Radioactive decay is exponential. The progeny radioactivity builds up exponentially at the same rate as the "parent" decays, but decays at its characteristic rate. When the net radioactivity buildup of the progeny is equal to the rate at which the "parent" radionuclide decays, the radioactivity of the progeny remains constant, and the parent and progeny are said to be in secular equilibrium. The U-238 decay chain contains a number of secular equilibria.
- **Total Exposure:** The sum of the external gamma radiation and internal radon exposure.
- **Uranium:** A naturally occurring radioactive element with symbol U and atomic number 92, commonly found as a mixture of three isotopes including U-238, U-235, and U-234.
- **Working Level (WL)**: Any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha particle energy.
- **Working Level Month (WLM):** An exposure to 1 working level for 170 hours (2,000 working hours per year/12 months per year = approximately 170 hours per month).

Executive Summary

AECOM Technical Services, Inc. has prepared this Evaluation of Exposures to Uranium Ore Specimens on behalf of Federal Occupational Health (FOH) and the National Park Service (NPS). This Evaluation of Exposures to Uranium Ore Specimens was conducted to evaluate potential worker and public exposures to uranium ore specimens stored in the Museum Collections at the Grand Canyon National Park (GRCA). The assessment evaluates exposures at three previous specimen storage locations at GRCA including the current Museum Collections Building, the former GRCA Visitors Center (current Park Headquarters Building), and the former Naturalists Building (current Community Library). Based on worker and visitor stay times in these areas and documented or assumed past activities in each area, individual doses were estimated based on specific exposure scenarios. The total estimated dose included external radiation dose from direct exposure to the ore specimens and internal exposures due to the inhalation of radon gas which is naturally emitted from the decay of uranium. The estimated doses from past exposures to uranium ore specimens at GRCA in these areas were determined to be a small fraction of the natural background radiation received by the average member of the United States population.

Additionally, this Evaluation of Exposures to Uranium Ore Specimens examined the high radiation dose rates recorded at the current Museum Collection Building in August 2018 and later reported to the public in February 2019. While the uranium ore specimens that were measured directly in August 2018 have been relocated to the Orphan Mine site and were not available for additional direct measurements, the investigation team's Certified Health Physicist conducted a side-by-side comparison of the radiation detection instrument used in August 2018 with a separate instrument in a background radiation area. This comparison determined that the instrument used in August 2018 was not accurately reporting the background radiation level. Following a review of the instrument calibration records, it was determined that the instrument was not properly set to provide accurate measurements with the detector probe used to conduct the August 2018 surveys.

1. Introduction

1.1 Summary

AECOM Technical Services, Inc. (AECOM; contractor) has prepared this Evaluation of Exposures to Uranium Ore Specimens on behalf of the Federal Occupation Health (FOH) and the National Park Service (NPS). Work was performed in support of Contract HHSP233201400013I issued by Federal Occupation Health to Resource Management Group under subcontract to URS Group, Inc. (URS), an AECOM company. This Evaluation of Exposures to Uranium Ore Specimens (herein referred to as exposure evaluation) was conducted to evaluate potential worker and public exposures to uranium ore specimens stored in the Museum Collections at the Grand Canyon National Park (GRCA). The assessment evaluates exposures at three previous specimen storage locations at GRCA.

The worker and public exposure scenarios are modeled for the current Museum Collections Building, the former GRCA Visitors Center (current Park Headquarters Building), and the former Naturalists Building (current Community Library). Potential exposure areas within each of these buildings are referred to as areas of concern (AOCs). Exposure evaluations were then compared to the applicable exposure limits specified by Occupational Safety and Health Administration (OSHA) in Title 29 of the Code of Federal Regulations (CFR) Part 1910, and the Nuclear Regulatory Commission (NRC) in 10 CFR Part 20. NPS worker and visitor activities identified in Section 5 that resulted in exposure evaluations that had the potential to exceed the regulatory exposure limit, ½ of the regulatory limit (i.e., Action Level), and As Low As Reasonably Achievable" (**ALARA**) principles, were included in the exposure control recommendations to minimize worker exposures to **ionizing radiation** and **residual contamination** from other **naturally occurring radioactive materials (NORM)** in the Museum Collections were identified.

Based on worker and visitor stay times in the AOCs and anticipated activities in each AOC, individual doses were estimated based on specific exposure scenarios. The estimated doses from past exposures to uranium ore specimens at GRCA in these AOCs was determined to be a small fraction of the natural background radiation the average American receives. The NRC estimates that the average background dose from natural source (i.e., cosmic, terrestrial, and internal) is about 310 mrem/yr (NRC, 2019).

This report presents the following: (1) a brief summary of past uranium ore specimen storage and previous studies and radiation surveys; (2) the exposure evaluation results; (3) recommendations for exposure controls and ALARA; (4) **radon** action levels and exposure limits; (5) recommendation for engineering, administrative, and personal protective equipment (PPE) controls; and (6) other applicable information. This report includes a glossary of terms with the key terms bolded throughout the document for reference.

This exposure evaluation is organized into the following sections.

- Section 1 – Introduction: This section describes the background, site history, and presents the report organization and the objectives of the exposure evaluation.
- Section 2 – Site Contaminants and Regulatory Occupational Exposure Limits (OEL): This section defines the site contaminants included in the exposure evaluation and describes the regulatory occupational exposure limits.
- Section 3 – Exposure Evaluation Methodology: This section describes the scope, design, and methodology of the exposure evaluation including the OSHA objective data requirements.
- Section 4 – Objective Data Used to Evaluate Worker Exposures: This section presents the data collected at the site to evaluate measured **gamma radiation** exposure rates as well as the calculated theoretical external ionizing radiation exposures (**external exposure**) at the site based on time spent (stay time) and distance of potential receptors from the uranium samples in each area.
- Section 5 – Worker Exposure Evaluation Results: This section presents the results of the exposure evaluation based on the description of NPS activities described in Section 5. These results may only be used if work activities and site conditions remain the same as the conditions presented and documented in this report.

- Section 6 – Investigation into Recently Reported Dose Rate Data: This section describes interviews and interpretation of data reported in August 2018 and made public in February 2019 (NPS, 2018).
- Section 7 – Current Site Conditions: This section describes the current radiological conditions at the Museum Collections Building and at the GRCA Park Headquarters Building.
- Section 8 – Conclusions and Recommendations: This section presents the exposure control recommendations for NPS personnel and activities.

1.2 Site History

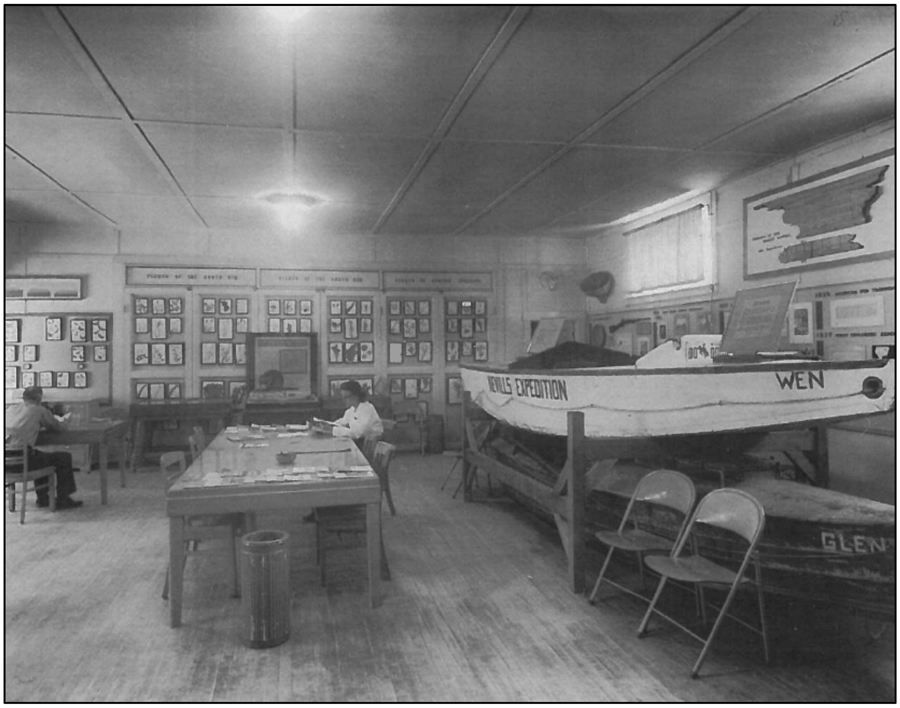
The Orphan Mine is a single, patented lode mining claim within GRCA, on the escarpment below Maricopa Point on the south rim. The claim was located for copper in 1893. Uranium was noted in the old workings by the US Geological Survey in 1951 and the claim was leased for **uranium** exploration in 1953. Because of favorable geology and high-grade uranium [greater than 1.00 percent uranium oxide (U_3O_8)] support extraction equipment was constructed and production commenced in April 1956. Early ore production was about 1,000 tons per month, averaging 0.43 percent U_3O_8. (Chenoweth, 1986)

A total of 25 uranium ore samples, the majority from the Orphan Mine, were logged into the NPS collections beginning in late 1950s. Several other specimens were logged into the collection in the early to mid-1960s. The earliest recorded uranium-containing specimen in the collection, a carnotite specimen from Monument Valley, Utah, was collected in 1944. The earliest recorded specimen from the Orphan Mine, a metatabentite (uranium ore) specimen from the redwall limestone formation, was collected in 1956. (NPS, 2019)

Mining operations at the Orphan Mine ended in 1969. In 1987, all rights associated with the Orphan Mine Claim were reverted to the government. By January 1988, most of the structures on the upper mine area were removed by NPS, leaving only a few structures standing, including the 80-foot-high steel headframe, foundations of previously standing buildings, remnants of water and septic tanks, ore storage pads, and various concrete and asphalt pads. Between November 2008 and June 2009, nearly all of these remaining man-made features were removed from the Site by Pangea-Group, Inc. and are described in two reports: Construction Completion Report (Pangea 2010a) and Headframe Characterization Report (Pangea 2010b).

All 25 uranium ore specimens are believed to have been in storage or on display in the former GRCA Naturalist Building (currently the Community Library) from their point of being added to the collection until they were relocated to a newly constructed GRCA Visitors Center in 1966. Figure 1-1 provides a photo of the interior Naturalist Building display area from 1952 – before the specimens were added to the collections.

Figure 1-1, Naturalist Building Display Area (1952)



The uranium ore specimens were located in the former Visitors Center, what is now the GRCA Park Headquarters Building, from 1966 until 2000. At the former Visitors Center, most of the specimens were in storage in either the basement boiler room or in the former museum collections room (former Room 128) while at least one specimen was on display in the Visitors Center. The display from the 1980s containing at least two uranium ore specimens is shown in Figure 1-2. The specimen on the wall is labeled "Malachite, Azurite, Chalcocite, Chalcopyrite, Bornite" which is consistent with the description of Museum Catalog Records specimen #17091 (NPS, 2019). The specimen on the base is labeled "Uraninite" which is consistent with the description of Museum Catalog Records specimen #20081 which is noted as being removed from the exhibit in January 1997 (NPS, 2019). The last location that an ore specimen was on display in the Visitors Center is shown in Figure 1-3. It is believed the specimen on display was of Museum Catalog Records specimen #17091 (NPS, 2019).

Figure 1-2, Former Visitor Center Mining Display (1980s)

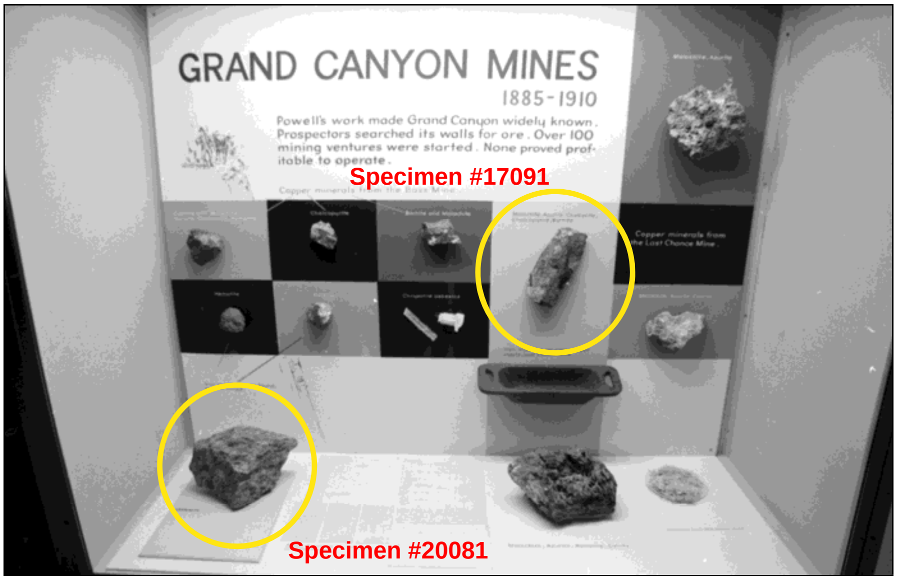


Figure 1-3, Former Visitor Center Display Area (2000)

All 25 uranium ore specimens were removed from the former Visitors Center in 2000 and moved to the Natural History Room of current Museum Collections Building (Figure 1-4). The 20 smaller specimens were placed in cabinets such as the one shown in Figure 1-5. One of the large specimens (#17091) was stored on an open shelf (shelf N.A08.02 in Figure 1-6) and the four remaining large samples were stored in three plastic 5-gallon buckets. Six additional small uranium ore specimens that were not catalogued as part of the museum collection were stored in a separate cabinet in the Interpretive Collection Room. All 31 samples were removed from the Museum Collections Building on June 18, 2018.

Figure 1-4, Museum Collections Building (2019)

Figure 1-5, Mineral Specimen Storage Cabinet

Figure 1-6, Shelf N.A08.02

1.3 Objectives of the Investigation

The objectives of the overall investigation were to determine the validity of recently gamma radiation dose rate data (NPS 2018), to investigate areas for residual contamination, and to conduct the exposure evaluation, which was developed to evaluate potential worker and visitor exposures to the uranium ore specimens with the following objectives:

- To identify potentially exposed individuals and populations;
- To define AOCs and conservative exposure scenarios;
- To determine the radioactive source terms using available information on uranium concentrations in Orphan Mine ores and previous radiological survey data;
- To calculate external radiation doses and doses from radon inhalation for each exposure scenario; and
- To identify exposure control measures NPS may need to implement to minimize potential worker exposures to residual contaminants.

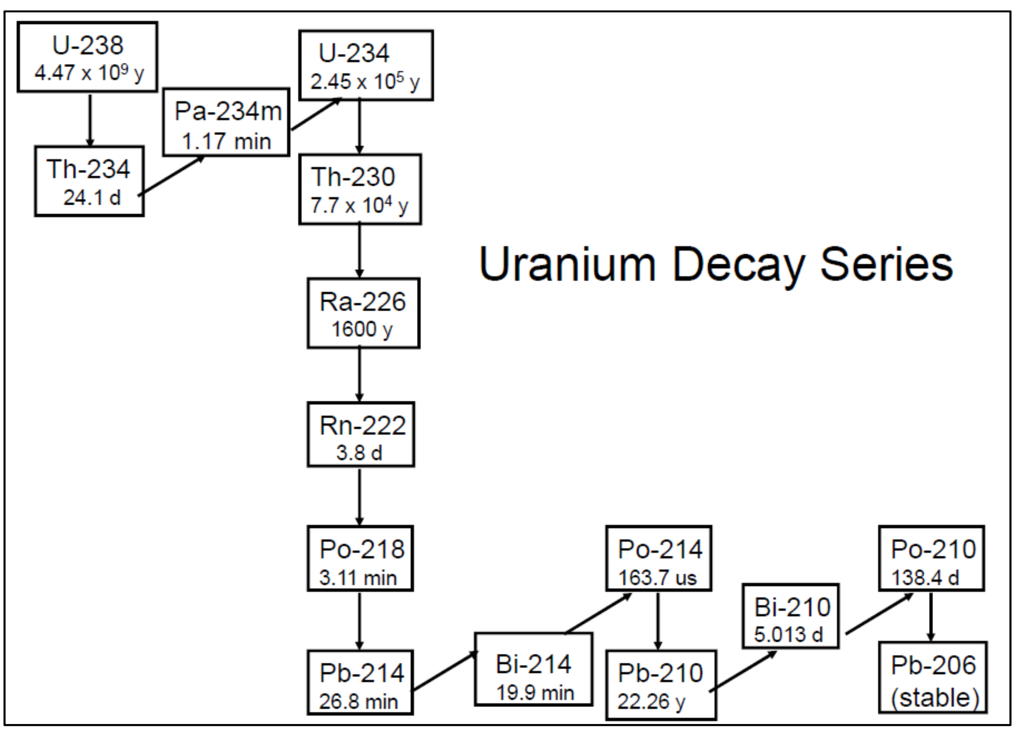
2. Radiation and Regulatory Occupational Exposure Limits

2.1 Radiation from Uranium

Any mineral or ore containing uranium is naturally radioactive, because all uranium is radioactive. Thus, sources of ionizing radiation were present at each collection's storage area due to the presence of ore specimens. The main sources of ionizing radiation are from natural uranium, including uranium **progeny** as shown in the uranium series decay chain in Figure 2-1. Natural uranium contains three **isotopes** of uranium – uranium-238 (U-238), 99.28% by weight, uranium-235 (U-235), 0.72% by weight, and uranium-234 (U-234), 0.0055% by weight – along with the decay chain, which includes all decay progeny. The decay progeny shown in Figure 2-1 with **radioactive half-lives** provided in years (y), days (d), minutes (m), or microseconds (us). In a natural (unprocessed) state, the U-238 and U-235 in uranium ore are in **secular equilibrium** with its decay progeny, except for radon-222 (Rn-222), which is a gas rather than a solid, and may be emitted from the uranium ore sample. On a radioactivity basis there is the same amount of U-238 as there is radium-226 (Ra-226) or lead-210 (Pb-210). However, some Rn-222 is emitted leaving the decay progeny below Rn-222 at lower radioactivity levels than U-238. While there is also likely some naturally occurring radioactive thorium also present in ore containing uranium, thorium concentrations and dose from thorium are considered insignificant.

Uranium isotopes emit **alpha particles (α)** by radioactive decay, as do thorium, radium, radon, and other progeny. An alpha particle is a "large" particle — essentially a helium nucleus -- that can travel only a few millimetres in air and will not penetrate paper or a thin layer of skin. Emission of an alpha particle decreases the mass of the emitting radionuclide by four atomic mass units as from U-234 to thorium-230 (Th-230). Decay progeny also emit high energy gamma radiation and **beta particles (β)** during radioactive decay. Gamma radiation can penetrate solid materials. All of these parts of the decay series are ionizing radiation and can contribute to the total dose. If the atomic mass is unchanged [such as from lead-214 (Pb-214) to bismuth-214 (Bi-214)], the decay was a beta decay. The most gamma energy is emitted during the decays of Pb-214 and Bi-214.

Figure 2-1, Uranium Decay Series



2.2 Regulatory Occupational Exposure Limits for Site Contaminants

Occupational **dose limits** for radiological contaminants, airborne contaminants, and ionizing radiation are governed by several regulatory agencies and have the following applicability to GRCA:

- NRC regulations and regulatory limits apply only to **licensed radioactive materials.** However, these regulations are often referenced as being protective for **non-licensed materials** like uranium ore specimens and thus aid in exposure evaluation and control. Therefore, NRC regulations are discussed in this report from an exposure evaluation and control standpoint and not as a regulatory authority.
- EPA provides guidance and public dose limits regarding radioactive material and cleanup levels. Under EPA, historical uranium mining falls under the NORM guidance. From this perspective, the EPA provides guidance documents but does not specify regulations until after a contaminated site has been cleaned up. EPA also provides public dose limit from nuclear power plants and other uranium fuel cycle facilities.
- OSHA specifies regulatory requirements on how workers are protected from chemical contaminants (e.g., metals/organics) as well as non-licensed radioactive materials (e.g., uranium ore specimens). While OSHA regulates non-licensed radioactive materials exposures, OSHA incorporates several sections of the NRC regulations and regulatory exposure limits by reference. Therefore, the OSHA regulations, and applicable NRC regulations, discussed in this report are the regulatory requirements for exposures to uranium ore specimens at GRCA. The regulatory requirements specified by the OSHA, EPA and NRC are described in detail in the following sections.
- The National Council on Radiation Protection (NCRP) is a nongovernmental public service organization that provides information, guidance, and recommendations about radiation protection. NCRP closely cooperates with other radiation protection organizations throughout the world. Although the NCRP has no regulatory authority, the NRC, EPA, and other governmental organizations utilize the NCRP's recommendations as the scientific basis of their radiation protection activities.

2.2.1 Radon Exposure

A significant concern for radiation exposure is inhalation of the radioactive gas radon (Rn-222) and its short-lived alpha-emitting progeny. Although several short-lived isotopes of radon exist, Rn-222 is the most common and primary risk driver. Rn-222 is an inert gas that is part of the uranium decay series (See Figure 2-1); it is introduced into ambient air by diffusion through pores in soil and rocks. Because radon is chemically inert, the inhalation and exhalation of Rn-222 itself do not contribute significantly to dose. The dose is due primarily to the short-lived Rn-222 progeny that enter the respiratory system through attachment of aerosols and particulates that can lodge and concentrate in lung tissue. These progeny have half-lives on the order of minutes and emit alpha radiation. Although alpha particles generally do not penetrate paper or skin layers, they can severely damage more delicate tissue like lung tissue and can also lodge, in bone, as can their radioactive progeny.

Much of the information about **radon exposure** comes from miners exposed to naturally radioactive minerals in poorly ventilated areas. Thus, it is important to consider exposure to radon gas when handling uranium ores. However, people are exposed to Rn-222 every day and at low concentrations which do not appear to pose a significant health risk. The risk from high radon concentrations can be reduced by providing sufficient ventilation to prevent accumulation of stagnant air and by isolating uranium ore bearing materials. The average indoor radon level in the United States is about 1.3 picocurie per liter (pCi/L) and current U.S. Environmental Protection Agency (EPA) residential guidelines suggest that radon concentrations of 4 pCi/L or higher are considered hazardous and should be reduced. Radon concentration can dramatically fluctuate due to environmental conditions and it is recommended that testing occur over longer time to obtain more accurate representation of radon exposure. The greatest risk posed by radon exposure arises in airtight, insufficiently ventilated buildings.

OSHA establishes permissible exposure limits (PELs) to protect workers against the effects of exposures to hazardous substances in 29 CFR 1910.1000, Tables Z-1, Z-2, and Z-3. Radon gas (Rn-222) is the only airborne exposure concern for the AOCs containing uranium ore specimen. However, there is no PEL for Rn-222. Therefore, in 29 CFR 1910.1096(c)(1), OSHA incorporates airborne radiological exposure limits set by the NRC 10 CFR 20, Appendix B, *Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposures.*

In 10 CFR 20, Appendix B, the DAC limit for Rn-222 with daughters from Table 1 is 3E-08 microcuries per milliliter (30 pCi/L or 0.33 **working levels** for 4 **working level months**) for chronic occupational exposures for a 2000-hour work year. Therefore, the applicable occupational limit for radon is the DAC value (30 pCi/L) incorporated by reference by OSHA in 29 CFR 1910.1096(c)(1). However, while the NRC limit applies to a 2000-hour work year, OSHA limits exposure averaging to 40 hours in any workweek of 7 consecutive days. The OSHA limits for minors are established in 29 CFR 1910.1096(c)(2) and restrict average airborne concentrations over a period of not more than 1 week to the limits in 10 CFR 20 Appendix B, Table 2 (effluent limits). The Appendix B, Table 2 limit is 0.1 pCi/L.

> *Note: The OSHA ionization standard was written in 1971 considering the NRC's limits provided in 1969. The NRC revised 10 CFR 20, Appendix B in 2003. This has led to some discrepancy in the interpretation of the OSHA limits, the limits discussed in this document are the more restrictive limits.*

The NCRP has recently released Report No. 180. It details new guidelines for management of exposure to ionizing radiation (NCRP, 2018). The guidelines recommend factoring radon dose contribution into an individual's annual occupational effective dose when activity concentrations that remain in air are greater than 8.1 pCi/L [300 Becquerel per cubic meter (Bq/m^3)] after radon mitigation measures. NCRP Report No. 180 recommends that radon levels in dwellings and workplaces should be assessed and mitigated to reduce the activity concentration in air of radon in dwellings and workplaces to less than 8.1 pCi/L. NCRP recommends trying to achieve the World Health Organization (WHO) activity concentration goal of 2.7 pCi/L (100 Bq/m^3) (WHO, 2009).

2.2.2 Ionizing Radiation

Dose Limits (i.e., exposure limits) for ionizing radiation (i.e., external exposure, radon exposure, the sum of which equal the total exposure) have been set by the EPA in Title 40 CFR Part 300, NRC in 10 CFR 20, and OSHA in 29 CFR 1910.1096. Table 2-1 presents the public and/or occupational EPA, NRC, and OSHA dose limits for ionizing radiation.

Table 2-1, Whole Body Radiation Dose Limits

Agency	Occupational Limit	Limit for Minors	Public Limit
NRC (10 CFR 20)	5,000 mrem/yr for trained radiation workers	500 mrem/yr for trained radiation workers	100 mrem/yr from licensed activities or materials
EPA (40 CFR 190)	Not applicable	Not applicable	25 mrem/yr from nuclear power plants and other uranium fuel cycle facilities
OSHA (29 CFR 1910.1096)	1250 mrem/quarter for non-licensed activities or materials; 1 Working Level Month for Rn-222	125 mrem/quarter for non-licensed activities or materials	Not applicable
NCRP 180	5,000 mrem/yr	100 mrem/year (occupational)	100 mrem/year from stable, characterized sources subject to an advance control program; **OR** 2,000 mrem/year for the first year after identification of radioactive material not previously subject to control reducing dose using optimization of protection in later years.

3. Exposure Evaluation Methodology

3.1 Objective Data Methodology

The contractor conducted an exposure evaluation using **objective data** for NPS personnel and visitors that may have been exposed to uranium ore specimens. According to OSHA, objective data is data the employer uses to predict/estimate **worker exposures** associated with a new process/activity conducted at the workplace. To use this data, the employer must demonstrate the workplace conditions/exposures (i.e., process, exposure duration, etc.) associated with the objective data closely represent the workplace conditions/exposures associated with the predicted/estimated exposure. The contractor obtained this information by participating in interviews with personnel that worked with the GRCA's specimen collection.

If historical monitoring data is used as objective data, the historical monitoring data must also represent a worst-case exposure scenario when compared to the predicted/estimated exposure. The contractor used data provided in the following documents to help prepared the exposure assessment:

- A 2000 evaluation of the uranium ore specimens conducted by NPS (NPS, 2000);
- A 1986 evaluation of the Orphan Mine conducted by the USGS (Chenoweth, 1986);
- A 1981 radiation survey report prepared by Metal and Nonmetal Mine Safety and Health Administration (MSHA) (Day, et. al., 1981);
- A 1985 Radon Study conducted by the NPS (NPS, 1985b); and
- Historical photographs provided by NPS personnel.

Therefore, as the "predicted/estimated" exposures presented in this report are based entirely upon the use of objective data, the source of the objective data as well as descriptions of the new workplace activities have been presented in the sections below.

The following information regarding NPS activities was documented in this report and evaluated during the exposure evaluation to identify if the activity meets the OSHA objective data requirements:

- A description of the work activities conducted by NPS personnel and visiting researchers;
- A description of the work activities conducted NPS minor interns less than 18 years of age;
- The duration and frequency of work activities;
- The duration and frequency of school-aged visitors;
- The specific areas where uranium ore specimens were stored over time; and
- Any other data relevant to the activity, operation, process, material or employee exposure.

3.2 Evaluation of Radiation Dose

The radiation hazard presented by a collection of geological specimens containing NORM depends on the quantity (total mass) of the specimens, the amount of radioactive contamination being released to the surroundings, and the exposure scenario. The GRCA exposure evaluation was based on workers and visitors conducting routine activities in the AOCs and non-disruptive tasks associated with the ore specimens (i.e. non-specimen disturbing). The exposure evaluation does not include potential internal doses to any other airborne radiation source such as dust generated from handling the specimens. A study conducted at the National Museum of Wales, which housed some 500 uranium and thorium containing specimens, indicated that exposures from the inhalation of dust were unlikely (Lambert, 1994). The Wales study also concluded that dose from beta radiation was insignificant given the shielding provided by storage containers (Lambent, 1994). The total dose evaluations herein only assess external gamma dose and internal dose to radon and do not include beta dose or internal doses to any other airborne radiation source (i.e., dust containing non-radon progeny radionuclides).

3.2.1 External Dose Evaluation Methodology

External **ionizing radiation** exposures (or **external dose**) for activities were evaluated using historical radiation surveys and information obtained from NPS personnel interviews. Because **external exposures** also depend on the length of time spent in the work area and the distance from the radioactive materials, exposures were also evaluated based on the time a person would spend within each AOC and their distance from the ore specimens.

External doses were modeled using the MicroShield^{TM} dose modeling program (Version 9.08). The source uranium concentrations were modeled based on historical information uranium concentrations in Orphan Mine ores (Chenoweth, 1986). The source geometries were based on the ore specimen dimensions provided on the collections catalog cards (NPS, 2019) and historical information on how the specimens were stored or displayed. The Museum Collections ore specimens catalog is provided in Appendix D. Results from previous surveys conducted on specific ore specimens (NPS, 2000) were used to validate the modeled results.

3.2.2 Radon Dose Evaluation Methodology

Internal exposures (or **radon dose**) for each exposure scenario identified in Section 5 were assessed using calculated **radon** concentrations based on historical uranium concentrations in Orphan Mine ores (Chenoweth, 1986), a radon emission model reported by the Health Physics Society (HPS) (HPS, 2019), applications from a health physics text (Cember, 2009) and historical information on room sizes and air exchange rates. Because exposures to **radon** are also dependent on the time spent in the work area, exposures were also evaluated based on the time a worker or visitor would spend within each AOC. Radon exposures were assessed using the following historical data and methodologies:

- Determination of reasonable uranium concentration ore samples (Chenoweth, 1986):
    - The USGS report provided information on U_3O_8 ore content at the Orphan Mine.
    - Notable concentrations included (Chenoweth, 1986):
        - 0.43% - The average ore content over lifespan of mine.
        - 1.55% - Highest quarterly ore concentration. Occurred 4th quarter of 1958.
        - 4.09% - Highest reported one-time shipment (unable to verify records; reported by a former mining employee).
    - 1.55% ore content was selected as the ore concentration used in modeling. It was a conservative value compared to the 0.43% average concentration and the majority of experimental contact dose rates were shown to be most similar to the modeled contact dose rates using the 1.55% ore concentration. The 4.09% ore concentration, from an unsubstantiated report by a former mining employee, would have made the most conservative parameter; however, specimens with this concentration would most likely be rare and unrealistic based on historical records.
    - Density of ore was estimated to be 2.87 g/cm^3 based on composition of ore minerals given in Table 7 of the USGS report.
    - The ore composition allowed for determination of activity of uranium progeny in equilibrium.
- Determination of radon emission rates from a model suggested by the HPS for determining radon emanation from granite counter tops (HPS, 2019):
    - The granite countertop model aided in providing a conservative framework to determine radon influx rate and concentration. Granite countertops can be used as an analog to uranium ore because they both contain levels of NORM and can emit radon.
    - Demonstrated application of 20% emission rate (NRC, 1980).
    - Radon generation and emission was determined from Ra-226 activity.

- o Demonstrated calculation of steady state radon concentration and interpretation from radon influx rate.
- Used methods and equations from Cember, a reputable health physics text. to determine radon concentrations in air and working level months (WLM) (Cember, 2009):
  - o Provided methods for determining Rn-222 steady state concentration with ventilation.
  - o Utilized assumptions aiding in determining WLM from a Rn-222 concentration in air.
  - o The WLM developed allowed for application a simple, yet conservative, dose conversion factor to later determine a dose rate from the International Council on Radiation Protection (ICRP) Publication 137 (ICRP, 2017).
- The NPS supplied documents pertaining to size of collection's specimens, dimensions of the building AOCs, and information on building ventilation:
  - o The catalog of collection's specimens provided approximate size of each specimen (NPS, 2019).
  - o Drawings of the Museum Collections Building, the former Visitor Center, and the former Naturalist Building allowed for estimation of room volumes.
  - o Ventilation information was supplied in some building drawings and information obtained with NPS maintenance personnel helped estimate air exchange rates and performance of system.

3.2.3 Radon Dose Calculation

A dose and concentration model for annual radon exposures was developed for the Collections Building (2000 to 2018), and Visitor Center (1967 to 2000), Naturalist Building (1950s to 1967). Parameters were obtained from historical data and records, interviews, and are conservative. The following steps provide the methods used to calculate the dose. The example given is for an adult researcher spending eight hours a day and 15 days a year (120 total hours) in the Natural History Room of the Collections Building is demonstrated below with assumptions provided. Abbreviations used in the equations below include:

- λ – radioactive decay constant
- µm – micron (micrometer)
- AE_{rate} – air supply rate/volume
- Bq – Becquerel
- C – concentration in air
- CFM – cubic feet per minute
- Ci – Curie
- DCF - Dose Conversion Factor
- ft^3 – cubic feet
- G – Rn-222 generation rate
- g – gram
- g/cm^3 – grams per cubic centimeter
- hr - hour
- kg - kilogram
- L - liter
- mSv – milliseivert (1 mSv = 100 mrem)
- pCi - picocurie
- Q – AE × Room Volume
- s – seconds
- V - volume
- $V \times \frac{dC}{dt}$ – activity rate of change
- WLM – working level month

1. Determination of radon isotope

Rn-222 was the only isotope of radon considered. Other isotopes occur less and are not expected to contribute substantially to dose estimations

2. Determination of Rn-222 activity generation (G) into ambient air.

$$\boldsymbol{G} = 4.4 \times 10^{-9}\frac{Ci}{g} \times \frac{3.7 \times 10^{10} Bq}{1\,Ci} \times \frac{1\,atom}{1\,Bq \cdot s} \times \frac{3600\,sec}{hour} \times \frac{2.1 \times 10^{-6} decay}{atom \cdot s} \times 0.2 = \mathbf{0.247}\frac{\boldsymbol{Bq}}{\boldsymbol{g \cdot hour}}$$

Assumptions:

- A U_3O_8 mass percent of 1.55% was selected. This was the highest average concentration of uranium ore reported over a quarter for the nearby Orphan Mine (Chenoweth, 1986).
- Specific activity of U-238 and progeny in 1.55% ore was calculated to be 4.4 x 10^{-9} Ci/g. U-235 decay series was not included due because Rn-219 dose being considered insignificant compared to Rn-222 due to much shorter half-life.
- Assumed U-238 decay series equilibrium. Activity of U-238 = Activity Ra-226 = Production rate Rn-222.
- Radon emanation rate of 20% was selected. This is a conservative estimation used for uranium mill tailings (NRC, 1980).

3. Determination of Rn-222 Concentration without Air Recirculation

$$activity\ change = generated\ activity - recirculated\ activity - decayed\ activity$$

$$V \times \frac{dC}{dt} = G - (C \times V \times AE\ rate) - (\lambda \times V \times C)$$

$$C\ (steady\ state) = \frac{G}{Q + \lambda V} \approx \frac{G}{Q}\ if\ Q \gg \lambda V$$

$$\text{Where } Q = AE_{rate} \times Room\ Volume$$

$$C_{ss} = \frac{0.247\frac{Bq}{g \cdot hr} \times \frac{27\,pCi}{1\,Bq}}{(2.19 \times 10^5 Liters \times 7.75\,hr^{-1})} = \mathbf{3.92} \times \mathbf{10^{-6}}\frac{\boldsymbol{pCi}}{\boldsymbol{L \cdot g}}$$

Assumptions:

- If there is no appreciable ventilation and air recirculation then the radon concentration will be approximately equal to the radon equilibrium value divided by the volume of the room (Lambert, 1994).
- Obtain activity concentration of ^{222}Rn through activity balance.
- Natural History Room Volume (V) ≈ 7,742 ft^3 = 2.19 x 10^5 L.
- Air Supply Rate = 1000 CFM.
- AE_{rate} = Air Supply Rate/Volume 1000 CFM/7,742 ft^3 = 7.75 hr^{-1}.

4. Determination of Rn-222 Concentration with Air Recirculation

$$C = \frac{G + (C_v \times Q_v)}{Q} = C_{ss} + \frac{(C_{ss} \times P) \times (Q \times r)}{Q} = C_{ss}(1 + P \times r)$$

Where: C_v is the recirculated and ventilated radon concentration, Q_v is the ventilation rate, P is the filter penetration, and r is the air recirculated ratio.

$$C = 3.92 \times 10^{-6} \frac{pCi}{L \cdot g}(1 + 0.9 \times 0.35) = \mathbf{5.16 \times 10^{-6} \frac{pCi}{L \cdot g}}$$

$$C\ (including\ ore\ mass) = 5.16 \times 10^{-6} \frac{pCi}{L \cdot g} \times 93{,}500\ g\ ore = \mathbf{4.82 \times 10^{-1} \frac{pCi}{L}}$$

Assumptions:

- 90% of indoor air is recirculated.
- Assume Rn-222 progeny only sorb to small particles < 3 μm (conservative).
- MERV Filter Rating of 11 filters 65% of particles < 3 μm. Thus, 35% of < 3μm particles penetrate filter.
- Air is perfectly mixed.
- All ore specimens are stored in Natural History Room. Total mass of ore is estimated to be approximately 93.5 kg. The mass was estimated by obtaining length dimensions of ore samples (NPS, 2019) and using a density of 2.87 g/cm^3. All dimensionless samples were estimated to have mass based off average of other similar samples (excluding bucket samples).

5. Determination of Radon Dose

$$WLM_{Annual} = C_{Rn-222} \times f \times \frac{0.01\ WL}{\frac{pCi_{equilibrium}}{L}} \times \frac{\frac{hr\ exposed}{year}}{170 \frac{hr}{WLM}}$$

$$WLM_{Annual} = 4.82 \times 10^{-1} \frac{pCi}{L} \times 0.4 \times \frac{0.01\ WL}{\frac{pCi_{equilibrium}}{L}} \times \frac{8 \frac{hr}{day} \times \frac{15\ day}{year}}{170 \frac{hr}{WLM}}$$

$$= \mathbf{1.36 \times 10^{-3} \frac{WLM}{year}}$$

$$Dose = WLM \times DCF \left(\frac{mSv}{WLM}\right) \times 100 \frac{mrem}{mSv}$$

$$Dose = 1.36 \times 10^{-3} \frac{WLM}{year} \times 10 \left(\frac{mSv}{WLM}\right) \times 100 \frac{mrem}{mSv} = \mathbf{1.35 \frac{mrem}{year}}$$

Assumptions:

- Researcher spends 8 hours a day for 15 days a year in the Natural History Room.
- The **Equilibrium Factor** (*f*) = 0.4. A review of Rn-222 equilibrium factors demonstrates that 0.4 is typical and appropriate for use in indoor environments when the local environment has not been adequately characterized. Variability in equilibrium factors can vary by more than

50% due to factors such as particle concentrations, ventilation rates, local surfaces, and radon emanation (Chen, 2018).

- Rn-222 Dose Conversion Factor from ICRP 137 (DCF) = 10 mSv/WLM (ICRP, 2017; 1,000 mrem/WLM). Note: The DCF from ICRP 137 is developed for occupational intake; however, it is intended that the same DCF applies for public exposures until radionuclide intakes by members of the public are eventually published.

3.2.4 Assumptions and Parameters in Radon Models

The following additional assumptions and parameters (provided in Table 3-1) apply to the radon dose models.

Assumptions:

- Museum Collection Building
  - A total of 93.5 kg of uranium ore is stored in this Natural History Room.
  - Radon dose in Museum Collection Building offices, the Wet Lab, and the Map Room is solely due to recirculated and ventilated air from Natural History Room. This assumes all recirculated from Natural History is recirculated into these rooms. This is an extremely conservative and worst-case exposure. Likely air supply is from other ventilation systems and/or diluted substantially.
- Former Visitor Center
  - Assume only three large ore specimens (approximately 40 kg) were stored in display cases in the display area (V = 520 m^3).
  - No information was provided regarding recirculating of air in the former Visitor Center. Therefore, calculations used same recirculating and filtration values as in Natural History Room in the Collection Building.
  - Air Exchange Rate in room is estimated to be 6.5 exchanges per hour based on an estimated 2000 CFM air supply.
- Former Naturalist Building
  - All 93.5 kg of ore was stored in north entry room (V = 365 m^3).
  - Little information about ventilation in the 50s and 60s. Use 1989 HVAC diagrams to estimate 5.91 air changes per hour. Assume no recirculated air.

3.2.5 Total Ionizing Radiation Dose Calculation

Total ionizing radiation dose (herein referred to as total dose) was calculated by adding the external dose and the radon dose results for each exposure scenario.

Table 3-1, Radon Dose Calculation Parameters

	Museum Collections		Visitor Center	Naturalist Building
Years	1999-2018		1967 - 1999	1950s - 1967
Current Use	Collection Building		Park Headquarters	Community Library
Room	Natural History Museum	Other Rooms	Display Room	Display Room
Modeled Ore Specimen #	#20081	#20081	#20081	#20081
Uranium Content (%)	1.55	1.55	1.55	1.55
Generation Rn-222 in Ore (atoms/g•s)	1.62E+02	1.62E+02	1.62E+02	1.62E+02
Emanation Factor	2.00E-01	2.00E-01	2.00E-01	2.00E-01
Ore in Room (g)	9.35E+04	0.00E+00	4.00E+04	9.35E+04
Volume (m^3)	2.19E+02	N/A	5.20E+02	3.65E+02
Air Recirculate Ratio	9.00E-01	9.00E-01	9.00E-01	0.00E+00
Filter Penetration (P)	3.50E-01	3.50E-01	3.50E-01	0.00E+00
Ventilation Rate (CFM)	1.00E+03	1.00E+03	2.00E+03	1.27E+03
C no recirculation (pCi/L)	3.67E-01	0.00E+00	7.85E-02	2.89E-01
C with recirculation (pCi/L)	1.16E-01	1.16E-01	2.47E-02	0.00E+00
C total (pCi/L)	4.82E-01	1.16E-01	1.03E-01	2.89E-01
Equilibrium Factor (f)	4.00E-01	4.00E-01	4.00E-01	4.00E-01
Working Levels (WL)	1.93E-03	4.62E-04	4.13E-04	1.16E-03
Dose Conversion Factor (mSv/WLM) (ICRP, 2017)	1.00E+01	1.00E+01	1.00E+01	1.00E+01

4. Objective Data Used to Evaluate Worker Exposures

4.1 Historical Gamma Surveys

Previous gamma survey measurements on several of the uranium ore specimens in the GRCA museum collections were measured as part of a limited reconnaissance conducted by the NPS to examine NORM at GRCA (NPS, 2000). The report from this reconnaissance effort provides a general background and history and identified the AOCs as the Museum Collections Building (Natural History Room), the "Old Warehouse," The Interpretation Garage, the NPS Visitor's Center basement, and the NPS Visitor's Center uranium mining display. The assessment included measuring external gamma radiation on contact with and various distances from specific ore specimens, measuring total alpha and beta activity on ore specimens and mine drill core samples, and measuring alpha and beta radioactivity on removal contamination "swipe" samples taken from ore specimens.

Historical survey data from 1981 (Day, et. al, 1982) was compared against data reported by NPS on 2000. In 1985, external radiation dosimeters (badges) were placed in storage areas and worn by personnel working in the immediate vicinity of Orphan mine core samples to obtain worker dose estimates (NPS, 1985a). Additional gamma radiation survey measurements were reported as part of a 1985 radon study by NPS (NPS, 1985b). The information from the 1981 MSHA report (Day, et. al., 1981) and the 1985 NPS radon study were used primarily to validate the information from the 2000 NPS report and assumptions and conclusions of the exposure assessment presented in this report.

Table 4-1, Historical Gamma Surveys

Date	Reference	Measurement Location	Gamma Exposure Rate [microR/hr (µR/hr)]	Position of Measurement
June 20-22, 2000	NPS, 2000	Museum Collection Building, Natural History Room	5,000	On contact with Specimen #20081
June 20-22, 2000	NPS, 2000	Museum Collection Building, Natural History Room	500	1 meter from Specimen #20081 [a]
June 20-22, 2000	NPS, 2000	Former Visitor center (Basement)	490	On contact with Specimen #7540 [b]
June 20-22, 2000	NPS, 2000	Former Visitor center (Basement)	800	On contact with Specimen #7539 [b]
June 20-22, 2000	NPS, 2000	Former Visitor center (Basement)	3200	On contact with Specimen #20235 [b]
June 20-22, 2000	NPS, 2000	Former Visitor center (Basement)	4800	On contact with Specimen #17508 [c]
June 20-22, 2000	NPS, 2000	Former Visitor center (Basement)	200	On contact with Specimen #20057 [c]
June 20-22, 2000	NPS, 2000	Former Visitor center (Basement)	4,000	On contact with Specimen #20082 [b]
May 12, 1985	NPS, 1985	Community Building (Background)	24	General Area
May 12, 1985	NPS, 1985	Boiler Room/ Headquarters Facility	38	General Area

Date	Reference	Measurement Location	Gamma Exposure Rate [microR/hr (µR/hr)]	Position of Measurement
May 12, 1985	NPS, 1985	Orphan Mine Core Samples/ Headquarters Facility	41	General Area
May 12, 1985	NPS, 1985	Study Collection Office/ Headquarters Facility	32	General Area
May 14, 1985	NPS, 1985	Study Collection Storage Rm./ Headquarters Facility	2,200	1 foot from 100 pound ore specimen [d]
May 28, 1985	NPS, 1985	Study Collection Storage Rm./ Headquarters Facility	1,300 – 4,400	Along the northern wall at floor levels
May 28, 1985	NPS, 1985	Study Collection Storage Rm./ Headquarters Facility	2,800 – 3,200	Large specimen container with numerous samples [d]
June 4, 1985	NPS, 1985	Study Collection Storage Rm./ Headquarters Facility	40	General Area
July 16, 1980	NPS, 1980	Atchison Topeka and Santa Fe Railroad siting previously used to load ore	3,000	On contact with ore

Notes:

a. Specimen reported as later being stored in one of three buckets in the Museum Collection Building, Natural History Room.
b. Specimen reported as later being stored in Drawer N.B16.01 in the Museum Collection Building, Natural History Room.
c. Specimen reported as later being stored in Drawer N.B17.04 in the Museum Collection Building, Natural History Room.
d. Removed from the Study Collection and place in a wooden enclosure located in the Boiler Room.

The historical gamma dose rates provided in Table 4-1 are similar to the measurements made on the collection at the National Museum of Wales. However, the maximum gamma radiation dose rate measurement in the Wales collection room was 9,000 µR/hr near drawers containing 50 uraninite specimens totaling about 10 kilograms (Lambert, 1994). This dose rate was more than twice what was recorded in the former GRCA Study Collections Storage Room. The higher dose rate could be attributed to influences from nearby ore specimens, differences in ore composition, and the orientation of specimens within the drawers.

4.2 Historical Radon Data

Historical radon data is presented in the 1985 NPS radon study (NPS, 1985b). This study evaluated radon level in various locations within the former Visitor Center (current Park Headquarters Building). Results from the 1985 report are provided in Table 4-2. However, the exact location and appropriate geometry of the radon samples with respect to the uranium ore specimens are unknown. The radon concentrations provided in Table 4-2 are similar to the radon data from the National Museum of Wales study. In that study, it was shown that in conditions of very poor ventilation, radon concentrations can exceed 145 pCi/L in a small (28 m^3) poorly ventilated room (Lambert, 1994). The Wales study also demonstrated that for a larger closed room (200 m^3), an average radon concertation of more than 20 pCi/L would not be unexpected and that the concentration would drop off by a factor of about 5 when the door to the room was opened (Lambert, 1994).

Separate studies were conducted in 1982 that presented radon levels in the Study Collections Room of the former Visitor Center, the Orphan Mine, and a “Playing Field” and the Grand Canyon High School (EPA, 1982a and NPS, 1982). These data are presented in Table 4-3. It should be noted that the EPA’s evaluation of the NPS radon sampling concluded that the single grab samples did not accurately describe potential health risks (EPA, 1982b).

This data was compared against the modeled results for validation of the radon exposure assessment approach.

Table 4-2, Historical Radon Data – Part 1

Location in Former Visitor Center [a]	Sample Period					
	Nov. 1982 – Feb. 1983	Feb. 1983 – May 1983	May 1983 – Sept. 1983	Sept. 1983 – Dec. 1983	Sept. 1984 – Dec. 1984	Dec. 1984 – Mar. 1985
	Radon (Rn-222) Concentrations [picocuries per liter (pCi/L)] [b]					
Study Collection/ Storage Rm. Core Vault [c]	24.19	16.54	16.27	26.08	11.50	25.47
Study Collection/ Storage Rm. North Wall [d]	12.62	6.79	3.22	5.59	9.32	19.37
Visitor Center Boiler Rm./ North Wall	No Data	No Data	No Data	No Data	1.32	2.30
Visitor Center Boiler Rm./ Vault Container	No Data	No Data	No Data	No Data	0.94	1.28

Notes:

a. The documents report that the rooms were poorly ventilated, and the detectors were placed near the ore sources (NPS, 1985b).
b. Assessment used Track Etch detectors analyzed by the US EPA (NPS, 1985b).
c. Average activity for the entire Study Collection/Storage Room is 14.8 ± 7.9 pCi/L.
d. Average activity for the North Wall in the Study Collection/Storage Room North Wall is 9.5 ± 5.8 pCi/L.

Table 4-3, Historical Radon Data – Part 2

Location	Reference	Radon Concentration (pCi/L)	Working Level (WL)
Visitor Center Specimen Storage Room	EPA, 1982a	12.5 [a]	0.042
Visitor Center Archaeology Specimen Storage Area	EPA, 1982a	6.4 [a]	0.020
Visitor Center Study Collection Room	NPS, 1982	No Data	0.136 [b]
			0.294 [b]
			0.107 [b]
			0.251 [b]

Notes:

a. Assessment used Track Etch detectors analyzed by the Lawrence Livermore National Laboratory (EPA, 1982).
b. . The study only reported the WL. The method used for this assessment, counting alpha emissions from a glass fiber filter (NPS, 1982), is considered less accurate than the Track Etch detectors also reported in this table. The poor accuracy is due to the method of radon collection by grab samples and cannot provide a reasonable determination of risk.

4.3 Historical Worker Exposure Monitoring

In 1985, a radiation exposure assessment was performed by the GRCA Safety Officer using film badges (NPS, 1985a). According to the Safety Officer's report, the "study was purposely conducted to identify the possibility of over-exposure conditions for employees." The study concluded that there was no reportable dose greater than the minimum reportable dose of 1.25 millirem (mrem). The results of the study are provided in Table 4-4.

Table 4-4, Historical Worker Exposure Monitoring

Film Badge Number	Location	Start Date	End Date	Reported Collective Dose (mrem)
5924-0001	Study Collections Office	February 11, 1985	March 11, 1985	< 1.25
5924-0002	Study Collections Storage Room	February 11, 1985	March 11, 1985	< 1.25
5924-0003	Boiler Room (on vault)	February 11, 1985	March 11, 1985	< 1.25
5924-0004	Employee	February 11, 1985	March 11, 1985	< 1.25
5924-0005	Employee	February 11, 1985	March 11, 1985	< 1.25
5924-0006	Control	February 11, 1985	March 11, 1985	< 1.25

5. Exposure Scenarios and Dose Evaluation Results

The worker and visitor exposure scenarios and dose evaluation results for NPS activities at the GRCA Museum Collections Building and other former uranium ore storage and display locations (the AOCs) are discussed in this section. OSHA only allows historical monitoring data to be used as “objective data” if the historical data represents a “worst-case” exposure scenario. In the event that some of the data may be questioned as being the most conservative and lead to the “worst case” dose estimate, other conservative exposure assumptions with respect to exposure times and distance are added to exposure scenario to build in additional conservatism. Each subsection below both defines the exposure scenario and provides the results of the dose evaluation.

The following are parameters that are common to all exposure scenarios:

- Uranium ore grade (% U_3O_8): 1.55% (Chenoweth, 1986)
- Density of ore: 2.87 grams per cubic centimeter (g/cm^3) (Chenoweth, 1986)
- Grams of uranium per gram of ore: 0.0132 (calculated)
- Specific activity of natural uranium: 6.92 E-07 curies per gram (Ci/g)
- Uranium decay series activity: 4,389 picocuries per gram (pCi/g) of uranium
- Uranium series decay progeny are in secular equilibrium with U-238
- Actinium decay series activity: 202 pCi/g of uranium
- Actinium series decay progeny are in secular equilibrium with U-235
- Specimen volume: 4,646 cm^3
- Specimen mass: 13,344 g (from specimen #20081)

5.1 NPS Employees

During this exposure and dose evaluation, NPS employees working in the GRCA Museum Collections Building were interviewed to determine the following:

- Short-term and long-term of uranium ore specimen storage locations;
- Primary work locations of NPS employees;
- Secondary work locations of NPS employees close to uranium ore specimen storage locations; and
- Maximum number of hours likely spent in areas close to uranium ore specimen storage locations.

For exposures in the Former Visitor Center, a full-time cashier and a maintenance worker are assumed to receive exposure from ore specimens in the display case shown in Figure 1-3. The maintenance worker is assumed to be in close proximity to the specimens on display while cleaning the glass for one hour per week. The collections staff is assumed to receive their exposures from the ore specimens in storage (Study Collection) and not on display. Personnel were generally in the Study Collection area two hours or less per day (NPS, 1982). In December 1984, uranium mine cores were removed from the Study Collection area and moved to the basement boiler room (NPS, 1985b). In May 1985, ore specimens and other mineral samples were removed from the Study Collection and placed in a wooden cabinet in the boiler room (NPS, 1985b). Exposures to the Study Collection in the boiler room are expected to less than the per-1985 exposures in other areas.

A full-time employee in former Naturalist Building is assumed to be exposed to specimens on display for 8 hours per day and 250 days per year.

All exposure parameters are summarized in Table 5-1. The work locations were used to approximate the distance from the individual “worker” to source.

Table 5-1, NPS Employee Exposure Scenario

Scenario Number	Work Location	Source Location	Worker	Description of Source Term	Distance to Source (feet)	Exposure Time		Room Volume (m^3)
						hr/d	d/y	
1999 – 2018: Museum Collections Building								
1	Office	Natural History Room	Collections Staff	53,375 g in Buckets	21	7	250	Not needed for radon dose estimate
2	Natural History Room	Natural History Room	Collections Staff	53,375 g in Buckets	3	1	87	219
3	Map Room/ Dry Lab	Natural History Room	Collections Staff	53,375 g in Buckets	3	4	20	Not needed for radon dose estimate
1967 – 1999: Former Visitor Center								
4	Display Room Checkout	Display Case	Cashier	40,032 g on display	20	8	250	521
5	Display Room at Case	Display Case	Maintenance	40,032 g on display	1	1	50	521
6	Study Collection Office	Storage Room	Collections Staff	Full inventory w/o display specimens	10	2 (NPS, 1982)	250	283
Mid 1950s – 1967: Naturalist Building								
7	Display Room	Display Case	Collections Staff	26,288 g on display	10	8	250	365

Using the exposure scenarios described in Table 5-1, the maximum dose was modeled with MicroShield™ and summed with an estimated radon dose. The MicroShield™ model results for the source term and the exposure distances are provided in Appendix A. Additional information on the source term and the resulting gamma exposure dose rate and annual dose, radon dose rate and annual dose (if applicable), and the total annual dose are provided in Table 5-2. The external dose rates assume no shielding of the gamma radiation through walls or other solid materials other than self-shielding from the ore mass itself.

The external dose for exposure Scenario #6 was not modeled using MicroShield™. Instead, the external dose was estimated using historical exposure rates provided for the Study Collection Storage Room in the former Visitor Center in Tables 4-1. The historical Study Collection Storage Room radon data provided in Tables 4-2 and 4-3 were useful in providing a general idea of radon concentrations in the storage room which contained some ore specimens and mine core samples. However, in a poorly ventilated room, storage methods and position can result in pockets of radon accumulation that are not always representative of the breathing zone. It is likely that the higher concentration radon samples from the 1985 study were placed in close proximity to specimen collections and containers; however, the exact location and geometry of the radon samplers in relation to exposure points remain unknown. Because of the lack of information regarding radon sampler placement, the historical radon measurement concentrations were not used to calculate a radon dose for the Study Collection Storage Room exposure scenario (Scenario #6). Instead, for consistency, the same radon dose model methodology used for the other exposure scenarios were applied for Scenario #6. Table 5-2 shows that a concentration of 9.5 pCi/L was calculated for the poorly ventilated Study Collection Office in Scenario #6. This modeled concentration is consistent with the 14.8 ± 7.9 pCi/L and 9.5 ± 5.8 pCi/L averages obtained from samples collected from the entire room and along the North Wall, respectively in the collection/storage room in Table 4-2.

Table 5-2, NPS Employee Radiation Doses

Scenario Number	Number of Specimens	Total Source Mass (grams)	Modeled Source Shape	Modeled Contact Dose Rate (mrem/hr)	Exposure Point External Dose Rate (mrem/hr)	Annual External Dose (mrem)	
1	4	53,376	Cylindrical Solid	10.2	0.00439	7.7	
2	4	53,376	Cylindrical Solid	10.2	0.175	15.2	
3	4	53,376	Cylindrical Solid	10.2	0.175	14.0	
4	3	40,032	Rectangular Solid	5.5	0.00246	4.9	
5	3	40,032	Rectangular Solid	5.5	0.607	30.4	
6	Full Inventory w/o display specimens + other specimens and mine core samples for a total source mass of 154,000			4.4 [a]	0.05 [b]	25	
7	2	26,288	Rectangular Solid	5.3	0.00650	13.0	
Scenario Number	**Added Radon Conc. (pCi/L)**	**Equilibrium Factor**	**Working Level (WL)**	**Working Level Months per Year [c]**	**Dose Conversion Factor (ICRP, 2017)**	**Annual Radon Dose (mrem)**	**Total Annual Dose (mrem)**
1	0.116	0.4	4.62E-04	4.76E-3	10	4.76	**12.5**
2	0.482	0.4	1.93E-3	9.88E-4	10	0.988	**16.2**
3	0.116	0.4	4.62E-4	2.17E-4	10	0.22	**14.2**
4	0.103	0.4	4.13E-4	4.86E-3	10	4.86	**9.8**
5	0.103	0.4	4.13E-4	1.22E-4	10	0.12	**30.5**
6	9.5 [d]	0.4	3.80E-2	1.12E-1	10	111.76	**136.8**
7	0.289	0.4	1.16E-3	1.36E-2	10	13.58	**26.6**

Notes:

a. From Table 4-1.

b. Estimated based on historical measurements.

c. $Working\ Level\ Months\ per\ Year\ (WLM) = WL \times \frac{Hours\ Exposed}{year} \times \frac{WLM}{170\ hours}$

d. Assumes 154 kg of source and a very poor air exchange rate of 1 room volume per hour and a poor mixing vertical profile factor of 2.

5.2 Part-time Interns and Visiting Researchers

During this exposure and dose evaluation, full-time NPS employees working in the GRCA Museum Collections Building were interviewed to determine the following:

- Work schedules for recent interns (minors);
- Estimated works schedule for typical visiting researcher; and
- Work locations for minor interns and visiting researchers.

The exposure parameters for the minor interns and visiting researchers are summarized in Table 5-3.

Table 5-3, Minor Intern and Visiting Researcher Exposure Scenario

Scenario Number	Work Location	Source Location	Worker	Description of Source Term	Distance to Source (feet)	Exposure Time		Room Volume (m^3)
						hr/d	d/y	
1999 – 2018: Museum Collections Building								
8	Natural History Room	Natural History Room	Visiting researcher	53,375 g in Buckets	3	8	15	219
9	Natural History Room	Natural History Room	Intern (minor)	53,375 g in Buckets	3	1	40	219
10	Wet Lab	Natural History Room	Intern (minor)	53,375 g in Buckets	17	2	112	N/A

Using the exposure scenarios described in Table 5-3, the maximum dose was modeled with MicroShield^{TM} and summed with a calculated radon dose. The MicroShield^{TM} model results for the source term and the exposure distances are provided in Appendix A. Additional information on the source term and the resulting gamma exposure dose rate and annual dose, radon dose rate and annual dose, and the total annual dose are provided in Table 5-4. The external dose rates assume no shielding of the gamma radiation through walls or other solid materials.

Table 5-4, Minor Intern and Visiting Researcher Radiation Doses

Scenario Number	Number of Specimens	Total Source Mass (grams)	Modeled Source Shape	Modeled Contact Dose Rate (mrem/hr)	Exposure Point External Dose Rate (mrem/hr)	Annual External Dose (mrem)	
8	4	53,376	Cylindrical Solid	10.2	0.175	21.0	
9	4	53,376	Cylindrical Solid	10.2	0.175	7.0	
10	4	53,376	Cylindrical Solid	10.2	0.00666	1.5	
Scenario Number	**Radon Conc. (pCi/L)**	**Equilibrium Factor**	**Working Level (WL)**	**Working Level Months per Year [a]**	**Dose Conversion Factor (ICRP, 2017)**	**Annual Radon Dose (mrem)**	**Total Annual Dose (mrem)**
8	0.482	0.4	1.93E-3	1.36E-3	10	1.36	**22.4**
9	0.482	0.4	1.93E-1	4.54E-4	10	0.45	**7.5**
10	0.116	0.4	4.62E-4	6.09E-4	0	0.61	**2.1**

Notes:

a. $$Working\ Level\ Months\ per\ Year\ (WLM) = WL \times \frac{Hours\ Exposed}{year} \times \frac{WLM}{170\ hours}$$

5.3 Visitors - Adult and Children

During this exposure and dose evaluation, full-time NPS employees working in the GRCA Museum Collections Building were interviewed to determine the following:

- Nature of tours and lectures in the Collections Building;
- Number of adult and children visitors per year; and
- Locations of children in relation to uranium ore specimens.

The exposure parameters for the adult and children visitors are summarized in Table 5-5.

Table 5-5, Adult and Children Visitor Exposure Scenario

Scenario Number	Visit Location	Source Location	Visit Type	Description of Source Term	Distance to Source (feet)	Exposure Time		Room Volume (m^3)
						hr/d	d/y	
1999 – 2018: Museum Collections Building								
11	Natural History Room	Natural History Room	Field Trip with Lecture	53,375 g in Buckets	1	1	2	219
1967 – 1999: Former Visitor Center								
12	Display Room	Display Case	Tourist	40,032 g on display	3	1	5	521
Mid 1950s – 1967: Naturalist Building								
13	Display Room	Display Case	Tourist	26,288 g on display	3	1	5	365

Using the exposure scenarios described in Table 5-5, the maximum dose was modeled with MicroShield™ and summed with a calculated radon dose. The MicroShield™ model results for the source term and the exposure distances are provided in Appendix A. Additional information on the source term and the resulting gamma exposure dose rate and annual dose, radon dose rate and annual dose, and the total annual dose are provided in Table 5-6. The external dose rates assume no shielding of the gamma radiation through walls or other solid materials.

Table 5-6, Adult and Children Visitor Radiation Doses

Scenario Number	Number of Specimens	Total Source Mass (grams)	Modeled Source Shape	Modeled Contact Dose Rate (mrem/hr)	Exposure Point External Dose Rate (mrem/hr)	Annual External Dose (mrem)	
11	4	53,376	Cylindrical Solid	10.2	1.02	4.1	
12	3	40,032	Rectangular Solid	5.5	0.0973	0.5	
13	2	26,288	Rectangular Solid	5.3	0.0659	0.3	
Scenario Number	**Radon Conc. (pCi/L)**	**Equilibrium Factor**	**Working Level (WL)**	**Working Level Months per Year (a)**	**Dose Conversion Factor (ICRP, 2017)**	**Annual Radon Dose (mrem)**	**Total Annual Dose (mrem)**
11	0.482	0.4	1.93E-3	4.54E-5	10	0.04	**4.1**
12	0.103	0.4	4.13E-4	1.22E-5	10	0.01	**0.5**
13	0.289	0.4	1.16E-3	3.40E-5	10	0.03	**0.3**

Notes:

a. $$Working\ Level\ Months\ per\ Year\ (WLM) = WL \times \frac{Hours\ Exposed}{year} \times \frac{WLM}{170\ hours}$$

6. Investigation into Recently Reported Dose Rate Data

6.1 Relocation of Ore Specimen Buckets

In 2017, NPS employees working in the Museum Collections Building were made aware that there were three 5-gallon buckets in the Natural History Room that contained radioactive uranium ore specimens. The buckets had been stored in a location adjacent to a taxidermy cabinet (Location A in Figure 6-1) since being moved from the former Visitor Center Collections Storage Room. One of the buckets is also visible in the photo provided as Figure 6-2. While at least one of the buckets had a radioactive materials label or radiation "tri-foil" symbol on it, staff were not concerned with their storage location until a visitor with a Geiger counter demonstrated that the ore specimens in the buckets did in fact emit detectable gamma radiation.

After recognizing the ore specimens in the buckets as a potential health and safety issue, the employees relocated the three buckets to a position in a less frequently visited area of the building adjacent to a rear exit door (Location B on Figure 6-1). The buckets are visible at this location in Figure 6-3. The three buckets remained in this location for approximately eight months. On June 15, 2018 the three buckets were moved to a storage shelf adjacent to the rear roll-up door in the Large Items Room (Location C on Figure 6-1) by the NPS Intermountain Region Occupational Safety and Health Manager / Radiation Safety Officer (RSO). The buckets were stored at that location for two days until the removed from the building on June 18, 2018.

Figure 6-1, Museum Collection Building Layout and Bucket Storage Locations

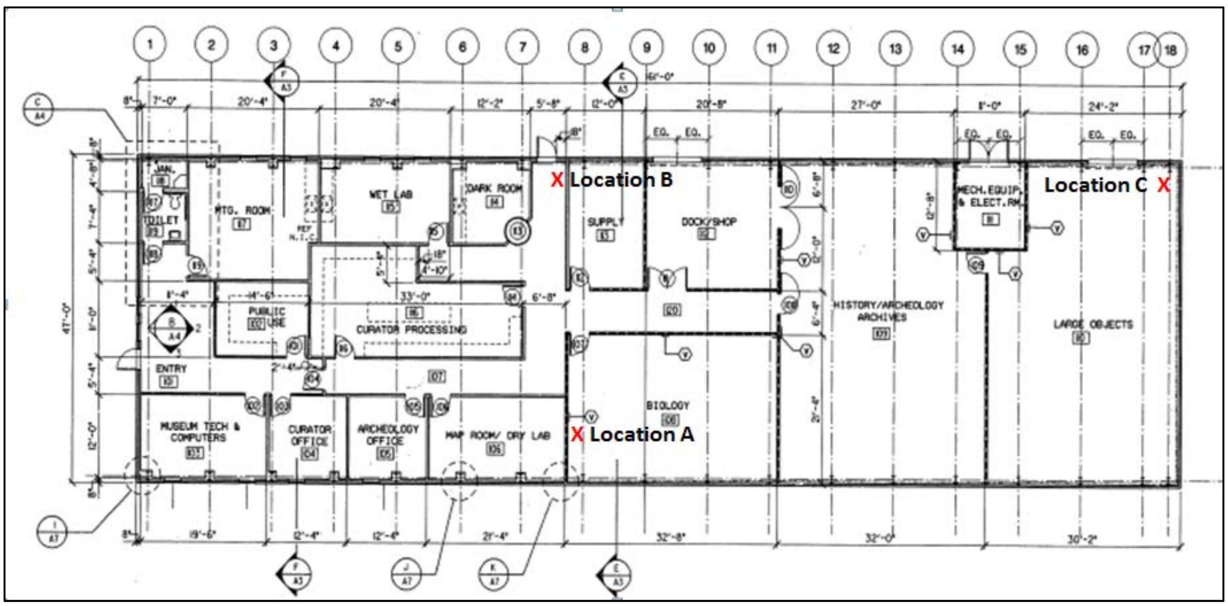


Figure 6-2, Natural History Room with Uranium Ore Storage Bucket (2017)

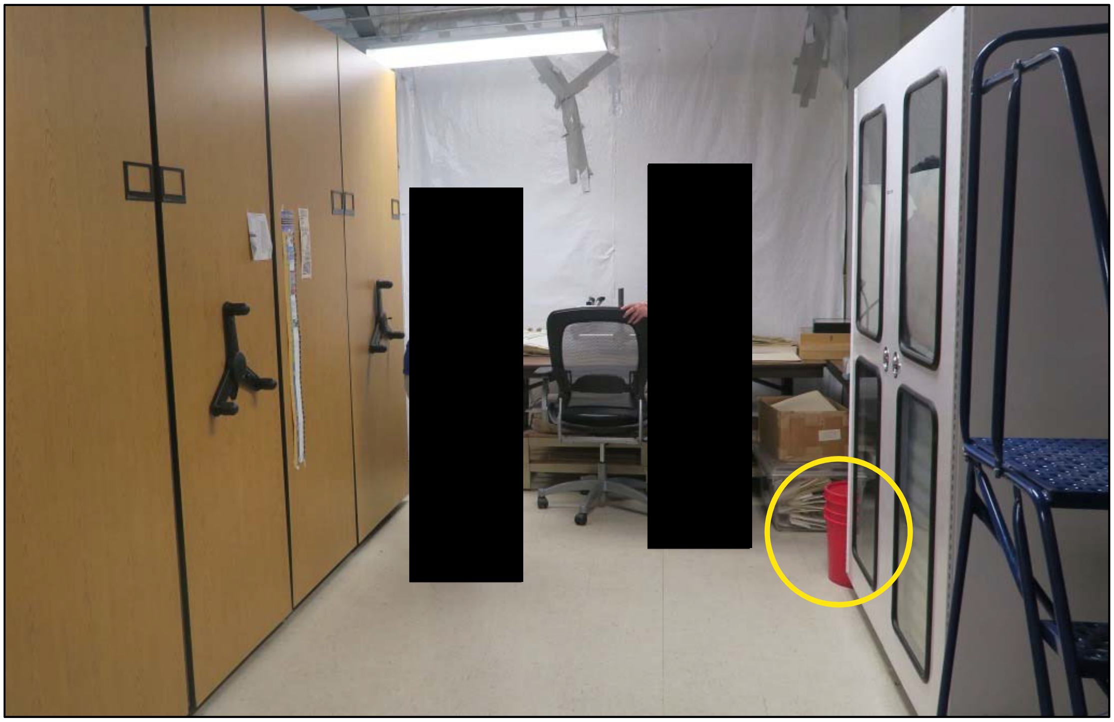
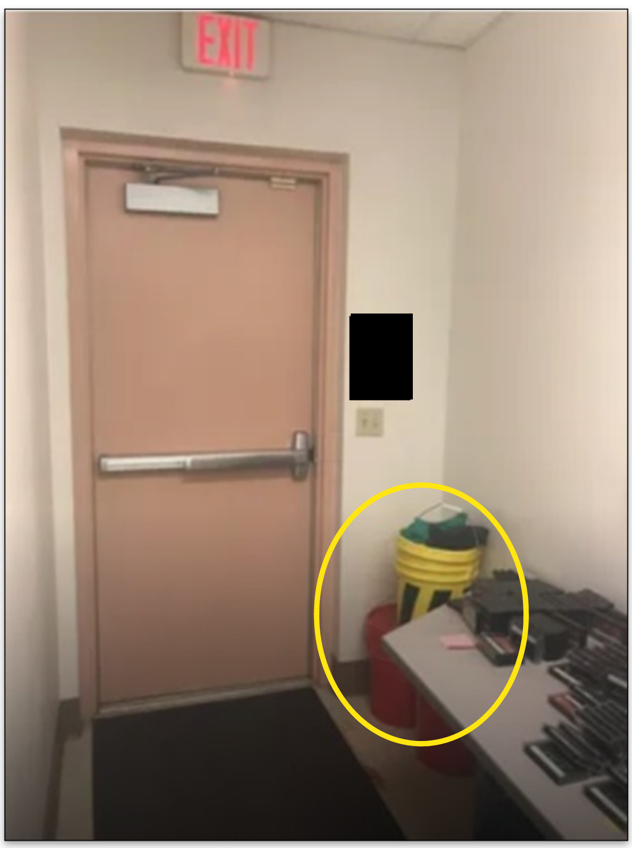


Figure 6-3, Museum Collections Building Hallway with Uranium Ore Storage Bucket



6.2 Reported Dose Rates at the Museum Collections Building

On June 14, 2018, the NPS Intermountain Region RSO responding to the GRCA Museum Collections Building to manage the uranium ore specimens conducted radiological surveys of the three buckets containing ore samples stored next to the exit door (Location B in Figure 6-1) and other ore specimens in the Natural History Room and the Interpretive Collection Room. The RSO recorded gamma radiation exposure rates using a gamma scintillation detector and monitored for surface contamination levels with a Geiger-Mueller "pancake" detector. In August 2018, the results from this survey were reported in a Trip Report memorandum to the Superintendent of the GRCA (NPS, 2018). The reported dose rates were in the Trip Report were in the range of 2.5 milliRoentgen per hour (mR/hr) for a background measurement to 800 mR/hr for a contact measurement with one of the ore samples inside one of the three plastic buckets (NPS, 2018). These radiation levels indicated the ore samples could be a significant health hazard to those that were previously exposed to them.

In February 2019, the RSO's survey results were made public after a GRCA safety official raised concerns with the magnitude of the gamma exposure rates measured by the RSO. These results were published by many print and on-line media on February 18 and 19, 2019 and the results were quickly met with skepticism in the scientific community. The skepticism was voiced in several articles published on February 20 and 21, 2019.

> "Buckets of Uranium at the Grand Canyon? Don't Worry Oak Ridge Experts Say," *Knoxville News Sentinel*, February 21, 2019. https://www.knoxnews.com/story/news/2019/02/21/grand-canyon-radiation-risks-uranium/2919975002/

> "Canyon Park Museum May or May Not Pose Health Risk," *National Public Radio*, February 20, 2019. https://www.npr.org/2019/02/19/696001017/grand-canyon-museum-reportedly-had-buckets-of-uranium-sitting-around-for-18-year

6.3 Radiation Detector Side-by-side Comparison

An element of the scope of the NPS's evaluation conducted in early March 2019 was to investigate the potential for the unusually high measurements reported by the NPS Intermountain Region RSO. Therefore, the consulting health physicist supporting the investigation, a Certified Health Physicist (CHP) with 25 years of environmental assessment experience, participated in an interview with the RSO and later inspected the instruments he used for the surveys.

During the consulting CHP's investigation of the RSO's instrument, he performed a side-by-side comparison of the instrument the consulting CHP brought to the site and the RSO's instrument. The consulting CHP used an analog Ludlum Model 19 exposure rate meter with an internal 1-inch by 1-inch sodium iodide gamma scintillation detector (calibration record provided in Appendix B). The RSO's instrument was a Ludlum Model 3001 digital rate meter coupled to an external Ludlum Model 44-3 1-inch by 1-inch sodium iodide gamma scintillation detector. The Model 3001 digital rate meter is capable of being calibrated to use up to four external detectors (one at a time). When detectors are switched out on the Model 3001, the user switches the calibration by selecting the appropriate detector (Detector 1 through Detector 4).

The side-by-side comparison was made outside the Museum Collections Building, in a background radiation area. Here the consulting CHP's Ludlum Model 19 was reporting a gamma exposure rate of about 12 microRoentgen per hour (μR/hr) or 0.012 mR/hr. The RSO's Ludlum Model 3001 was reporting a gamma exposure rate of 2.35 mR/hr, an exposure rate of approximately 200 times higher than the consulting CHP's detector measurement. However, the RSO's detector measurement was consistent with the background measurement reported in the Trip Report (NPS, 2018).

Upon seeing results of the side-by-side comparison, the consulting CHP requested the calibration records for the Ludlum Model 3001 rate meter and detectors. In his review, he noted that the calibration for "Detector 1" was for a Ludlum Model 44-9 GM detector and the calibration for "Detector 2" was for the Model 44-3 1-inch by 1-inch sodium iodide gamma scintillation detector. The consulting CHP then noted that the Ludlum Model 3001 rate meter was set to operate with Detector 1, but the Model 44-3 detector was connected. The consulting CHP then concluded that RSO likely operated the rate meter in “Detector 1” mode with the 44-3 detector (calibrated as “Detector 2”) connected during the June 2018 surveys. This resulted in reporting gamma exposure rates that were approximately 200 times too high.

To check this theory, the consulting CHP divided the maximum measurement made by the RSO, 800 mR/hr made a contact measurement with one of the ore samples inside on of the three plastic buckets, by 200. The result, 4 mR/hr, is consistent with the contact gamma exposure rate measurement of 5 mR/hr measured on one of the ore specimens from the buckets in June 2000 (NPS, 2000).

7. Current Site Conditions

During this exposure and dose evaluation, full-time NPS employees working in the GRCA Museum Collections Building were interviewed to determine the following:

- Locations where the three buckets that contained uranium ore specimens were stored;
- Location(s) where other ore specimens removed from the building were stored; and
- Location(s) of Orphan Mine drill core samples.

The information provided by the NPS staff directed the investigation team's consulting CHP where to conduct residual alpha/beta contamination surveys and additional gamma exposure rate measurements. For the residual alpha/beta contamination surveys, the CHP used a Ludlum Model 2224 digital rate meter coupled with a Ludlum Model 43-89 alpha/beta scintillation detector. For the gamma exposure rate measurements, the CHP used a Ludlum Model 19 gamma exposure rate meter. Calibration records are provided in Appendix B.

7.1 Surveys at Ore Storage Bucket Locations

Residual alpha/beta contamination surveys were conducted in the three locations where the uranium ore specimen buckets were stored (see Locations A, B, and C in Figure 6-1). The surveys did not indicate the presence of any residual contamination. The survey record for is provided as Survey No. 2 in Appendix C. Survey No. 2 does show measurements that appear to be elevated above background, but these elevated readings are due to the concrete floor.

7.2 Surveys of Other Storage Areas and Taxidermy Items

Residual alpha/beta contamination surveys were conducted in other areas where uranium ores specimens were stored. The list of those locations is provided below:

- Current Park Headquarters Basement/Boiler Room
- Taxidermy Cabinet N.H01 in the Natural History Room of the Museum Collections Building
- Open shelf N.A08.02 in the Natural History Room of the Museum Collections Building
- Drawers within storage cabinets N.B16, N.B18, and N.E01 in the Natural History Room of the Museum Collections Building (Note: Specimens located in cabinet N.B18 were improperly labels as being in N.B17, which was an empty cabinet; current non-ore specimens in N.B18 are now properly labeled.)
- On top of cabinets N.B15 and N.B17 in the Natural History Room of the Museum Collections Building
- Drawers within the Paleo/Geo storage cabinet in the Interpretive Collection Room of the Museum Collections Building

Additionally, surveys were conducted on taxidermy specimens from Cabinet N.H01 in the Natural History Room of the Museum Collections Building and specimens from the Park's Desert View facility. The Desert View specimens, a coyote pup and a great horned owl, were once stored in the in the Natural History Room of the Museum Collections Building.

The surveys of the Park Headquarters Basement/Boiler Room did not indicate the presence of residual alpha or beta contamination or elevated gamma exposure rates. The results of the survey are provided as Survey No. 1 in Appendix C. Survey No. 1 does show measurements that appear to be elevated above background, but these elevated readings are due to the concrete floor.

The surveys of the taxidermy cabinet, the taxidermy specimens, the open shelf, and the tops of cabinets N.B15 and N.B17 in the Natural History Room and the surveys inside the Paleo/Geo storage cabinet in the Interpretive Collection Room did not indicate the presence of any residual contamination. The survey records are provided as in Appendix C.

However, surveys inside storage cabinets N.B16, N.B18, and N.E01 in the Natural History Room of the Museum Collections Building did indicate the presence of low levels of residual alpha and beta contamination, total and removable. The results of the survey are provided as Survey No. 3 in Appendix C. The source of this residual low-level contamination is most likely radon gas (Rn-222) generated from the uranium ore specimens that deposited on surfaces inside the cabinets and decayed to progeny alpha and beta emitters such as lead-210 (Pb-210; beta-emitter) and polonium-210 (Po-210; alpha-emitter). With the source of the radon removed, the residual radioactivity will decay with the half-life of Pb-210, 22.26 years (see Figure 2-1). While these residual contamination levels, which as summarized in Table 7-1, do not pose any significant health hazard, some ALARA recommendations are provided in Section 8.2 of this report.

Table 7-1, Summary of Maximum Residual Contamination Measurements

Cabinet Identification Number	Maximum Total Alpha ($dpm/100cm^2$)	Maximum Removable Alpha ($dpm/100cm^2$)	Maximum Total Beta ($dpm/100cm^2$)	Maximum Removable Beta ($dpm/100cm^2$)
N.B16	1116	244	1533	< MDC
N.B18	3826	349	3511	541
N.E01	163	No swipe sample taken	541	No swipe sample taken

Notes:

$dpm/100cm^2$ – disintegrations per minute per 100 square centimeters

< MDC – less than the minimum detectable concentration

Gamma exposure rate measurements were recorded outside the N.B14 which contains core drill samples from the Orphan Mine. These samples contain NORM and produce an external gamma radiation exposure rate above background levels at 90 µR/hr at the surface of the closed cabinet. While these exposure rates do not pose any significant health hazard, some ALARA recommendations are provided in Section 8.2 of this report. It is likely that Rn-222 gas emitted from the core samples has impacted the interior of cabinet N.B14. As the Rn-222 source is still present, this report provides no recommendations for managing potential residual contamination from Rn-222 on the interior of cabinet N.B14.

8. Conclusions and Recommendations

8.1 Dose Estimates from Past Exposures to Uranium Ore Specimens

Past exposures to uranium ore specimens at GRCA are a small fraction of the natural background radiation the average American receives. The NRC estimates that the average background dose from natural source (i.e., cosmic, terrestrial, and internal) is about 310 mrem/yr. Therefore, past exposures do not represent a significant health risk. Table 8-1 summarizes the modeled exposures and shows the maximum modeled total dose from exposure to the uranium ore specimens. The doses under Scenarios #1, #2, and #3 are summed to give the maximum possible estimated annual dose, 42.9 mrem/yr, to a single full-time employee working in the Museum Collections Building. This annual dose estimate of 42.9 mrem/yr is:

- Approximately 2% of the NCRP recommended 2,000 mrem/year limit for the first year after identification of radioactive material not previously subject to control (NCRP, 2018);
- Approximately 3.5% of the quarterly limit of 1,250 mrem and (29 CFR 1910.1096);
- Approximately 14% of the annual average dose from natural background radiation of 310 mrem/yr (NRC, 2019);
- Approximately 43% of the NRC's public dose limit of 100 mrem/yr from licensed materials (10 CFR 20) and the NCRP's recommended annual public dose limit from materials that area stable, characterized, and subject to an advanced control (NCRP, 2018); and
- Less than twice the EPA's recommended 25 mrem/year dose limit that applies to those exposed from the nuclear power and uranium fuel cycle sources (40 CFR 190).

While little is known about the exact implementation of the 1985 radon study performed in the Study Collection Storage Room of the former Visitor Center (NPS, 1985b), the radon concentration data are similar to the data observed in the National Museum of Wales collection room (Lambert, 1994). The 137 mrem/yr dose estimated from radon in the Study Collection Storage Room (Scenario #6) is believed to be a significant over estimation of the dose to a worker in the area due to the source size estimate (154 kg) and the assumed very poor mixing conditions. The 1985 radon study report showed a high level of variability of radon concentrations in the Study Collection area with higher radon concentrations near the specimen collections and containers and lower concentrations at locations further from the specimen (NPS, 1985b). However, even considering several conservative assumptions, the total annual dose estimate of 137 mrem/yr for a full-time employee under Scenario #6 would increase the employee's annual average dose including 310 mrem/yr from natural background radiation (NRC, 2019) by less than 50%.

Additionally, the investigation of the radiation detection instrument used in August 2018 to perform direct measurements on the ore specimens in the Museum Collections Building revealed that the instrument was not setup properly resulting in measurements approximately 200 times higher than should have been recorded. The historical records and radiation dose modeling provided a more accurate representation of the true radiation exposure dose.

Table 8-1, Summary of Dose Estimates from Past Exposures to Uranium Ore Specimens

Exposure Scenario Number	Description of Exposure Scenario	Annual Gamma Dose (mrem)	Annual Radon Dose (mrem)	Annual Total Dose (mrem)
1	Full-time staff in Museum Collections Building	7.7	4.76	
2	Full-time staff in while in the Natural History Room	15.2	0.99	42.9[a]
3	Full-time staff working in the Map Room / Dry Lab	14.0	0.22	
4	Full-time NPS employee working in the former Visitor Center	4.9	4.86	9.8
5	NPS maintenance employee working in the former Visitor Center	30.4	0.13	30.5
6	Full-time NPS employee working in the former Collections Office	25.0	111.76	136.8 [b]
7	Full-time NPS employee working in the former Naturalist Building	13.0	13.58	26.6
8	Visiting researcher in the Museum Collections Nat. History Room	21.0	1.36	22.4
9	Minor intern in the Museum Collections Nat. History Room	7.0	0.45	7.5
10	Minor intern in the Museum Collections Wet Lab	1.5	0.61	2.1
11	Child visiting the Museum Collections Nat. History Room	4.1	0.04	4.1
12	Tourist visiting the former Visitor Center display room	0.5	0.01	0.5
13	Tourist visiting the former Naturalist Building display room	0.3	0.03	0.3
Background	Annual average dose from natural background radiation	81 [c]	229 [c]	310 [c]

Notes:

a. The doses for Scenarios 1, 2, and 3 were summed as they could apply to the same NPS employee over the course of one year.

b. Considered an over-estimate based on uncertainties in the location of the radon detectors with respect to workers.

c. NRC, 2019.

8.2 Current Radiological Health and Safety Hazards

The current radiological conditions in the Museum Collections Building and the Park Head Quarters Building basement (Boiler Room) do not pose any significant health hazards. No radiation or contamination was detected in the Park Head Quarters Building boiler Room. In the Museum Collections Building, only low levels of residual alpha and beta contamination (likely from the decay of Rn-222) was identified in three mineral specimen storage cabinets in the Natural History Room. Because the cabinets are kept shut and are not opened on a routine basis, the internal residual contamination is not considered a routine hazard.

An elevate gamma exposure rate was detected outside the cabinet in the Natural History Room of the Museum Collections Building containing the Orphan Mine drill core samples. The gamma exposure rates are about 90 µR/hr on contact with the cabinet N.B14 and it drops off to background when less than five feet away. No other areas of elevated gamma radiation were measured in the Museum Collections Building.

8.2.1 Personnel Protective Equipment and Postings

There is no need for NPS personnel to consider the use of personnel protective equipment (PPE) on a full-time basis. However, AECOM recommends that Museum Collections staff and visiting researchers wear disposable nitrile gloves when handling any mineral specimens from cabinets N.B16, N.B17, and N.E01. This is due to the low levels of residual alpha and beta contamination detected in these cabinets. Personnel should also wear disposable gloves when handling Orphan Mine drill core samples from cabinet N.B13. After use, the gloves can be disposed of as municipal waste (regular garbage). The recommended use of gloves would be rescinded if decontamination efforts as indicated below are performed.

The cabinet containing the Orphan Mine drill core samples should bare a label with the words “Caution, Radioactive Materials” and a reminder to wear gloves when handling samples.

8.2.2 Radon Monitoring

The NPS staff in the Museum Collections Building purchased and mounted four digital real-time radon monitors and deployed them in the Collections Building. Two are located in the Natural History Room and one each are located in the Cultural History Room and the Large Objects Room. At the time of the contractor CHP’s visit, all four detectors were reported less than 1 pCi/L. AECOM recommends the staff continue to monitor the detectors, noted the detector in the Large Objects Room may generally report a higher radon concentration due to the concrete floor in the room, and noted the level at which the EPA recommends mitigation measures is 4 pCi/L for residential exposures. OSHA’s occupational limit is 30 pCi/L average over 40 hours in 7 days (0.1 pCi/L average over 1 week for minor employees).

8.2.3 Decontamination

AECOM recommends the NPS decontaminate the interior of cabinets N.B16, N.B17, and N.E01 in the Natural History Room at the Museum Collections Building. This decontamination effort should include a wipe down of the interiors of the cabinets (drawers, wall, doors, etc.) with lint-free cloths and a mild non-hazardous cleaning solution. However, as discussed in the previous paragraphs, there is no immediate health concern with the low-level residual contamination and staff can wear disposable gloves to reduce contamination risks in lieu of decontamination.

9. Limitations

This report has been prepared for the exclusive use of NPS and its assignees. The conclusions in this report are based upon data and information obtained during historical monitoring events at the property identified herein during the activities described on the dates specified. Conclusions contained in this report are based on the expertise and experience of the contractor in conducting exposure evaluations and according to current and accepted regulations. The contractor's objective is to perform our work with care, exercising the customary thoroughness and competence of environmental and engineering consulting professionals, in accordance with the standard for professional services at the time and location those services are rendered. Results presented in this report are indicative of activities and processes described herein. The contractor is not responsible for evaluating the persons/organizations to which this report is distributed to or for implementing the recommendations specified in this plan.

Additional technical limitations of this evaluation include:

- The uranium ore specimens once contained in the GRCA collections were not available for direct analysis. They were relocated to the Orphan Mine site in August 2018. However, modeling closely approximates historical radiation dose rate measurements.
- While naturally occurring radioactive thorium is likely also present in some or all of the uranium ore specimens, the dose contribution from the thorium is thought to be insignificant and was not considered in this evaluation.
- Historical radon data are included primarily for information purposes and should not be considered representative of the average working environment because of the limited information available on the placement of the radon samplers.

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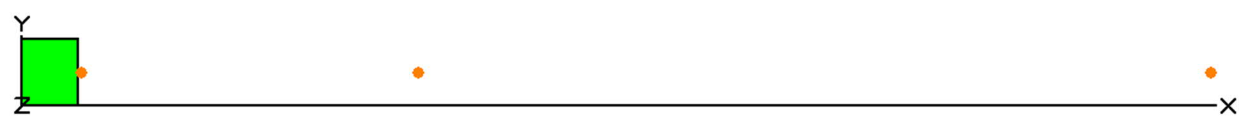
Appendix A
MicroShield^{TM} Dose Models
(14 pages)

TWO SPECIMEN MODEL OF SAMPLE #20081

Two Specimen Sample	
Dimension	**Magnitude (cm)**
Length (X)	15.24
Width (Y)	34.29
Height (Z)	17.78

Default View:

Front View:



Top View:

Note: Exposure rates are listed below. Dose rates are obtained by generating an individual Dose Equivalent Report in Microshield^{TM} for each point. The dose rates in the report are selected as the effective dose equivalent rate (ICRP 51 – 1987) for anterior/posterior geometry with buildup.

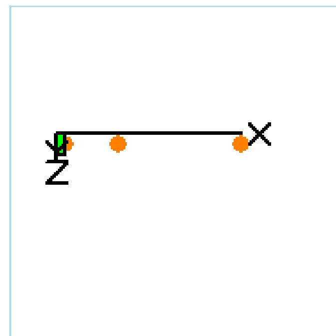
MicroShield 9.08
Microsoft (9.08-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Two Brick Exposure 1.55 Percent.msd	April 9, 2019	1:43:24 PM	00:00:01

Project Info	
Case Title	Grand Canyon Ore
Description	Effective Dose Two brick #20081 Dose at 1.55%
Geometry	13 - Rectangular Volume

Source Dimensions	
Length	15.24 cm (6.0 in)
Width	34.29 cm (1 ft 1.5 in)
Height	17.78 cm (7.0 in)



Dose Points			
A	X	Y	Z
#1	16.24 cm (6.4 in)	8.57 cm (3.4 in)	17.8 cm (7.0 in)
#2	106.68 cm (3 ft 6.0 in)	8.57 cm (3.4 in)	17.8 cm (7.0 in)
#3	320.04 cm (10 ft 6.0 in)	8.57 cm (3.4 in)	17.8 cm (7.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	9291.465 cm³	Aluminum	2.87
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ac-227	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Bi-210	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Bi-211	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Bi-214	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Pa-231	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Pa-234m	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Pb-210	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Pb-211	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Pb-214	1.1706e-004	4.3313e+006	1.2599e-002	4.6615e+002
Po-210	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Po-214	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Po-215	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Po-218	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Ra-223	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Ra-226	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Rn-219	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Rn-222	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Th-227	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Th-230	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002

Th-231	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
Th-234	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
Tl-207	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
U-234	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002
U-235	5.3800e-006	1.9906e+005	5.7903e-004	2.1424e+001
U-238	1.1706e-004	4.3312e+006	1.2599e-002	4.6615e+002

Buildup: The material reference is Source **Integration Parameters**	
X Direction	10
Y Direction	20
Z Direction	20

Results - Dose Point # 1 - (16.2401,8.57,17.8) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	3.763e+06	3.583e-03	3.804e-03	3.073e-04	3.263e-04	2.683e-04	2.849e-04	2.683e-06	2.849e-06
0.02	1.095e+03	3.481e-05	3.836e-05	1.206e-06	1.329e-06	1.053e-06	1.160e-06	1.053e-08	1.160e-08
0.03	4.788e+04	1.895e-02	2.364e-02	1.878e-04	2.343e-04	1.640e-04	2.046e-04	1.640e-06	2.046e-06
0.04	7.544e+02	9.356e-04	1.373e-03	4.138e-06	6.072e-06	3.612e-06	5.301e-06	3.612e-08	5.301e-08
0.05	2.459e+05	6.113e-01	1.052e+00	1.628e-03	2.804e-03	1.422e-03	2.447e-03	1.422e-05	2.447e-05
0.06	1.869e+05	7.402e-01	1.557e+00	1.470e-03	3.093e-03	1.284e-03	2.700e-03	1.284e-05	2.700e-05
0.08	1.129e+06	8.041e+00	2.066e+01	1.273e-02	3.269e-02	1.111e-02	2.854e-02	1.111e-04	2.854e-04
0.1	3.256e+05	3.360e+00	9.512e+00	5.140e-03	1.455e-02	4.487e-03	1.270e-02	4.487e-05	1.270e-04
0.15	5.630e+04	1.041e+00	3.058e+00	1.715e-03	5.035e-03	1.497e-03	4.396e-03	1.497e-05	4.396e-05
0.2	6.207e+05	1.693e+01	4.768e+01	2.988e-02	8.416e-02	2.608e-02	7.347e-02	2.608e-04	7.347e-04
0.3	1.014e+06	4.752e+01	1.209e+02	9.014e-02	2.294e-01	7.869e-02	2.003e-01	7.869e-04	2.003e-03
0.4	1.709e+06	1.178e+02	2.752e+02	2.296e-01	5.363e-01	2.004e-01	4.682e-01	2.004e-03	4.682e-03
0.5	7.832e+04	7.298e+00	1.587e+01	1.432e-02	3.115e-02	1.251e-02	2.720e-02	1.251e-04	2.720e-04
0.6	2.088e+06	2.492e+02	5.106e+02	4.863e-01	9.966e-01	4.246e-01	8.701e-01	4.246e-03	8.701e-03
0.8	4.263e+05	7.521e+01	1.411e+02	1.431e-01	2.683e-01	1.249e-01	2.342e-01	1.249e-03	2.342e-03
1.0	1.398e+06	3.343e+02	5.878e+02	6.162e-01	1.083e+00	5.379e-01	9.459e-01	5.379e-03	9.459e-03
1.5	8.246e+05	3.420e+02	5.387e+02	5.754e-01	9.063e-01	5.023e-01	7.912e-01	5.023e-03	7.912e-03
2.0	1.159e+06	7.044e+02	1.041e+03	1.089e+00	1.610e+00	9.510e-01	1.405e+00	9.510e-03	1.405e-02
Totals	**1.507e+07**	**1.908e+03**	**3.314e+03**	**3.297e+00**	**5.804e+00**	**2.879e+00**	**5.067e+00**	**2.879e-02**	**5.067e-02**

Results - Dose Point # 2 - (106.68,8.57,17.8) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	3.763e+06	1.774e-04	1.882e-04	1.522e-05	1.614e-05	1.328e-05	1.409e-05	1.328e-07	1.409e-07
0.02	1.095e+03	9.554e-07	1.041e-06	3.309e-08	3.606e-08	2.889e-08	3.148e-08	2.889e-10	3.148e-10
0.03	4.788e+04	2.798e-04	3.390e-04	2.773e-06	3.360e-06	2.421e-06	2.933e-06	2.421e-08	2.933e-08
0.04	7.544e+02	1.191e-05	1.681e-05	5.266e-08	7.436e-08	4.597e-08	6.492e-08	4.597e-10	6.492e-10
0.05	2.459e+05	7.487e-03	1.261e-02	1.994e-05	3.359e-05	1.741e-05	2.933e-05	1.741e-07	2.933e-07
0.06	1.869e+05	8.956e-03	1.857e-02	1.779e-05	3.689e-05	1.553e-05	3.220e-05	1.553e-07	3.220e-07
0.08	1.129e+06	9.673e-02	2.496e-01	1.531e-04	3.950e-04	1.336e-04	3.448e-04	1.336e-06	3.448e-06

0.1	3.256e+05	4.040e-02	1.159e-01	6.180e-05	1.774e-04	5.395e-05	1.548e-04	5.395e-07	1.548e-06
0.15	5.630e+04	1.254e-02	3.755e-02	2.065e-05	6.183e-05	1.803e-05	5.398e-05	1.803e-07	5.398e-07
0.2	6.207e+05	2.043e-01	5.885e-01	3.607e-04	1.039e-03	3.148e-04	9.067e-04	3.148e-06	9.067e-06
0.3	1.014e+06	5.757e-01	1.500e+00	1.092e-03	2.845e-03	9.534e-04	2.483e-03	9.534e-06	2.483e-05
0.4	1.709e+06	1.432e+00	3.420e+00	2.790e-03	6.664e-03	2.435e-03	5.817e-03	2.435e-05	5.817e-05
0.5	7.832e+04	8.890e-02	1.974e-01	1.745e-04	3.875e-04	1.523e-04	3.383e-04	1.523e-06	3.383e-06
0.6	2.088e+06	3.042e+00	6.355e+00	5.937e-03	1.240e-02	5.183e-03	1.083e-02	5.183e-05	1.083e-04
0.8	4.263e+05	9.213e-01	1.756e+00	1.752e-03	3.340e-03	1.530e-03	2.915e-03	1.530e-05	2.915e-05
1.0	1.398e+06	4.105e+00	7.313e+00	7.566e-03	1.348e-02	6.605e-03	1.177e-02	6.605e-05	1.177e-04
1.5	8.246e+05	4.216e+00	6.696e+00	7.093e-03	1.127e-02	6.192e-03	9.835e-03	6.192e-05	9.835e-05
2.0	1.159e+06	8.701e+00	1.293e+01	1.346e-02	2.000e-02	1.175e-02	1.746e-02	1.175e-04	1.746e-04
Totals	**1.507e+07**	**2.345e+01**	**4.119e+01**	**4.051e-02**	**7.215e-02**	**3.537e-02**	**6.298e-02**	**3.537e-04**	**6.298e-04**

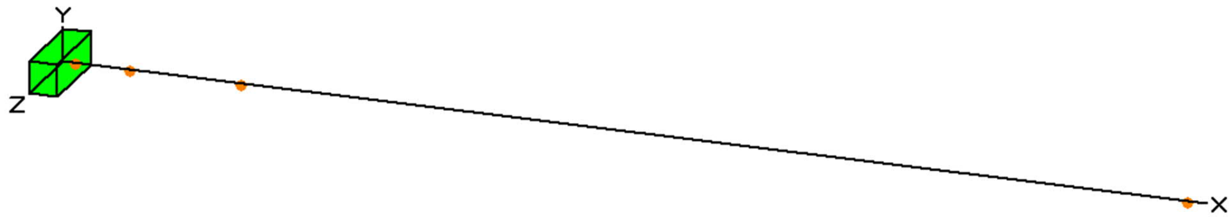
Results - Dose Point # 3 - (320.04,8.57,17.8) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	3.763e+06	1.124e-05	1.192e-05	9.643e-07	1.022e-06	8.419e-07	8.925e-07	8.419e-09	8.925e-09
0.02	1.095e+03	7.338e-08	8.017e-08	2.542e-09	2.777e-09	2.219e-09	2.424e-09	2.219e-11	2.424e-11
0.03	4.788e+04	2.373e-05	2.898e-05	2.352e-07	2.872e-07	2.053e-07	2.507e-07	2.053e-09	2.507e-09
0.04	7.544e+02	1.039e-06	1.500e-06	4.597e-09	6.632e-09	4.013e-09	5.790e-09	4.013e-11	5.790e-11
0.05	2.459e+05	6.629e-04	1.145e-03	1.766e-06	3.051e-06	1.542e-06	2.664e-06	1.542e-08	2.664e-08
0.06	1.869e+05	8.003e-04	1.711e-03	1.590e-06	3.399e-06	1.388e-06	2.967e-06	1.388e-08	2.967e-08
0.08	1.129e+06	8.738e-03	2.343e-02	1.383e-05	3.708e-05	1.207e-05	3.237e-05	1.207e-07	3.237e-07
0.1	3.256e+05	3.674e-03	1.102e-02	5.620e-06	1.686e-05	4.906e-06	1.472e-05	4.906e-08	1.472e-07
0.15	5.630e+04	1.152e-03	3.627e-03	1.897e-06	5.972e-06	1.656e-06	5.214e-06	1.656e-08	5.214e-08
0.2	6.207e+05	1.889e-02	5.718e-02	3.333e-05	1.009e-04	2.910e-05	8.810e-05	2.910e-07	8.810e-07
0.3	1.014e+06	5.370e-02	1.466e-01	1.019e-04	2.780e-04	8.892e-05	2.427e-04	8.892e-07	2.427e-06
0.4	1.709e+06	1.344e-01	3.352e-01	2.619e-04	6.531e-04	2.286e-04	5.702e-04	2.286e-06	5.702e-06
0.5	7.832e+04	8.391e-03	1.939e-02	1.647e-05	3.805e-05	1.438e-05	3.322e-05	1.438e-07	3.322e-07
0.6	2.088e+06	2.883e-01	6.250e-01	5.627e-04	1.220e-03	4.913e-04	1.065e-03	4.913e-06	1.065e-05
0.8	4.263e+05	8.791e-02	1.731e-01	1.672e-04	3.292e-04	1.460e-04	2.874e-04	1.460e-06	2.874e-06
1.0	1.398e+06	3.937e-01	7.222e-01	7.258e-04	1.331e-03	6.336e-04	1.162e-03	6.336e-06	1.162e-05
1.5	8.246e+05	4.080e-01	6.632e-01	6.865e-04	1.116e-03	5.993e-04	9.741e-04	5.993e-06	9.741e-06
2.0	1.159e+06	8.469e-01	1.284e+00	1.310e-03	1.985e-03	1.143e-03	1.733e-03	1.143e-05	1.733e-05
Totals	**1.507e+07**	**2.255e+00**	**4.066e+00**	**3.891e-03**	**7.119e-03**	**3.397e-03**	**6.215e-03**	**3.397e-05**	**6.215e-05**

THREE - SPECIMEN MODEL OF SAMPLE #20081

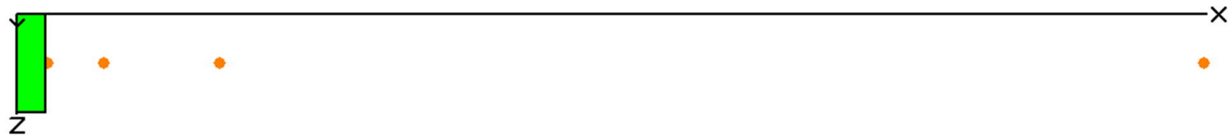
Three Specimen Sample	
Dimension	**Magnitude (cm)**
Length (X)	15.24
Width (Y)	51.435
Height (Z)	17.78

Default View:



Front View:

Top View:



Note: Exposure rates are listed below. Dose rates are obtained by generating an individual Dose Equivalent Report in Microshield^{TM} for each point. The dose rates in the report are selected as the effective dose equivalent rate (ICRP 51 – 1987) for anterior/posterior geometry with buildup.

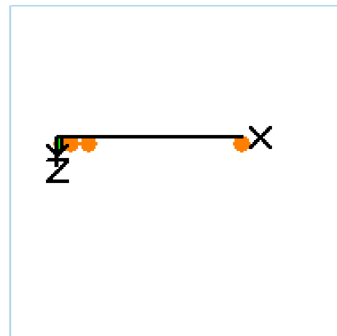
MicroShield 9.08
Microsoft (9.08-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Triple Brick Exposure 1.55 Percent.msd	April 9, 2019	1:59:05 PM	00:00:01

Project Info	
Case Title	Grand Canyon Ore
Description	Effective Dose Triple Brick #20081 Dose at 1.55%
Geometry	13 - Rectangular Volume

Source Dimensions	
Length	15.24 cm (6.0 in)
Width	51.435 cm (1 ft 8.3 in)
Height	17.78 cm (7.0 in)



Dose Points

A	X	Y	Z
#1	16.24 cm (6.4 in)	8.57 cm (3.4 in)	25.718 cm (10.1 in)
#2	45.72 cm (1 ft 6.0 in)	8.57 cm (3.4 in)	25.718 cm (10.1 in)
#3	106.68 cm (3 ft 6.0 in)	8.57 cm (3.4 in)	25.718 cm (10.1 in)
#4	624.84 cm (20 ft 6.0 in)	8.57 cm (3.4 in)	25.718 cm (10.1 in)

Shields

Shield N	Dimension	Material	Density
Source	1.39e+04 cm³	Aluminum	2.87
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ac-227	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Bi-210	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Bi-211	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Bi-214	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Pa-231	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Pa-234m	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Pb-210	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Pb-211	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Pb-214	1.7559e-004	6.4969e+006	1.2599e-002	4.6615e+002
Po-210	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Po-214	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Po-215	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Po-218	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Ra-223	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Ra-226	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Rn-219	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Rn-222	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Th-227	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001

Th-230	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Th-231	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
Th-234	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
Tl-207	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
U-234	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002
U-235	8.0700e-006	2.9859e+005	5.7903e-004	2.1424e+001
U-238	1.7559e-004	6.4968e+006	1.2599e-002	4.6615e+002

Buildup: The material reference is Source **Integration Parameters**	
X Direction	10
Y Direction	20
Z Direction	20

Results - Dose Point # 1 - (16.2401,8.57,25.7175) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	5.645e+06	3.875e-03	4.113e-03	3.324e-04	3.528e-04	2.902e-04	3.080e-04	2.902e-06	3.080e-06
0.02	1.642e+03	3.509e-05	3.866e-05	1.215e-06	1.339e-06	1.061e-06	1.169e-06	1.061e-08	1.169e-08
0.03	7.182e+04	1.893e-02	2.362e-02	1.877e-04	2.341e-04	1.638e-04	2.043e-04	1.638e-06	2.043e-06
0.04	1.132e+03	9.352e-04	1.373e-03	4.136e-06	6.074e-06	3.611e-06	5.303e-06	3.611e-08	5.303e-08
0.05	3.689e+05	6.121e-01	1.055e+00	1.631e-03	2.811e-03	1.423e-03	2.454e-03	1.423e-05	2.454e-05
0.06	2.803e+05	7.423e-01	1.566e+00	1.474e-03	3.110e-03	1.287e-03	2.715e-03	1.287e-05	2.715e-05
0.08	1.694e+06	8.079e+00	2.083e+01	1.278e-02	3.296e-02	1.116e-02	2.878e-02	1.116e-04	2.878e-04
0.1	4.885e+05	3.379e+00	9.612e+00	5.169e-03	1.471e-02	4.513e-03	1.284e-02	4.513e-05	1.284e-04
0.15	8.444e+04	1.049e+00	3.102e+00	1.727e-03	5.109e-03	1.507e-03	4.460e-03	1.507e-05	4.460e-05
0.2	9.311e+05	1.706e+01	4.852e+01	3.012e-02	8.564e-02	2.629e-02	7.477e-02	2.629e-04	7.477e-04
0.3	1.521e+06	4.797e+01	1.236e+02	9.100e-02	2.345e-01	7.944e-02	2.047e-01	7.944e-04	2.047e-03
0.4	2.563e+06	1.191e+02	2.823e+02	2.321e-01	5.500e-01	2.026e-01	4.801e-01	2.026e-03	4.801e-03
0.5	1.175e+05	7.388e+00	1.632e+01	1.450e-02	3.204e-02	1.266e-02	2.797e-02	1.266e-04	2.797e-04
0.6	3.132e+06	2.526e+02	5.264e+02	4.930e-01	1.027e+00	4.304e-01	8.970e-01	4.304e-03	8.970e-03
0.8	6.394e+05	7.645e+01	1.460e+02	1.454e-01	2.777e-01	1.269e-01	2.424e-01	1.269e-03	2.424e-03
1.0	2.097e+06	3.406e+02	6.103e+02	6.279e-01	1.125e+00	5.482e-01	9.822e-01	5.482e-03	9.822e-03
1.5	1.237e+06	3.505e+02	5.629e+02	5.897e-01	9.470e-01	5.148e-01	8.268e-01	5.148e-03	8.268e-03
2.0	1.739e+06	7.253e+02	1.093e+03	1.122e+00	1.690e+00	9.791e-01	1.475e+00	9.791e-03	1.475e-02
Totals	**2.261e+07**	**1.951e+03**	**3.445e+03**	**3.369e+00**	**6.028e+00**	**2.941e+00**	**5.263e+00**	**2.941e-02**	**5.263e-02**

Results - Dose Point # 2 - (45.72,8.57,25.7175) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	5.645e+06	1.519e-03	1.611e-03	1.303e-04	1.382e-04	1.138e-04	1.206e-04	1.138e-06	1.206e-06
0.02	1.642e+03	9.363e-06	1.022e-05	3.243e-07	3.540e-07	2.831e-07	3.090e-07	2.831e-09	3.090e-09
0.03	7.182e+04	2.891e-03	3.498e-03	2.865e-05	3.467e-05	2.501e-05	3.027e-05	2.501e-07	3.027e-07
0.04	1.132e+03	1.215e-04	1.705e-04	5.376e-07	7.543e-07	4.693e-07	6.585e-07	4.693e-09	6.585e-09
0.05	3.689e+05	7.569e-02	1.259e-01	2.016e-04	3.354e-04	1.760e-04	2.928e-04	1.760e-06	2.928e-06
0.06	2.803e+05	8.986e-02	1.828e-01	1.785e-04	3.631e-04	1.558e-04	3.170e-04	1.558e-06	3.170e-06

0.08	1.694e+06	9.606e-01	2.408e+00	1.520e-03	3.810e-03	1.327e-03	3.326e-03	1.327e-05	3.326e-05
0.1	4.885e+05	3.987e-01	1.104e+00	6.100e-04	1.689e-03	5.325e-04	1.475e-03	5.325e-06	1.475e-05
0.15	8.444e+04	1.227e-01	3.527e-01	2.021e-04	5.808e-04	1.764e-04	5.071e-04	1.764e-06	5.071e-06
0.2	9.311e+05	1.989e+00	5.490e+00	3.511e-03	9.689e-03	3.065e-03	8.459e-03	3.065e-05	8.459e-05
0.3	1.521e+06	5.561e+00	1.391e+01	1.055e-02	2.638e-02	9.210e-03	2.303e-02	9.210e-05	2.303e-04
0.4	2.563e+06	1.375e+01	3.163e+01	2.680e-02	6.164e-02	2.340e-02	5.381e-02	2.340e-04	5.381e-04
0.5	1.175e+05	8.503e-01	1.823e+00	1.669e-03	3.579e-03	1.457e-03	3.125e-03	1.457e-05	3.125e-05
0.6	3.132e+06	2.899e+01	5.863e+01	5.658e-02	1.144e-01	4.939e-02	9.991e-02	4.939e-04	9.991e-04
0.8	6.394e+05	8.729e+00	1.618e+01	1.660e-02	3.078e-02	1.450e-02	2.687e-02	1.450e-04	2.687e-04
1.0	2.097e+06	3.873e+01	6.735e+01	7.138e-02	1.241e-01	6.232e-02	1.084e-01	6.232e-04	1.084e-03
1.5	1.237e+06	3.948e+01	6.156e+01	6.643e-02	1.036e-01	5.799e-02	9.042e-02	5.799e-04	9.042e-04
2.0	1.739e+06	8.113e+01	1.188e+02	1.255e-01	1.836e-01	1.095e-01	1.603e-01	1.095e-03	1.603e-03
Totals	**2.261e+07**	**2.209e+02**	**3.795e+02**	**3.819e-01**	**6.648e-01**	**3.334e-01**	**5.804e-01**	**3.334e-03**	**5.804e-03**

Results - Dose Point # 3 - (106.68,8.57,25.7175) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	5.645e+06	2.546e-04	2.701e-04	2.184e-05	2.316e-05	1.906e-05	2.022e-05	1.906e-07	2.022e-07
0.02	1.642e+03	1.395e-06	1.520e-06	4.831e-08	5.264e-08	4.217e-08	4.596e-08	4.217e-10	4.596e-10
0.03	7.182e+04	4.111e-04	4.981e-04	4.074e-06	4.937e-06	3.557e-06	4.310e-06	3.557e-08	4.310e-08
0.04	1.132e+03	1.750e-05	2.472e-05	7.739e-08	1.093e-07	6.756e-08	9.543e-08	6.756e-10	9.543e-10
0.05	3.689e+05	1.101e-02	1.854e-02	2.932e-05	4.940e-05	2.560e-05	4.313e-05	2.560e-07	4.313e-07
0.06	2.803e+05	1.317e-02	2.732e-02	2.616e-05	5.426e-05	2.284e-05	4.737e-05	2.284e-07	4.737e-07
0.08	1.694e+06	1.423e-01	3.673e-01	2.251e-04	5.813e-04	1.965e-04	5.075e-04	1.965e-06	5.075e-06
0.1	4.885e+05	5.943e-02	1.707e-01	9.092e-05	2.612e-04	7.937e-05	2.280e-04	7.937e-07	2.280e-06
0.15	8.444e+04	1.846e-02	5.534e-02	3.039e-05	9.114e-05	2.653e-05	7.956e-05	2.653e-07	7.956e-07
0.2	9.311e+05	3.008e-01	8.677e-01	5.308e-04	1.531e-03	4.634e-04	1.337e-03	4.634e-06	1.337e-05
0.3	1.521e+06	8.476e-01	2.212e+00	1.608e-03	4.197e-03	1.404e-03	3.664e-03	1.404e-05	3.664e-05
0.4	2.563e+06	2.108e+00	5.047e+00	4.108e-03	9.834e-03	3.586e-03	8.585e-03	3.586e-05	8.585e-05
0.5	1.175e+05	1.310e-01	2.914e-01	2.570e-04	5.720e-04	2.244e-04	4.994e-04	2.244e-06	4.994e-06
0.6	3.132e+06	4.481e+00	9.382e+00	8.747e-03	1.831e-02	7.636e-03	1.599e-02	7.636e-05	1.599e-04
0.8	6.394e+05	1.358e+00	2.593e+00	2.583e-03	4.932e-03	2.255e-03	4.306e-03	2.255e-05	4.306e-05
1.0	2.097e+06	6.051e+00	1.080e+01	1.115e-02	1.991e-02	9.738e-03	1.738e-02	9.738e-05	1.738e-04
1.5	1.237e+06	6.219e+00	9.895e+00	1.046e-02	1.665e-02	9.134e-03	1.453e-02	9.134e-05	1.453e-04
2.0	1.739e+06	1.284e+01	1.912e+01	1.986e-02	2.956e-02	1.734e-02	2.581e-02	1.734e-04	2.581e-04
Totals	**2.261e+07**	**3.458e+01**	**6.085e+01**	**5.974e-02**	**1.066e-01**	**5.215e-02**	**9.303e-02**	**5.215e-04**	**9.303e-04**

Results - Dose Point # 4 - (624.84,8.57,25.7175) cm

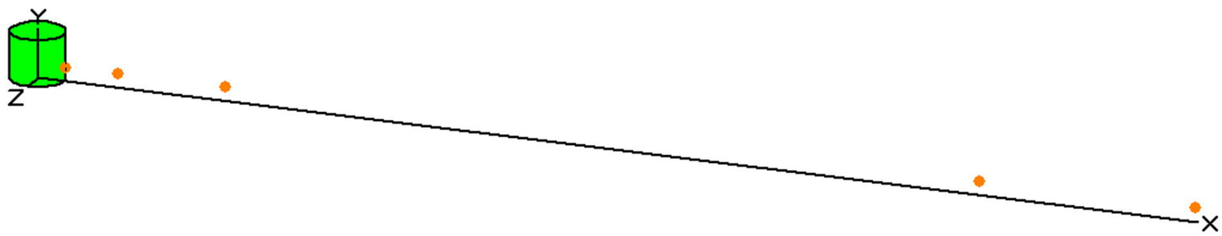
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	5.645e+06	2.398e-06	2.539e-06	2.057e-07	2.178e-07	1.796e-07	1.901e-07	1.796e-09	1.901e-09
0.02	1.642e+03	2.109e-08	2.314e-08	7.305e-10	8.017e-10	6.377e-10	6.999e-10	6.377e-12	6.999e-12
0.03	7.182e+04	7.903e-06	9.759e-06	7.832e-08	9.672e-08	6.837e-08	8.444e-08	6.837e-10	8.444e-10
0.04	1.132e+03	3.588e-07	5.327e-07	1.587e-09	2.356e-09	1.385e-09	2.057e-09	1.385e-11	2.057e-11
0.05	3.689e+05	2.321e-04	4.133e-04	6.183e-07	1.101e-06	5.398e-07	9.611e-07	5.398e-09	9.611e-09
0.06	2.803e+05	2.823e-04	6.247e-04	5.607e-07	1.241e-06	4.895e-07	1.083e-06	4.895e-09	1.083e-08
0.08	1.694e+06	3.107e-03	8.650e-03	4.917e-06	1.369e-05	4.293e-06	1.195e-05	4.293e-08	1.195e-07

0.1	4.885e+05	1.313e-03	4.094e-03	2.008e-06	6.263e-06	1.753e-06	5.468e-06	1.753e-08	5.468e-08
0.15	8.444e+04	4.147e-04	1.361e-03	6.829e-07	2.241e-06	5.962e-07	1.956e-06	5.962e-09	1.956e-08
0.2	9.311e+05	6.835e-03	2.150e-02	1.206e-05	3.795e-05	1.053e-05	3.313e-05	1.053e-07	3.313e-07
0.3	1.521e+06	1.957e-02	5.524e-02	3.713e-05	1.048e-04	3.241e-05	9.147e-05	3.241e-07	9.147e-07
0.4	2.563e+06	4.925e-02	1.265e-01	9.595e-05	2.465e-04	8.377e-05	2.152e-04	8.377e-07	2.152e-06
0.5	1.175e+05	3.086e-03	7.323e-03	6.057e-06	1.437e-05	5.288e-06	1.255e-05	5.288e-08	1.255e-07
0.6	3.132e+06	1.064e-01	2.363e-01	2.076e-04	4.611e-04	1.812e-04	4.026e-04	1.812e-06	4.026e-06
0.8	6.394e+05	3.258e-02	6.551e-02	6.198e-05	1.246e-04	5.410e-05	1.088e-04	5.410e-07	1.088e-06
1.0	2.097e+06	1.464e-01	2.736e-01	2.699e-04	5.044e-04	2.356e-04	4.404e-04	2.356e-06	4.404e-06
1.5	1.237e+06	1.526e-01	2.517e-01	2.568e-04	4.235e-04	2.242e-04	3.697e-04	2.242e-06	3.697e-06
2.0	1.739e+06	3.180e-01	4.878e-01	4.918e-04	7.543e-04	4.293e-04	6.585e-04	4.293e-06	6.585e-06
Totals	**2.261e+07**	**8.401e-01**	**1.541e+00**	**1.448e-03**	**2.696e-03**	**1.264e-03**	**2.354e-03**	**1.264e-05**	**2.354e-05**

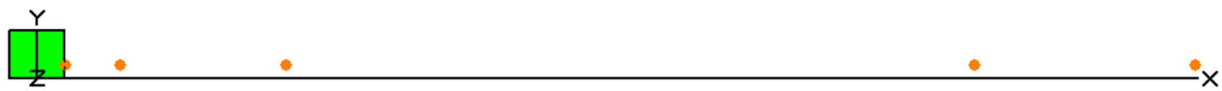
FOUR – SPECIMEN (CYLINDER) MODEL OF SAMPLE #20081

Four Specimen Sample	
Dimension	**Magnitude (cm)**
Radius (X,Z)	15
Height (Y)	26.3

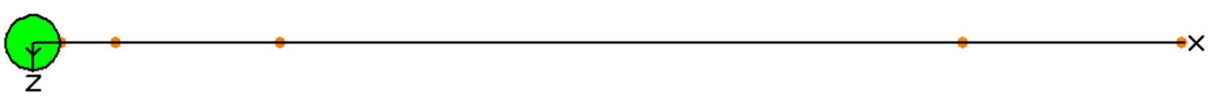
Default View:



Front View:



Top View:



Note: Exposure rates are listed below. Dose rates are obtained by generating an individual Dose Equivalent Report in Microshield[TM] for each point. The dose rates in the report are selected as the effective dose equivalent rate (ICRP 51 – 1987) for anterior/posterior geometry with buildup.

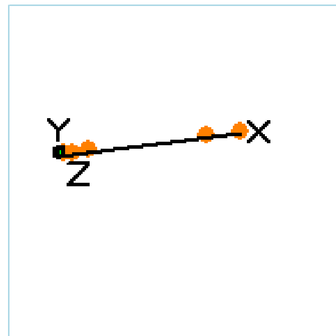
MicroShield 9.08
Microsoft (9.08-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Cylinder 4x Exposure 1.55 Percent.msd	April 9, 2019	2:57:36 PM	00:00:01

Project Info	
Case Title	Grand Canyon Ore
Description	Cylinder #20081 mass x 4 Dose at 1.55%
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions	
Height	26.3 cm (10.4 in)
Radius	15.0 cm (5.9 in)



Dose Points			
A	X	Y	Z
#1	16.0 cm (6.3 in)	7.5 cm (3.0 in)	0.0 cm (0 in)
#2	45.48 cm (1 ft 5.9 in)	7.5 cm (3.0 in)	0.0 cm (0 in)
#3	106.44 cm (3 ft 5.9 in)	7.5 cm (3.0 in)	0.0 cm (0 in)
#4	533.16 cm (17 ft 5.9 in)	7.5 cm (3.0 in)	0.0 cm (0 in)
#5	655.08 cm (21 ft 5.9 in)	7.5 cm (3.0 in)	0.0 cm (0 in)

Shields			
Shield N	Dimension	Material	Density
Source	1.86e+04 cm³	Aluminum	2.87
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: Grove

Nuclide	Ci	Bq	μCi/cm³	Bq/cm³
Ac-227	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Bi-210	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Bi-211	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Bi-214	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Pa-231	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Pa-234	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Pa-234m	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Pb-210	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Pb-211	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Pb-214	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Po-210	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Po-214	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Po-215	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Po-218	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Ra-223	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Ra-226	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Rn-219	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001

Rn-222	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Th-227	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Th-230	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Th-231	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
Th-234	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
Tl-207	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
U-234	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002
U-235	1.0756e-005	3.9797e+005	5.7858e-004	2.1407e+001
U-238	2.3400e-004	8.6580e+006	1.2587e-002	4.6572e+002

Buildup: The material reference is Source **Integration Parameters**	
Radial	10
Circumferential	10
Y Direction (axial)	20

Results - Dose Point # 1 - (16,7.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	1.736e+07	2.636e-03	2.817e-03	2.261e-04	2.416e-04	1.974e-04	2.109e-04	1.974e-06	2.109e-06
0.02	2.189e+03	2.645e-05	2.943e-05	9.161e-07	1.019e-06	7.998e-07	8.899e-07	7.998e-09	8.899e-09
0.03	9.572e+04	1.776e-02	2.217e-02	1.760e-04	2.197e-04	1.537e-04	1.918e-04	1.537e-06	1.918e-06
0.04	1.211e+04	6.777e-03	9.857e-03	2.997e-05	4.359e-05	2.617e-05	3.806e-05	2.617e-07	3.806e-07
0.05	4.916e+05	5.353e-01	8.993e-01	1.426e-03	2.396e-03	1.245e-03	2.091e-03	1.245e-05	2.091e-05
0.06	6.765e+05	1.157e+00	2.375e+00	2.299e-03	4.718e-03	2.007e-03	4.119e-03	2.007e-05	4.119e-05
0.08	2.268e+06	6.911e+00	1.748e+01	1.094e-02	2.766e-02	9.548e-03	2.414e-02	9.548e-05	2.414e-04
0.1	5.673e+06	2.499e+01	7.022e+01	3.823e-02	1.074e-01	3.337e-02	9.379e-02	3.337e-04	9.379e-04
0.15	2.842e+06	2.242e+01	6.619e+01	3.692e-02	1.090e-01	3.223e-02	9.516e-02	3.223e-04	9.516e-04
0.2	3.067e+06	3.568e+01	1.018e+02	6.298e-02	1.797e-01	5.498e-02	1.569e-01	5.498e-04	1.569e-03
0.3	2.655e+06	5.318e+01	1.385e+02	1.009e-01	2.628e-01	8.806e-02	2.294e-01	8.806e-04	2.294e-03
0.4	3.948e+06	1.166e+02	2.806e+02	2.271e-01	5.468e-01	1.983e-01	4.773e-01	1.983e-03	4.773e-03
0.5	9.461e+05	3.785e+01	8.526e+01	7.430e-02	1.674e-01	6.486e-02	1.461e-01	6.486e-04	1.461e-03
0.6	7.400e+06	3.802e+02	8.100e+02	7.420e-01	1.581e+00	6.478e-01	1.380e+00	6.478e-03	1.380e-02
0.8	7.634e+06	5.834e+02	1.144e+03	1.110e+00	2.175e+00	9.687e-01	1.899e+00	9.687e-03	1.899e-02
1.0	8.119e+06	8.461e+02	1.560e+03	1.560e+00	2.875e+00	1.361e+00	2.510e+00	1.361e-02	2.510e-02
1.5	2.860e+06	5.244e+02	8.691e+02	8.823e-01	1.462e+00	7.702e-01	1.277e+00	7.702e-03	1.277e-02
2.0	2.473e+06	6.727e+02	1.047e+03	1.040e+00	1.619e+00	9.082e-01	1.413e+00	9.082e-03	1.413e-02
Totals	**6.853e+07**	**3.306e+03**	**6.193e+03**	**5.889e+00**	**1.112e+01**	**5.141e+00**	**9.709e+00**	**5.141e-02**	**9.709e-02**

Results - Dose Point # 2 - (45.48,7.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	1.736e+07	1.646e-03	1.745e-03	1.412e-04	1.497e-04	1.233e-04	1.307e-04	1.233e-06	1.307e-06
0.02	2.189e+03	4.992e-06	5.460e-06	1.729e-07	1.891e-07	1.510e-07	1.651e-07	1.510e-09	1.651e-09
0.03	9.572e+04	1.827e-03	2.239e-03	1.810e-05	2.219e-05	1.580e-05	1.937e-05	1.580e-07	1.937e-07
0.04	1.211e+04	6.596e-04	9.430e-04	2.917e-06	4.171e-06	2.547e-06	3.641e-06	2.547e-08	3.641e-08

0.05	4.916e+05	5.209e-02	8.779e-02	1.388e-04	2.339e-04	1.212e-04	2.042e-04	1.212e-06	2.042e-06
0.06	6.765e+05	1.129e-01	2.336e-01	2.243e-04	4.639e-04	1.958e-04	4.050e-04	1.958e-06	4.050e-06
0.08	2.268e+06	6.751e-01	1.718e+00	1.068e-03	2.718e-03	9.326e-04	2.373e-03	9.326e-06	2.373e-05
0.1	5.673e+06	2.440e+00	6.869e+00	3.733e-03	1.051e-02	3.259e-03	9.174e-03	3.259e-05	9.174e-05
0.15	2.842e+06	2.187e+00	6.446e+00	3.602e-03	1.061e-02	3.144e-03	9.266e-03	3.144e-05	9.266e-05
0.2	3.067e+06	3.480e+00	9.926e+00	6.142e-03	1.752e-02	5.362e-03	1.529e-02	5.362e-05	1.529e-04
0.3	2.655e+06	5.186e+00	1.357e+01	9.837e-03	2.574e-02	8.587e-03	2.247e-02	8.587e-05	2.247e-04
0.4	3.948e+06	1.137e+01	2.761e+01	2.215e-02	5.380e-02	1.934e-02	4.697e-02	1.934e-04	4.697e-04
0.5	9.461e+05	3.695e+00	8.422e+00	7.252e-03	1.653e-02	6.331e-03	1.443e-02	6.331e-05	1.443e-04
0.6	7.400e+06	3.714e+01	8.026e+01	7.250e-02	1.567e-01	6.329e-02	1.368e-01	6.329e-04	1.368e-03
0.8	7.634e+06	5.712e+01	1.139e+02	1.086e-01	2.167e-01	9.484e-02	1.891e-01	9.484e-04	1.891e-03
1.0	8.119e+06	8.303e+01	1.560e+02	1.530e-01	2.876e-01	1.336e-01	2.511e-01	1.336e-03	2.511e-03
1.5	2.860e+06	5.176e+01	8.755e+01	8.709e-02	1.473e-01	7.603e-02	1.286e-01	7.603e-04	1.286e-03
2.0	2.473e+06	6.674e+01	1.060e+02	1.032e-01	1.639e-01	9.010e-02	1.430e-01	9.010e-04	1.430e-03
Totals	**6.853e+07**	**3.250e+02**	**6.186e+02**	**5.788e-01**	**1.110e+00**	**5.053e-01**	**9.693e-01**	**5.053e-03**	**9.693e-03**

Results - Dose Point # 3 - (106.44,7.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	1.736e+07	2.595e-04	2.751e-04	2.225e-05	2.360e-05	1.943e-05	2.060e-05	1.943e-07	2.060e-07
0.02	2.189e+03	7.690e-07	8.422e-07	2.664e-08	2.917e-08	2.325e-08	2.547e-08	2.325e-10	2.547e-10
0.03	9.572e+04	3.017e-04	3.702e-04	2.990e-06	3.669e-06	2.610e-06	3.203e-06	2.610e-08	3.203e-08
0.04	1.211e+04	1.065e-04	1.520e-04	4.711e-07	6.722e-07	4.113e-07	5.868e-07	4.113e-09	5.868e-09
0.05	4.916e+05	8.359e-03	1.410e-02	2.227e-05	3.757e-05	1.944e-05	3.280e-05	1.944e-07	3.280e-07
0.06	6.765e+05	1.809e-02	3.741e-02	3.593e-05	7.431e-05	3.137e-05	6.487e-05	3.137e-07	6.487e-07
0.08	2.268e+06	1.081e-01	2.767e-01	1.711e-04	4.379e-04	1.494e-04	3.823e-04	1.494e-06	3.823e-06
0.1	5.673e+06	3.912e-01	1.116e+00	5.985e-04	1.707e-03	5.225e-04	1.490e-03	5.225e-06	1.490e-05
0.15	2.842e+06	3.519e-01	1.065e+00	5.795e-04	1.754e-03	5.059e-04	1.531e-03	5.059e-06	1.531e-05
0.2	3.067e+06	5.617e-01	1.659e+00	9.914e-04	2.928e-03	8.655e-04	2.556e-03	8.655e-06	2.556e-05
0.3	2.655e+06	8.419e-01	2.296e+00	1.597e-03	4.356e-03	1.394e-03	3.803e-03	1.394e-05	3.803e-05
0.4	3.948e+06	1.855e+00	4.705e+00	3.615e-03	9.167e-03	3.156e-03	8.003e-03	3.156e-05	8.003e-05
0.5	9.461e+05	6.057e-01	1.441e+00	1.189e-03	2.829e-03	1.038e-03	2.470e-03	1.038e-05	2.470e-05
0.6	7.400e+06	6.114e+00	1.378e+01	1.193e-02	2.690e-02	1.042e-02	2.348e-02	1.042e-04	2.348e-04
0.8	7.634e+06	9.471e+00	1.964e+01	1.801e-02	3.736e-02	1.573e-02	3.262e-02	1.573e-04	3.262e-04
1.0	8.119e+06	1.385e+01	2.699e+01	2.553e-02	4.975e-02	2.229e-02	4.343e-02	2.229e-04	4.343e-04
1.5	2.860e+06	8.736e+00	1.524e+01	1.470e-02	2.565e-02	1.283e-02	2.239e-02	1.283e-04	2.239e-04
2.0	2.473e+06	1.135e+01	1.853e+01	1.756e-02	2.865e-02	1.533e-02	2.501e-02	1.533e-04	2.501e-04
Totals	**6.853e+07**	**5.427e+01**	**1.068e+02**	**9.656e-02**	**1.916e-01**	**8.430e-02**	**1.673e-01**	**8.430e-04**	**1.673e-03**

Results - Dose Point # 4 - (533.16,7.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	1.736e+07	4.238e-06	4.490e-06	3.635e-07	3.851e-07	3.174e-07	3.362e-07	3.174e-09	3.362e-09
0.02	2.189e+03	1.963e-08	2.166e-08	6.800e-10	7.502e-10	5.936e-10	6.549e-10	5.936e-12	6.549e-12
0.03	9.572e+04	9.310e-06	1.156e-05	9.227e-08	1.146e-07	8.055e-08	1.001e-07	8.055e-10	1.001e-09
0.04	1.211e+04	3.406e-06	5.028e-06	1.506e-08	2.224e-08	1.315e-08	1.941e-08	1.315e-10	1.941e-10
0.05	4.916e+05	2.718e-04	4.780e-04	7.239e-07	1.273e-06	6.320e-07	1.112e-06	6.320e-09	1.112e-08

0.06	6.765e+05	5.938e-04	1.292e-03	1.179e-06	2.566e-06	1.030e-06	2.240e-06	1.030e-08	2.240e-08
0.08	2.268e+06	3.596e-03	9.786e-03	5.690e-06	1.549e-05	4.967e-06	1.352e-05	4.967e-08	1.352e-07
0.1	5.673e+06	1.313e-02	4.022e-02	2.009e-05	6.153e-05	1.753e-05	5.371e-05	1.753e-07	5.371e-07
0.15	2.842e+06	1.199e-02	3.935e-02	1.974e-05	6.480e-05	1.723e-05	5.657e-05	1.723e-07	5.657e-07
0.2	3.067e+06	1.933e-02	6.187e-02	3.412e-05	1.092e-04	2.979e-05	9.533e-05	2.979e-07	9.533e-07
0.3	2.655e+06	2.941e-02	8.630e-02	5.579e-05	1.637e-04	4.870e-05	1.429e-04	4.870e-07	1.429e-06
0.4	3.948e+06	6.552e-02	1.775e-01	1.277e-04	3.458e-04	1.114e-04	3.019e-04	1.114e-06	3.019e-06
0.5	9.461e+05	2.157e-02	5.451e-02	4.234e-05	1.070e-04	3.697e-05	9.341e-05	3.697e-07	9.341e-07
0.6	7.400e+06	2.193e-01	5.222e-01	4.280e-04	1.019e-03	3.736e-04	8.899e-04	3.736e-06	8.899e-06
0.8	7.634e+06	3.433e-01	7.468e-01	6.530e-04	1.420e-03	5.701e-04	1.240e-03	5.701e-06	1.240e-05
1.0	8.119e+06	5.062e-01	1.029e+00	9.331e-04	1.897e-03	8.146e-04	1.656e-03	8.146e-06	1.656e-05
1.5	2.860e+06	3.237e-01	5.838e-01	5.447e-04	9.823e-04	4.755e-04	8.575e-04	4.755e-06	8.575e-06
2.0	2.473e+06	4.244e-01	7.122e-01	6.563e-04	1.101e-03	5.730e-04	9.615e-04	5.730e-06	9.615e-06
Totals	**6.853e+07**	**1.982e+00**	**4.065e+00**	**3.523e-03**	**7.292e-03**	**3.076e-03**	**6.366e-03**	**3.076e-05**	**6.366e-05**

Results - Dose Point # 5 - (655.08,7.5,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	1.736e+07	2.226e-06	2.359e-06	1.910e-07	2.024e-07	1.667e-07	1.767e-07	1.667e-09	1.767e-09
0.02	2.189e+03	1.164e-08	1.287e-08	4.032e-10	4.457e-10	3.520e-10	3.891e-10	3.520e-12	3.891e-12
0.03	9.572e+04	5.849e-06	7.295e-06	5.797e-08	7.230e-08	5.060e-08	6.312e-08	5.060e-10	6.312e-10
0.04	1.211e+04	2.169e-06	3.233e-06	9.592e-09	1.430e-08	8.373e-09	1.248e-08	8.373e-11	1.248e-10
0.05	4.916e+05	1.739e-04	3.095e-04	4.633e-07	8.246e-07	4.045e-07	7.199e-07	4.045e-09	7.199e-09
0.06	6.765e+05	3.811e-04	8.409e-04	7.570e-07	1.670e-06	6.608e-07	1.458e-06	6.608e-09	1.458e-08
0.08	2.268e+06	2.314e-03	6.394e-03	3.662e-06	1.012e-05	3.197e-06	8.834e-06	3.197e-08	8.834e-08
0.1	5.673e+06	8.466e-03	2.634e-02	1.295e-05	4.029e-05	1.131e-05	3.517e-05	1.131e-07	3.517e-07
0.15	2.842e+06	7.753e-03	2.583e-02	1.277e-05	4.254e-05	1.115e-05	3.714e-05	1.115e-07	3.714e-07
0.2	3.067e+06	1.253e-02	4.066e-02	2.211e-05	7.177e-05	1.930e-05	6.265e-05	1.930e-07	6.265e-07
0.3	2.655e+06	1.911e-02	5.675e-02	3.625e-05	1.077e-04	3.165e-05	9.398e-05	3.165e-07	9.398e-07
0.4	3.948e+06	4.265e-02	1.168e-01	8.311e-05	2.275e-04	7.256e-05	1.986e-04	7.256e-07	1.986e-06
0.5	9.461e+05	1.406e-02	3.587e-02	2.761e-05	7.041e-05	2.410e-05	6.147e-05	2.410e-07	6.147e-07
0.6	7.400e+06	1.431e-01	3.437e-01	2.794e-04	6.709e-04	2.439e-04	5.857e-04	2.439e-06	5.857e-06
0.8	7.634e+06	2.245e-01	4.917e-01	4.270e-04	9.353e-04	3.727e-04	8.165e-04	3.727e-06	8.165e-06
1.0	8.119e+06	3.314e-01	6.777e-01	6.109e-04	1.249e-03	5.333e-04	1.091e-03	5.333e-06	1.091e-05
1.5	2.860e+06	2.124e-01	3.848e-01	3.573e-04	6.474e-04	3.119e-04	5.652e-04	3.119e-06	5.652e-06
2.0	2.473e+06	2.788e-01	4.696e-01	4.311e-04	7.262e-04	3.764e-04	6.340e-04	3.764e-06	6.340e-06
Totals	**6.853e+07**	**1.298e+00**	**2.677e+00**	**2.306e-03**	**4.802e-03**	**2.013e-03**	**4.192e-03**	**2.013e-05**	**4.192e-05**

Appendix B
Survey Instrument Calibration Records
(4 pages)

Designer and Manufacturer of Scientific and Industrial Instruments

www.ludlums.com

CERTIFICATE OF CALIBRATION

DRAFT

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

CERT # 4084.01

Customer AECOM   ORDER NO. 20347815/473486

Mfg. Ludlum Measurements, Inc.   Model 19   Serial No. 85930

Mfg. ____   Model ____   Serial No. ____

Cal. Date 17-Jan-19   Cal Due Date 17-Jan-20   Cal. Interval 1 Year   Meterface 202-527

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec.   T. 72 °F   RH 34 %   Alt 708.0 mm Hg

☐ New Instrument   Instrument Received ☑ Within Toler. +-10%   ☐ 10-20%   ☐ Out of Tol.   ☐ Requiring Repair   ☐ Other-See comments

☑ Mechanical ck.   ☑ Meter Zeroed   ☐ Background Subtract   ☐ Input Sens. Linearity
☑ F/S Resp. ck   ☑ Reset ck.   ☐ Window Operation   ☑ Geotropism
☑ Audio ck.   ☐ Alarm Setting ck.   ☑ Batt. ck.
☐ Calibrated in accordance with LMI SOP 14.8   ☑ Calibrated in accordance with LMI SOP 14.9

Instrument Volt Set 550 V   Input Sens. 40 mV   Det. Oper. ____ V at ____ mV   Threshold Dial Ratio ____ = ____ mV

☐ HV Readout (2 points)   Ref./Inst. 500 / ____ V   Ref./Inst. 1200 / ____ V

COMMENTS:

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
5000	4000 uR/hr	4000	4000
5000	1000 uR/hr	1000	1000
500	400 uR/hr = 72060 cpm	400	400
500	100 uR/hr	100	100
250	200 uR/hr = 36100 cpm	200	200
250	100 uR/hr	100	100
50	7200 cpm	40	40
50	1800 cpm	10	10
25	3610 cpm	20	20
25	902 cpm	5	5

*Uncertainty within ± 10%   C.F. within ± 20%   Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout				Log Scale			

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques.
The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978   ISO/IE 17025:2005(E)   State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☑ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 2324/2521
☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ 2168CP ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be ☐ T-304 Ra-226 ☐ Y982

☐ Alpha S/N ____   ☐ Beta S/N ____   ☐ Other ____

☑ m 500 S/N 189509   ☐ Oscilloscope S/N ____   ☑ Multimeter S/N 71300492

Calibrator WENDELL WILLIAMS [signature]   Title Calibrator   Date 17 JAN 19

QC'd By [signature]   Title Final QC   Date 18 Jan 19

FORM C22A 10/03/2017   Page 1 of 1

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed: ____

Designer and Manufacturer of Scientific and Industrial Instruments

www.ludlums.com

CERTIFICATE OF CALIBRATION

DRAFT

LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

ilac-MRA ACCREDITED CERT # 4084.01

Customer AECOM ORDER NO. 20350731/475347

Mfg. Ludlum Measurements, Inc. Model 2224 Serial No. 114608

Mfg. Ludlum Measurements, Inc. Model 43-89 Serial No. PR193033

Cal. Date 1-Mar-19 Cal Due Date 1-Mar-20 Cal. Interval 1 Year Meterface 202-694

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 73 °F RH 38 % Alt 738.0 mm Hg

☐ New Instrument Instrument Received ☑ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☑ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☐ F/S Resp. ck ☑ Reset ck. ☐ Window Operation ☐ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck.
☑ Calibrated in accordance with LMI SOP 14.8 ☐ Calibrated in accordance with LMI SOP 14.9

Instrument Volt Set 700 V Input Sens. Comments mV Det. Oper. 700 V at Comments mV Threshold Dial Ratio = mV

☑ HV Readout (2 points) Ref./Inst. 500 / 497 V Ref./Inst. 1500 / 1493 V

COMMENTS:

Alpha Sens: 120mv Overload set to simulate light leak
Beta Sens: 3.5mv Firmware: 390063
Beta Window: 30mv HV set with detector not connected

Cal'D w/ 5ft cable

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
x1000	400kcpm	400	400
x1000	100kcpm	100	100
x100	40kcpm	400	400
x100	10kcpm	100	100
x10	4kcpm	400	400
x10	1kcpm	100	100
x1	400cpm	400	400
x1	100cpm	100	100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400kcpm	39948(0)	39948(0)	Log Scale			
	40kcpm	3995	3995				
	4kcpm	399	399				
	400cpm	40	40				
	40cpm	4	4				

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques.
The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 ISO/IE 17025:2005(E) State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources: Cs-137 S/N: ☐ 059 ☐ 2171CP ☐ 2261CP ☐ 720 ☐ 734 ☐ 781 ☐ 1131 ☐ 1616 ☐ 1696 ☐ 1909 ☐ 1916CP ☐ 2324/2521
☐ 5717CO ☐ 5719CO ☐ 60646 ☐ 70897 ☐ 73410 ☐ E552 ☐ G112 ☐ 2168CP ☐ S-394 ☐ S-1054 ☐ T10081 ☐ T10082 Neutron Am-241 Be ☐ T-304 Ra-226 ☐ Y982

☑ Alpha S/N Pu239 SN:7053 ☑ Beta S/N Tc99SN:5280,SrY90SN:5281 ☐ Other

☑ m 500 S/N 190566 ☐ Oscilloscope S/N ☑ Multimeter S/N 86250390

Calibrator Jason Flores [signature] Title Calibrator Date 1-MAR-19

QC'd By [signature] Title Final QC Date 1Mar19

FORM C22A 10/03/2017 Page 1 of 2

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Designer and Manufacturer of Scientific and Industrial Instruments
www.ludlums.com
LUDLUM MEASUREMENTS, INC.
501 Oak Street
325-235-5494
Sweetwater, TX 79556, U.S.A.

Bench Test Data For Detector

Customer AECOM ORDER NO. 20350731/475347

Detector 43-89 Serial No. PR193033
Counter 2224 Serial No. 114608
Count Time 1Minute
Other

Alpha Input Sensitivity 120 mV
Beta Input Sensitivity 3.5 mV
Beta Window 30 mV
Distance Source to Detector Surface

High Voltage	Background		Isotope Pu239 Size 249000dpm		Isotope Tc99 Size 932000dpm		Isotope Sr/90 Size 580070dpm	
	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
675	0	159	4225	388	15	8263	0	14871
700	0	178	4608	621	10	10986	0	19180
725	3	276	5130	1766	22	14563	0	23076

☐ Gas Proportional detector count rate decreased ≤ 10% after 15 hour static test using 39" cable.

☐ Gas proportional detector count rate decreased ≤ 10% after 5 hour static test using 39" cable and alpha/beta counter.

Signature Jason Flores [signature] Date 1-MAR-19

Designer and Manufacturer of Scientific and Industrial Instruments	Work Order: 20350731	LUDLUM MEASUREMENTS, INC
	DRAFT	POST OFFICE BOX 810 PH: 325-235-5494
	TAG #: 475347	501 OAK STREET FAX: 325-235-4672
		SWEETWATER, TEXAS79556, U.S.A.

Date Received: 2/28/2019   Rec'd Via: FEPO   Condition Received: FAIR

SHIP TO:

AECOM
ATTN:KEVIN TAYLOR MICHELLE ETSITTY
1576 SHUTTLE BUS RD
GRAND CANYON AZ 86023
USA

BILL TO:

AECOM GREENVILLE
ACCOUNTS PAYABLE
PO BOX 5604
GLEN ALLEN VA 23058-56
USA

CUSTOMER ID: **33554**

1505-2524-4

CUST ACCT

CREDIT CARD

Reason for Return: Calibration   Cal Interval \ Special Instructions: 1 YR

Comments: Item 2 replaced tube, and cover. BB

Rush Calib

30 min labor
Received 1 March 19

ITEM	QTY	PART #	DESCRIPTION	PRICE	COST	ITEM	QTY	PART #	DESCRIPTION	PRICE	COST
01*	1.00 EA	2224	M 2224 FOR REPAIR/CAL			2	1	4002-510	PM Tube	363.00	
			*114608			2	1	7393-048	Cover	11.00	
02"	1.00 EA	43-89	M 43-89 FOR REPAIR/CAL								
			*PR193033								
03*	1.00 EA	C	'C' CABLE			1	2	21-9313	D Battery	~	
04*	1.00 EA	MPEL	PELICAN CASE MEDIUM								

SHIPPING DEPARTMENT 11:00 01.03.2019

Instrument Calibrated: ______ at ______

Secondary Detectors: ______ at ______

Extended Calibration: 1 at 150

Labor: 1/2 hour(s) at $ 100 per hour

Total Parts Cost: 374
Total Calibration Charge: 150
Total Labor: 50

Sub Total Calibration, Parts, and Labor: 574.00
Shipping Charges: —
Sales Tax: 20.95
Total Charges: 594.95

Signed: [signature]   Date: 1-MAR-19

QC Released: [signature]   Date: 1 Mar 19

Date: 3/1/19   Contacted: ERIC OLSON

Mon Delivery

PO Number: CC 3/1   Return Ship: 111 Fed Acct # 1303-2524-4   Phone #: 864-297-3102

Appendix C
Field Survey Records
(9 pages)

AECOM

Project 60600121

DRAFT

Survey No. 1

Surveyor:	Kevin Taylor	[signature]	3/5/2019
	Print		Survey Date
Reviewer:	Stephen Shafer	[signature]	4/2/2019
	Print	Sign	Review Date

Survey Meters

Total (Direct) β γ		Removable β γ		Total (Direct) α		Removable α		uR Meter
Instrument #	1	Instrument #		Instrument #	1	Instrument #		Model 19
Meter Model #	2224	Meter Model #		Meter Model #	2224	Meter Model #		#85930
Meter Serial #	114608	Meter Serial #		Meter Serial #	114608	Meter Serial #		Cal Due:
Detector Model #	43-89	Detector Model #		Detector Model #	43-89	Detector Model #		3/4/2020
Detector Serial #	PR193033	Detector Serial #		Detector Serial #	PR193033	Detector Serial #		
Cal Due	2/28/2020	Cal Due		Cal Due	2/28/2020	Cal Due		
Detector Efficiency (ε_i) (cpm/dpm	27.0%	Detector Efficiency (ε_i) (cpm/dpm)		Detector Efficiency (ε_i) (cpm/dp	34.4%	Detector Efficiency (ε_i) (cpm/dpm)		
Surface Efficiency (ε_s)	50%	Surface Efficiency (ε_s)		Surface Efficiency (ε_s)	25%	Surface Efficiency (ε_s)		
Sample Time (T_s) (min)	1	Sample Time (T_s) (min)		Sample Time (T_s) (min)	1	Sample Time (T_s) (min)		
Background Time (T_b) (min)	1	Background Time (T_b) (min)		Background Time (T_b) (min)	1	Background Time (T_b) (min)		
BKG (R_b) (cpm)	218	BKG (R_b) (cpm)		BKG (R_b) (cpm)	1	BKG (R_b) (cpm)		
Probe Area (A) (cm)	100	Swipte Area (A) (cm)		Probe Area (A) (cm)	100	Swipte Area (A) (cm)		
MDC (dpm/100cm2)	531	MDC (dpm/100cm2)	#DIV/0!	MDC (dpm/100cm2)	89	MDC (dpm/100cm2)	#DIV/0!	
Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	
ANSI/HPS N.12-13:	(Pb-210)			ANSI/HPS N.12-13:	(Po-210)			
Scan Rate (det. width/sec.)	1			Scan Rate (det. width/sec.)	1			
MDCR (gross cpm)	376			MDCR (gross cpm)	12			
ScanMDC (dpm/100cm2)	1653			ScanMDC (dpm/100cm2)	176			

$$MDC = \left[\frac{3 + 3.29\sqrt{(R_b)(T_s)(1 + T_s / T_b)}}{(T_s)(\varepsilon_t)(A/100)} \right]$$

$$\varepsilon_t = (\varepsilon_i) * (\varepsilon_s)$$

$$Al = Rb + ((guideline)(eff.))$$

$$dpm / 100cm^2 = \frac{gross\ cpm - bkg\ cpm}{(efficiency)}$$

AECOM

Project 60600121

Survey No. 1

Surveyor:	Kevin Taylor (Print)	(Sign)	3/5/2019 (Survey Date)
Reviewer:	Stephen Shafer (Print)	(Sign)	4/2/2019 (Review Date)

LOCATION: Grand Canyon Headquarters Building - Boiler Room (basement)

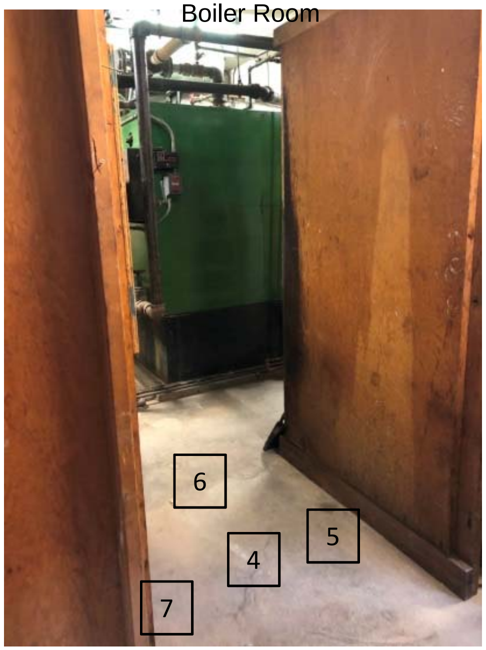
PURPOSE: Surveys in former location of uranium ore specimen storage

#	Description	Location	CPM - Direct β/γ - Total	dpm/100cm² β/γ - Total	CPM - Direct α - Total	dpm/100cm² α - Total	Exp. Rate µR/hr
1	Floro at top of stairs/hall leading to basement	1	402	1363	3	< MDC	13
2	Halfway down the stairs (on concrete surface)	2	346	948	1	< MDC	14
3	Doorway to the boiler room (on concrete floor)	3	396	1319	3	< MDC	15
4	Storage area concrete floor (crack)	4	338	889	1	< MDC	14
5	Storage area concrete floor (stain right)	5	396	1319	3	< MDC	-
6	Storage area concrete floor (stain middle)	6	410	1422	4	< MDC	-
7	Storage area concrete floor (stain left)	7	396	1319	5	< MDC	-
8	Boiler blowoff floor drain	8	301	615	4	< MDC	-

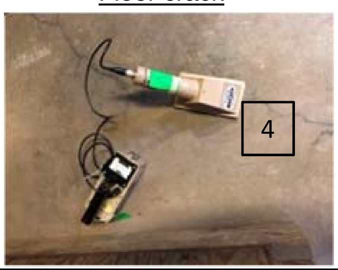
Measurements maded on concrete floors; background measurement made on wooden surface

A cabinet containing ore specimens was once located between the wooden cabinets visible in the photo.

Boiler Room



Floor crack



AECOM

Project 60600121

DRAFT

Survey No. 2

Surveyor:	Kevin Taylor		3/6/2019
	Print		Survey Date
Reviewer:	Stephen Shafer		4/2/2019
	Print	Sign	Review Date

Survey Meters

Total (Direct) β γ		Removable β γ		Total (Direct) α		Removable α	
Instrument #	1	**Instrument #**		**Instrument #**	1	**Instrument #**	
Meter Model #	2224	Meter Model #		Meter Model #	2224	Meter Model #	
Meter Serial #	114608	Meter Serial #		Meter Serial #	114608	Meter Serial #	
Detector Model #	43-89	Detector Model #		Detector Model #	43-89	Detector Model #	
Detector Serial #	PR193033	Detector Serial #		Detector Serial #	PR193033	Detector Serial #	
Cal Due	2/28/2019	Cal Due		Cal Due	2/28/2019	Cal Due	
Detector Efficiency (ε_i) (cpm/dpm	27.0%	Detector Efficiency (ε_i) (cpm/dpm)		Detector Efficiency (ε_i) (cpm/dpm	34.4%	Detector Efficiency (ε_i) (cpm/dpm)	
Surface Efficiency (ε_s)	50%	Surface Efficiency (ε_s)		Surface Efficiency (ε_s)	25%	Surface Efficiency (ε_s)	
Sample Time (T_s) (min)	1	Sample Time (T_s) (min)		Sample Time (T_s) (min)	1	Sample Time (T_s) (min)	
Background Time (T_b) (min)	1	Background Time (T_b) (min)		Background Time (T_b) (min)	1	Background Time (T_b) (min)	
BKG (R_b) (cpm)	202	BKG (R_b) (cpm)		BKG (R_b) (cpm)	0	BKG (R_b) (cpm)	
Probe Area (A) (cm)	100	Swipe Area (A) (cm)		Probe Area (A) (cm)	100	Swipe Area (A) (cm)	
MDC (dpm/100cm2)	512	MDC (dpm/100cm2)	#DIV/0!	MDC (dpm/100cm2)	35	MDC (dpm/100cm2)	#DIV/0!
Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600
ANSI/HPS N.12-13:	(Pb-210)			ANSI/HPS N.12-13:	(Po-210)		
Scan Rate (det. width/sec.)	1			Scan Rate (det. width/sec.)	1		
MDCR (gross cpm)	354			MDCR (gross cpm)	0		
ScanMDC (dpm/100cm2)	1592			ScanMDC (dpm/100cm2)	0		

$$MDC = \left[\frac{3 + 3.29\sqrt{(R_b)(T_s)(1 + T_s / T_b)}}{(T_s)(\varepsilon_t)(A/100)} \right]$$

$$\varepsilon_t = (\varepsilon_i) * (\varepsilon_s)$$

$$Al = Rb + ((\text{guideline})(\text{eff.}))$$

$$\text{dpm} / 100\text{cm}^2 = \frac{\text{gross cpm} - \text{bkg cpm}}{(efficiency)}$$

AECOM

Project 60600121

Survey No. 2

Surveyor: Kevin Taylor (Print) — 3/6/2019 (Survey Date)

Reviewer: Stephen Shafer (Print) — Sign — 4/2/2019 (Review Date)

LOCATION: Grand Canyon Collections Building

PURPOSE: Surveys in areas where uranium ore was stored in buckets

			Location	CPM - Direct β/γ - Total	dpm/100cm^2 β/γ - Total	CPM - Direct α - Total	dpm/100cm^2 α - Total
1.1	Nat Hist Rm	Floor where buckets were stored	1.1	275	541	0	< MDC
1.2	Nat Hist Rm	Floor where buckets were stored	1.2	255	< MDC	0	< MDC
1.3	Nat Hist Rm	Floor where buckets were stored	1.3	268	< MDC	1	< MDC
1.4	Nat Hist Rm	Desk next to where buckets were stored	1.4	242	< MDC	0	< MDC
1.5	Nat Hist Rm	Desk next to where buckets were stored	1.5	225	< MDC	0	< MDC
2.1	Hall	Floor where buckets were stored	2.1	281	585	1	< MDC
2.2	Hall	Floor where buckets were stored	2.2	262	< MDC	0	< MDC
2.3	Hall	Floor where buckets were stored	2.3	245	< MDC	0	< MDC
2.4	Hall	Floor where buckets were stored	2.4	258	< MDC	0	< MDC
2.5	Hall	Lower wall	2.5	240	< MDC	1	< MDC
3.1	Lrg Items Rm	Shelf where buckets were stored	3.1	263	< MDC	0	< MDC
3.2	Lrg Items Rm	Shelf where buckets were stored	3.2	286	622	1	< MDC
3.3	Lrg Items Rm	Shelf where buckets were stored	3.3	256	< MDC	1	< MDC
3.4	Lrg Items Rm	Concrete floor where buckets were stored	3.4*	369	1237	3	35
3.5	Lrg Items Rm	Concrete floor where buckets were stored	3.5*	362	1185	2	< MDC
3.6	Lrg Items Rm	Concrete floor background	3.6*	375	1281	0	< MDC

*** - Concrete floor**

Nat Hist Rm

Hall

Lrg Items Rm

Surveyor: Kevin Taylor (Print) — [signature] — 3/6/2019 (Survey Date)

Reviewer: Stephen Shafer (Print) — [signature] (Sign) — 4/2/2019 (Review Date)

Survey Meters

Total (Direct) β γ		Removable β γ		Total (Direct) α		Removable α		uR Meter
Instrument #	1	Instrument #	1	Instrument #	1	Instrument #	1	Model 19
Meter Model #	2224	Meter Model #	2224	Meter Model #	2224	Meter Model #	2224	#85930
Meter Serial #	114608	Meter Serial #	114608	Meter Serial #	114608	Meter Serial #	114608	Cal Due:
Detector Model #	43-89	Detector Model #	43-89	Detector Model #	43-89	Detector Model #	43-89	3/4/2020
Detector Serial #	PR193033	Detector Serial #	PR193033	Detector Serial #	PR193033	Detector Serial #	PR193033	
Cal Due	2/28/2019	Cal Due	2/28/2019	Cal Due	2/28/2019	Cal Due	2/28/2019	
Detector Efficiency (ε_i) (cpm/dpm	27.0%	Detector Efficiency (ε_i) (cpm/dp	27.0%	Detector Efficiency (ε_i) (cpm/dp	34.4%	Detector Efficiency (ε_i) (cpm/dpm	34.4%	
Surface Efficiency (ε_s)	50%	Surface Efficiency (ε_s)	50%	Surface Efficiency (ε_s)	25%	Surface Efficiency (ε_s)	25%	
Sample Time (T_s) (min)	1	Sample Time (T_s) (min)	1	Sample Time (T_s) (min)	1	Sample Time (T_s) (min)	1	
Background Time (T_b) (min)	1	Background Time (T_b) (min)	1	Background Time (T_b) (min)	1	Background Time (T_b) (min)	1	
BKG (R_b) (cpm)	202	BKG (R_b) (cpm)	202	BKG (R_b) (cpm)	0	BKG (R_b) (cpm)	0	
Probe Area (A) (cm)	100	Swipte Area (A) (cm)	100	Probe Area (A) (cm)	100	Swipte Area (A) (cm)	100	
MDC (dpm/100cm2)	512	MDC (dpm/100cm2)	512	MDC (dpm/100cm2)	35	MDC (dpm/100cm2)	35	
Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	
ANSI/HPS N.12-13:	(Pb-210)			ANSI/HPS N.12-13:	(Po-210)			
Scan Rate (det. width/sec.)	1			Scan Rate (det. width/sec.)	1			
MDCR (gross cpm)	354			MDCR (gross cpm)	0			
ScanMDC (dpm/100cm2)	1592			ScanMDC (dpm/100cm2)	0			

$$MDC = \left[\frac{3 + 3.29\sqrt{(R_b)(T_s)(1 + T_s / T_b)}}{(T_s)(\varepsilon_t)(A/100)} \right]$$

$$\varepsilon_t = (\varepsilon_i) * (\varepsilon_s)$$

$$Al = Rb + ((\text{guideline})(\text{eff.}))$$

$$\text{dpm} / 100\text{cm}^2 = \frac{\text{gross cpm} - \text{bkg cpm}}{(efficiency)}$$

Project 60600121

DRAFT

Survey No. 3

Surveyor: Kevin Taylor (Print) — [signature] (Sign) — 3/6/2019 (Survey Date)

Reviewer: Stephen Shafer (Print) — [signature] (Sign) — 4/2/2019 (Review Date)

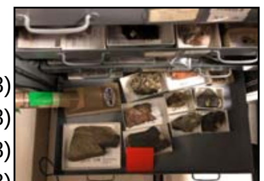
LOCATION: Grand Canyon Collections Building

PURPOSE: Surveys of drawers and shelves

# (photo)	Room	Cabinet*	Shelf/Drawer		Location	CPM - Direct β/γ - Total	dpm/100cm² β/γ - Total	CPM - Direct α - Total	dpm/100cm² α - Total	Exp. Rate μR/hr
1 (A)	Nat Hist Rm	N.H01	.03		1	243	< MDC	0	< MDC	-
2	Nat Hist Rm	N.H01	.03		2	222	< MDC	0	< MDC	-
3	Nat Hist Rm	N.H01	.04		3	242	< MDC	2	< MDC	-
4	Nat Hist Rm	N.H01	.04	(Beaver)	4	251	< MDC	1	< MDC	-
5	Nat Hist Rm	N.H01	.01	(Gashawk)	5	248	< MDC	2	< MDC	-
6	Interpretive Rm	Paleo/Geo	2	(Drawer 1 is top drawer)	6	201	< MDC	0	< MDC	5-7
7	Interpretive Rm	Paleo/Geo	3		7	235	< MDC	1	< MDC	5-7
8	Interpretive Rm	Paleo/Geo	3		8	240	< MDC	1	< MDC	5-7
9	Interpretive Rm	Paleo/Geo	4		9	249	< MDC	2	< MDC	5-7
10	Nat Hist Rm	N.A08	.02	(on foam)	10	241	< MDC	2	< MDC	15
11	Nat Hist Rm	N.A08	.02	(under foam)	11	231	< MDC	2	< MDC	15
12 (B)	Nat Hist Rm	N.B16	.01		12	402	1481	34	395	20
13	Nat Hist Rm	N.B16	.01		13	444	1793	63	733	20
14	Nat Hist Rm	N.B17	.03	(cabinet labeled as N.B.18)	14	409	1533	96	1116	11
15	Nat Hist Rm	N.B17	.03	(cabinet labeled as N.B.18)	15	291	659	13	151	11
16	Nat Hist Rm	N.B17	.04	(cabinet labeled as N.B.18)	16	676	3511	329	3826	11
17	Nat Hist Rm	N.B17	.04	(cabinet labeled as N.B.18)	17	324	904	324	3767	11
18	Nat Hist Rm	N.B17	Inside door		18	360	1170	128	1488	8
19 (C)	Nat Hist Rm	N.E01	.02		19	202	< MDC	12	140	8
20	Nat Hist Rm	N.E01	.02		20	275	541	0	< MDC	8
21	Nat Hist Rm	N.E01	.06		21	232	< MDC	14	163	8
22	Nat Hist Rm	N.E01	.06		22	256	< MDC	3	35	-
23 (D)	Nat Hist Rm	N.B17	top of cabinet		23	210	< MDC	3	35	-
24	Nat Hist Rm	N.B15	top of cabinet		24	259	< MDC	2	< MDC	-
25	Nat Hist Rm	N.B14	(cabinet contains Orphan Mine cores)		25	-	-	-	-	90

A

B



C

D

*Note: Drawers in cabinet N.B18 were labeled N.B17.xx

AECOM

Project 60600121

DRAFT

Survey No. 3

Surveyor: Kevin Taylor (Print) — [signature] — 3/6/2019 (Survey Date)

Reviewer: Stephen Shafer (Print) — [signature] (Sign) — 4/2/2019 (Review Date)

LOCATION: Grand Canyon Collections Building

PURPOSE: Surveys of drawers and shelves

	Room	Cabinet	Shelf/Drawer
1	Nat Hist Rm	N.B16	.01
2	Nat Hist Rm	N.B16	.01
3	Nat Hist Rm	N.B17	.03
4	Nat Hist Rm	N.B17	.03
5	Nat Hist Rm	N.B17	.04
6	Nat Hist Rm	N.B17	.04
7	Nat Hist Rm	N.B17	Inside Inside door

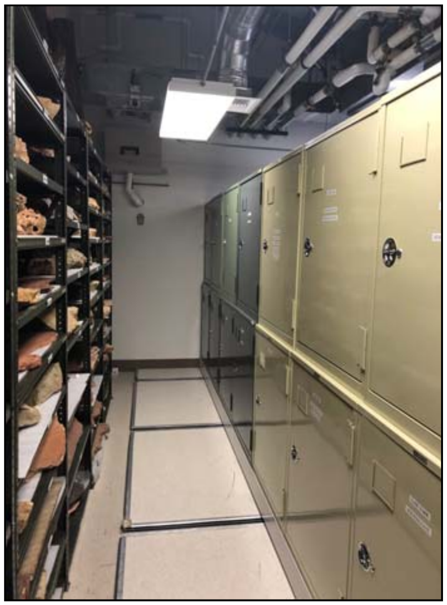
Initial Cnt.
3/6/2019
5:45 PM
Bkgd β: 196
Bkgd α: 0

Location	CPM β/γ - Remov.	dpm/100cm² β/γ - Remov.	CPM α - Remov.	dpm/100cm² α - Remov.
1	226	< MDC	21	244
2	222	< MDC	6	70
3	204	< MDC	13	151
4	216	< MDC	2	< MDC
5	281	630	35	407
6	207	< MDC	2	< MDC
7	180	< MDC	6	70

Second Cnt.
3/7/2019
10:00 PM
Bkgd β: 196
Bkgd α: 0

Location	CPM β/γ - Remov.	dpm/100cm² β/γ - Remov.	CPM α - Remov.	dpm/100cm² α - Remov.
1	236	< MDC	21	244
2	224	< MDC	3	35
3	204	< MDC	15	174
4	194	< MDC	2	< MDC
5	269	541	30	349
6	225	< MDC	3	35
7	208	< MDC	6	70

Isle with N.B17, N.B16, and N.B14



N.B16

AECOM

Project 60600121

Survey No. 4

DRAFT

Surveyor: Kevin Taylor (Print) — Survey Date: 3/7/2019

Reviewer: Stephen Shafer (Print) — Sign — Review Date: 4/2/2019

Survey Meters

Total (Direct) β γ		Removable β γ		Total (Direct) α		Removable α	
Instrument #	1	**Instrument #**		**Instrument #**	1	**Instrument #**	
Meter Model #	2224	Meter Model #		Meter Model #	2224	Meter Model #	
Meter Serial #	114608	Meter Serial #		Meter Serial #	114608	Meter Serial #	
Detector Model #	43-89	Detector Model #		Detector Model #	43-89	Detector Model #	
Detector Serial #	PR193033	Detector Serial #		Detector Serial #	PR193033	Detector Serial #	
Cal Due	2/28/2019	Cal Due		Cal Due	2/28/2019	Cal Due	
Detector Efficiency (ε_i) (cpm/dpm	27.0%	Detector Efficiency (ε_i) (cpm/dpm)		Detector Efficiency (ε_i) (cpm/dpm	34.4%	Detector Efficiency (ε_i) (cpm/dpm)	
Surface Efficiency (ε_s)	50%	Surface Efficiency (ε_s)		Surface Efficiency (ε_s)	25%	Surface Efficiency (ε_s)	
Sample Time (T_s) (min)	1	Sample Time (T_s) (min)		Sample Time (T_s) (min)	1	Sample Time (T_s) (min)	
Background Time (T_b) (min)	1	Background Time (T_b) (min)		Background Time (T_b) (min)	1	Background Time (T_b) (min)	
BKG (R_b) (cpm)	235	BKG (R_b) (cpm)		BKG (R_b) (cpm)	0	BKG (R_b) (cpm)	
Probe Area (A) (cm)	100	Swipe Area (A) (cm)		Probe Area (A) (cm)	100	Swipe Area (A) (cm)	
MDC (dpm/100cm2)	551	MDC (dpm/100cm2)	#DIV/0!	MDC (dpm/100cm2)	35	MDC (dpm/100cm2)	#DIV/0!
Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600	Release Limit (dpm/100cm2)	600
ANSI/HPS N.12-13:	(Pb-210)			ANSI/HPS N.12-13:	(Po-210)		
Scan Rate (det. width/sec.)	1			Scan Rate (det. width/sec.)	1		
MDCR (gross cpm)	399			MDCR (gross cpm)	0		
ScanMDC (dpm/100cm2)	1717			ScanMDC (dpm/100cm2)	0		

$$MDC = \left[\frac{3 + 3.29\sqrt{(R_b)(T_s)(1 + T_s / T_b)}}{(T_s)(\varepsilon_t)(A/100)} \right]$$

$$\varepsilon_t = (\varepsilon_i) * (\varepsilon_s)$$

$$Al = Rb + ((\text{guideline})(\text{eff.}))$$

$$\text{dpm} / 100\text{cm}^2 = \frac{\text{gross cpm} - \text{bkg cpm}}{(\textit{efficiency})}$$

AECOM

Project 60600121

DRAFT

Survey No. 4

Surveyor: Kevin Taylor (Print) — Survey Date: 3/7/2019

Reviewer: Stephen Shafer (Print) — Sign — Review Date: 4/2/2019

LOCATION: Grand Canyon Collections Building

PURPOSE: Survey of taxidermy specimens from Desert View

			Location	CPM - Direct β/γ - Total	$dpm/100cm^2$ β/γ - Total	CPM - Direct α - Total	$dpm/100cm^2$ α - Total
1	Nat Hist Rm	Great Horned Owl (PRT-753081) - feathers	1	213	< MDC	1	< MDC
2	Nat Hist Rm	Great Horned Owl (PRT-753081) - base	2	214	< MDC	0	< MDC
3	Nat Hist Rm	Coyote pup - fur	3	221	< MDC	1	< MDC
4	Nat Hist Rm	Coyote pup - base	4	287	< MDC	1	< MDC
5	Nat Hist Rm	Beaver pelt (Tag No. 472206) - fur side	5	227	< MDC	1	< MDC
6	Nat Hist Rm	Beaver pelt (Tag No. 472206) - skin side	6	220	< MDC	1	< MDC

Appendix D
Grand Canyon Ore Specimen Collections Cards
(25 pages)

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY ROCKS MINERALS Oxides	N.B16.01	N

OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER
STORAGE 2009	GRCA	4587

DRAFT

ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
FIELD COLLECTN	FIELD COLLECTN	GRCA-01240

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
URANINITE	1	EA

DESCRIPTION ONE SPECIMEN OF URANINITE.
TAKEN FROM AN AREA NEAR WHERE A SMALL POCKET TESTED 0.42% UO3.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, WEST RIM DRIVE	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 10.0, W10.0, T 5.0 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
STOCKERT, JOHN W.	Not Provided	12/10/1965		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/7/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

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MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION		CONTROLLED PROPERTY
GEOLOGY	N.E01.06		N
GEOLOGY	OBJECT STATUS AND YEAR: STORAGE 2005	PARK ACRONYM: GRCA	CATALOG NUMBER: 7527
MINERALS / Oxides	ACQUISITION TYPE: FIELD COLLECTN	ACQUISITION DATE: FIELD COLLECTN	ACCESSION NUMBER: GRCA-00624
OBJECT/SPECIMEN NAME: RADIOACTIVE ORE		LOT QUANTIFICATION — ITEM COUNT: 1	STORAGE UNIT: EA

DRAFT

DESCRIPTION: RADIOACTIVE ORE- SANDSTONE CEMENTED TOGETHER WITH HYDROUS IRON SULFATE AND IS ALTERING TO LIMONITE
ORIGINAL CATALOG CARD NOTES:
"REMARKS: SAMPLE ANALYSIS REF. NO. VP-864-865. BUREAU OF MINES, TUCSON, ARIZ. RADIOACTIVE (RADIOMETRIC) ANALYSIS SHOWED ACTIVITY EQUIVALENT TO ABOUE 14%U308 BASED ON PITCHBLENDE STANDARDS. CHEMICAL ANALYSIS GAVE 0.07 PERCENT U308 AND 3.6% LEAD. LEAD BEAD FROM BLOWPIPE ANALYSIS WAS HIGHLY RADIOACTIVE. INCLINED TO BELIEVE THAT THE LEAD IS ISOMORPHOUS WITH THE IRON AS PLUMBO JAROSITE.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN LODE CLAIM, BELOW HOGAN PROPERTY ON WEST RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
STRICKLEN, HOWARD	Not Provided	4/1/1951		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
GRAY, ROBERT C. 7/30/1959		OLD CAT # O-457

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION GEOLOGY ROCKS MINERALS Oxides	OBJECT LOCATION N.B16.01		CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE 2009	PARK ACRONYM GRCA	CATALOG NUMBER 7537
	ACQUISITION TYPE FIELD COLLECTN	ACQUISITION DATE FIELD COLLECTN	ACCESSION NUMBER GRCA-00601
OBJECT/SPECIMEN NAME METATABENITE		LOT QUANTIFICATION — ITEM COUNT 1	STORAGE UNIT EA

DRAFT

DESCRIPTION: ONE SPECIMEN OF METATABENITE (URANIUM ORE).
SECONDARY ORE URANIUM FROM THE REDWALL LIMESTONE FORMATION.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, GOLDEN CROWN MINING COMPANY (HOGAN PROPERTY	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	REDWALL LIMESTONE FORMATION	L 11.2, W 7.5, T 3.6 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHELLBACK, L.	Not Provided	8/21/1956		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/6/2009		OLD COLLECTION # O-467

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY ROCKS MINERALS Oxides	N.B16.01	N

OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER
STORAGE 2009	GRCA	7538

DRAFT

ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
FIELD COLLECTN	FIELD COLLECTN	GRCA-00601

OBJECT/SPECIMEN NAME /SPECIMEN NAME	ITEM COUNT (LOT QUANTIFICATION)	STORAGE UNIT
URANINITE	1	EA

DESCRIPTION: ONE SPECIMEN OF URANINITE, PITCHBLENDE (BLACK). URANIUM ORE.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, GOLDEN CROWN MINING COMPANY (HOGAN PROPERTY	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	REDWALL LIMESTONE FORMATION	L 11.0, W 8.6, T 6.9 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHELLBACK, L.	Not Provided	8/21/1956		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/7/2009		OLD COLLECTION # O-468

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION		CONTROLLED PROPERTY
GEOLOGY	N.B16.01		N
ROCKS	OBJECT STATUS AND YEAR: STORAGE 2009	PARK ACRONYM: GRCA	CATALOG NUMBER: 7539
MINERALS			
Oxides	ACQUISITION TYPE: FIELD COLLECTN	ACQUISITION DATE: FIELD COLLECTN	ACCESSION NUMBER: GRCA-00601

DRAFT

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
URANINITE	1	EA

DESCRIPTION
ONE SPECIMEN OF URANINITE, PITCHBLENDE, SPHALARITE.
URANIUM ORE.
TESTED FOR RADIATION ON JUNE OF 2000, SEE ACCESSION FOLDER FOR SUMMARY OF SURVEY RESULTS.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, GOLDEN CROWN MINING COMPANY (HOGAN PROPERTY	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	REDWALL LIMESTONE FORMATION	L 11.5, W 11.7, T 6.3 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHELLBACK, L.	Not Provided	8/21/1956		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/7/2009		OLD COLLECTION # O-469

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION GEOLOGY ROCKS MINERALS Oxides	OBJECT LOCATION N.B16.01		CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE 2009	PARK ACRONYM GRCA	CATALOG NUMBER NUMBER 7540
	ACQUISITION TYPE FIELD COLLECTN	ACQUISITION DATE FIELD COLLECTN	ACCESSION NUMBER GRCA-00601
OBJECT/SPECIMEN NAME /SPECIMEN NAME WULFENITE		LOT QUANTIFICATION ITEM COUNT 1	STORAGE UNIT EA

DRAFT

DESCRIPTION ONE SPECIMEN OF WULFENITE, SPHALERITE, GALENA, COPPER SUPPHATES.
URANIUM ORE.
TESTED FOR RADIATION ON JUNE OF 2000, SEE ACCESSION FOLDER FOR SUMMARY OF SURVEY RESULTS.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, GOLDEN CROWN MINING COMPANY (HOGAN PROPERTY	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	REDWALL LIMESTONE FORMATION	L 11.9, W 3.6, T 6.9 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHELLBACK, L.	Not Provided	8/21/1956		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/7/2009		OLD COLLECTION # O-470

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY	N.E01.06	N
GEOLOGY	OBJECT STATUS AND YEAR: STORAGE 1999	PARK ACRONYM: GRCA; CATALOG NUMBER: 8016
MINERALS	ACQUISITION TYPE: FIELD COLLECTN	ACQUISITION DATE: FIELD COLLECTN; ACCESSION NUMBER: GRCA-00624
Oxides		

DRAFT

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION ITEM COUNT	STORAGE UNIT
RADIOACTIVE ORE __RADIOACTIVE ORE	1	EA

DESCRIPTION: RADIOACTIVE ORE- SANDSTONE CEMENTED TOGETHER WITH HYDROUS IRON SULFATE AND IS ALTERING TO LIMONITE ORIGINAL CATALOG CARD NOTES: "REMARKS: SAMPLE ANALYSIS REF. NO. VP-864-865. BUREAU OF MINES, TUCSON, ARIZ. RADIOACTIVE (RADIOMETRIC) ANALYSIS SHOWED ACTIVITY EQUIVALENT TO ABOUE 14%U308 BASED ON PITCHBLENDE STANDARDS. CHEMICAL ANALYSIS GAVE 0.07 PERCENT U308 AND 3.6% LEAD. LEAD BEAD FROM BLOWPIPE ANALYSIS WAS HIGHLY RADIOACTIVE. INCLINED TO BELIEVE THAT THE LEAD IS ISOMORPHOUS WITH THE IRON AS PLUMBO JAROSITE.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN LODE CLAIM, BELOW HOGAN PROPERTY ON WEST RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN __ __ __ __		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
STRICKLEN, HOWARD	Not Provided	4/1/1951		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
GRAY, ROBERT C. 7/30/1959		OLD CAT # O-457

RESTRICTION	REPRODUCTION N	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY	N.E01.06	N

GEOLOGY

MINERALS

Oxides

OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER
STORAGE 1999	GRCA	8017

DRAFT

ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
FIELD COLLECTN	FIELD COLLECTN	GRCA-00624

OBJECT/SPECIMEN NAME /SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
RADIOACTIVE ORE __RADIOACTIVE ORE	1	EA

DESCRIPTION: RADIOACTIVE ORE- SANDSTONE CEMENTED TOGETHER WITH HYDROUS IRON SULFATE AND IS ALTERING TO LIMONITE
ORIGINAL CATALOG CARD NOTES:
"REMARKS: SAMPLE ANALYSIS REF. NO. VP-864-865. BUREAU OF MINES, TUCSON, ARIZ. RADIOACTIVE (RADIOMETRIC) ANALYSIS SHOWED ACTIVITY EQUIVALENT TO ABOUE 14%U308 BASED ON PITCHBLENDE STANDARDS. CHEMICAL ANALYSIS GAVE 0.07 PERCENT U308 AND 3.6% LEAD. LEAD BEAD FROM BLOWPIPE ANALYSIS WAS HIGHLY RADIOACTIVE. INCLINED TO BELIEVE THAT THE LEAD IS ISOMORPHOUS WITH THE IRON AS PLUMBO JAROSITE.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN LODE CLAIM, BELOW HOGAN PROPERTY ON WEST RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN __ __ __ __		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
STRICKLEN, HOWARD	Not Provided	4/1/1951		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
GRAY, ROBERT C. 7/30/1959		OLD CAT # O-457

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION GEOLOGY ROCKS MINERALS Oxides	OBJECT LOCATION N.B16.01		CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE DRAFT 2009	PARK ACRONYM GRCA	CATALOG NUMBER NUMBER 17364
	ACQUISITION TYPE FIELD COLLECTN	ACQUISITION DATE FIELD COLLECTN	ACCESSION NUMBER GRCA-00601
OBJECT/SPECIMEN NAME /SPECIMEN NAME METATABENITE		LOT QUANTIFICATION ITEM COUNT 1	STORAGE UNIT EA

DESCRIPTION ONE SPECIMEN OF METATABENITE (URANIUM ORE).
GREEN-TABULAR, SECONDARY ORE URANIUM FROM THE REDWALL LIMESTONE FORMATION.

CATALOG DATA

COLLECTION SITE ORPHAN MINE, GOLDEN CROWN MINING COMPANY (HOGAN PROPERTY	PARK GRCA	TOWNSHIP/RANGE/SECTION	COUNTY COCONINO	STATE AZ
WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG. UNKNOWN	ELEVATION	DEPTH
HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD REDWALL LIMESTONE FORMATION	DIMENSIONS/WEIGHT L 9.0, W 5.0, T 4.0 CM		
COLLECTOR SCHELLBACK, L.	COLLECTION NO. Not Provided	COLLECTION DATE 8/1/1956	MAINTENANCE CYCLE	CONDITION COM/GD
IDENTIFIED BY AND DATE UNKNOWN	TYPE N	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
CATALOGER AND DATE DAVIS, SARA 8/6/2009	EMINENT FIGURE ASSOCIATION		OTHER NUMBERS OLD COLLECTION # O-467	
RESTRICTION	REPRODUCTION N	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER / SIGNIFICANCE

U.S. DEPARTMENT OF THE INTERIOR **MUSEUM CATALOG RECORD CULTURAL RESOURCES** NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION GEOLOGY ROCKS MINERALS Oxides	OBJECT LOCATION N.B17.03			CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE 2009		PARK ACRONYM GRCA	CATALOG NUMBER 17403
	ACQUISITION TYPE FIELD COLLECTN		ACQUISITION DATE FIELD COLLECTN	ACCESSION NUMBER GRCA-00601
OBJECT/SPECIMEN NAME WULFENITE			LOT QUANTIFICATION ITEM COUNT 1	STORAGE UNIT EA

DRAFT

DESCRIPTION ONE SPECIMEN OF WULFENITE WITH SPHALERITE, GALENA, COPPER SUPPHATES. URANIUM ORE.

CATALOG DATA

COLLECTION SITE ORPHAN MINE	PARK GRCA	TOWNSHIP/RANGE/SECTION	COUNTY COCONINO	STATE AZ
WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG. UNKNOWN	ELEVATION	DEPTH
HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD REDWALL LIMESTONE FORMATION	DIMENSIONS/WEIGHT L 6.0, W 5.0, T 3.5 CM		
COLLECTOR SCHELLBACK, L.	COLLECTION NO. Not Provided	COLLECTION DATE 8/1/1956	MAINTENANCE CYCLE	CONDITION COM/GD
IDENTIFIED BY AND DATE UNKNOWN	TYPE N	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
CATALOGER AND DATE DAVIS, SARA 8/28/2009	EMINENT FIGURE ASSOCIATION		OTHER NUMBERS OLD COLLECTION # O-470	

RESTRICTION	REPRODUCTION N	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION GEOLOGY ROCKS MINERALS Oxides	OBJECT LOCATION N.B17.04			CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE 2009	PARK ACRONYM GRCA	CATALOG NUMBER	NUMBER 17508
	ACQUISITION TYPE FIELD COLLECTN	ACQUISITION DATE FIELD COLLECTN	ACCESSION NUMBER GRCA-01161	
OBJECT/SPECIMEN NAME /SPECIMEN NAME PITCHBLENDE		LOT QUANTIFICATION ITEM COUNT 3	STORAGE UNIT EA	

DRAFT

DESCRIPTION THREE PIECES OF OF PITCHBLENDE (CA 1% ORE), URANATE. COLOR MOSTLY DARK GRAY NEARLY BLACK, FEW RUSTY BLOTCHES. THE SPECIMEN WAS REMOVED FROM A CLEAR PLASTIC BOX AND IS NOW STORED IN AN ARCHIVAL BOX. THE SPECIMEN WAS TESTED FOR RADIATION ON 6/2000, SEE ACCESSION FOLDER FOR SUMMARY OF SURVEY RESULTS.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
LOST ORPHAN MINE, SOUTH RIM (1650 FT BELOW THE SURFACE)	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	VARIOUS

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
BEAL, MERRILL D.	Not Provided	11/18/1963		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/31/2009		

RESTRICTION	REPRODUCTION N	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION GEOLOGY ROCKS MINERALS Oxides	OBJECT LOCATION N.B17.04	CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE 2009	PARK ACRONYM GRCA — CATALOG NUMBER 20057
	ACQUISITION TYPE FIELD COLLECTN	ACQUISITION DATE FIELD COLLECTN — ACCESSION NUMBER GRCA-00140
OBJECT/SPECIMEN NAME /SPECIMEN NAME URANINITE	LOT QUANTIFICATION ITEM COUNT 1	STORAGE UNIT EA

DRAFT

DESCRIPTION ONE SPECIMEN OF URANINITE?
TYPICAL LOW GRADE ORE IN CRYSTALLINE LIMESTONE (LARGE AMOUNT NEAR NORTH MINE PROPERTY BOUNDARY).
TESTED FOR RADIATION 6/2000, SEE ACCESSION FOLDER FOR SUVEY OF TEST RESULTS.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, SOUTH RIM, 750' LEVEL	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 16.0, W 13.0, T 6.5 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHULTZ, PAUL E.	Not Provided	11/21/1958		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/6/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CATALOG DATA

DRAFT

CLASSIFICATION: GEOLOGY / ROCKS / MINERALS / Oxides

OBJECT LOCATION: N.B16.01

CONTROLLED PROPERTY: N

OBJECT STATUS AND YEAR: STORAGE 2009

PARK ACRONYM: GRCA

CATALOG NUMBER: 20058

ACQUISITION TYPE: FIELD COLLECTN

ACQUISITION DATE: FIELD COLLECTN

ACCESSION NUMBER: GRCA-00140

OBJECT/SPECIMEN NAME: URANINITE

LOT QUANTIFICATION — ITEM COUNT: 1; STORAGE UNIT: EA

DESCRIPTION: ONE SPECIMEN OF URANINITE?
TYPICAL LOW GRADE ORE IN CRYSTALLINE LIMESTONE (LARGE AMOUNT NEAR NORTH MINE PROPERTY BOUNDARY).

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, SOUTH RIM, 750' LEVEL	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 9.5, W 8.0, T 4.5 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHULTZ, PAUL E.	Not Provided	11/21/1958		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/6/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION: GEOLOGY / ROCKS / MINERALS / Sulfates

OBJECT LOCATION: N.E01.02

CONTROLLED PROPERTY: N

OBJECT STATUS AND YEAR: STORAGE 2017

DRAFT

PARK ACRONYM: GRCA

CATALOG NUMBER: 20059

ACQUISITION TYPE: FIELD COLLECTN

ACQUISITION DATE: FIELD COLLECTN

ACCESSION NUMBER: GRCA-00140

OBJECT/SPECIMEN NAME /SPECIMEN NAME: PYRITE

LOT QUANTIFICATION — ITEM COUNT: 1 — STORAGE UNIT: EA

DESCRIPTION: ONE SPECIMEN OF PYRITE.
HORIZON: ORPHAN MINE, 500 FT LEVEL.
BROKEN INTO TWO PIECES- MAIN PIECE AND FRAGMENT IN SMALL BAG.

CATALOG DATA

COLLECTION SITE: ORPHAN MINE, 500' LEVEL, SOUTH RIM

PARK: GRCA

TOWNSHIP/RANGE/SECTION:

COUNTY: COCONINO

STATE: AZ

WATERBODY/DRAINAGE:

UTM Z/E/N:

LAT. LONG.: UNKNOWN

ELEVATION:

DEPTH:

HABITAT/DEPOSITIONAL ENVIRONMENT:

FORMATION PERIOD: UNKNOWN

DIMENSIONS/WEIGHT: L 13.4, W 7.5, T 4.5 CM

COLLECTOR: SCHULTZ, PAUL E.

COLLECTION NO.: Not Provided

COLLECTION DATE: 3/11/1959

MAINTENANCE CYCLE:

CONDITION: COM/GD

IDENTIFIED BY AND DATE: UNKNOWN

TYPE: N

VALUE AT ACQUISITION, BASIS:

CURRENT VALUE, DATE, BASIS:

PHOTO NUMBER:

CATALOGER AND DATE: HINCHLIFFE, LOUISE 3/11/1959

EMINENT FIGURE ASSOCIATION:

OTHER NUMBERS:

RESTRICTION:

REPRODUCTION: N

PUBLICATION CITATION:

PRESERVATION TREATMENT:

CATALOG FOLDER:

SIGNIFICANCE:

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY ROCKS MINERALS Sulfates	N.B16.01	N

OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER
STORAGE 2009	GRCA	20063

DRAFT

ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
FIELD COLLECTN	FIELD COLLECTN	GRCA-00140

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION ITEM COUNT	STORAGE UNIT
PYRITE	1	EA

DESCRIPTION ONE SPECIMEN OF PYRITE/URANINITE.
TWO FRAGMENTS REFIT.
FROM PYRITE ZONE SURROUNDING A RELATIVELY RICH URANIUM ORE BODY.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, SOUTH RIM, 500' LEVEL	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 11.5, W 6.0, T 3.5 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHULTZ, PAUL E.	Not Provided	11/21/1958		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/6/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION GEOLOGY GEOLOGY MINERALS Oxides	OBJECT LOCATION LARGE OBJECT, RADIOACTIVE BUCKET ON SHELVES NEAR LOAD	CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE 2017	PARK ACRONYM: GRCA CATALOG NUMBER: 20071
	ACQUISITION TYPE FIELD COLLECTN	ACQUISITION DATE: FIELD COLLECTN ACCESSION NUMBER: GRCA-00140
OBJECT/SPECIMEN NAME LIMONITE		LOT QUANTIFICATION ITEM COUNT: 1 STORAGE UNIT: EA

DRAFT

DESCRIPTION ONE SPECIMEN. LIMONITE.
HORIZON: UNKNOWN. FROM THE ORPHAN MINE.
TESTED FOR RADIOACTIVITY IN JUNE 2000. SEE THE ACCESSION FOLDER FOR A SUMMARY OF THE SURVEY RESULTS.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, SOUTH RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	6.75 X 4 X 4 INCHES

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHULZ, PAUL E.	Not Provided	3/11/1959		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
HINCHLIFFE, LOUISE 3/11/1959		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION		CONTROLLED PROPERTY
GEOLOGY	N.B16.01		N
ROCKS	OBJECT STATUS AND YEAR: STORAGE 2009	PARK ACRONYM: GRCA	CATALOG NUMBER: 20072
MINERALS			
Oxides	ACQUISITION TYPE: FIELD COLLECTN	ACQUISITION DATE: FIELD COLLECTN	ACCESSION NUMBER: GRCA-00140

DRAFT

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
URANINITE	1	EA

DESCRIPTION: ONE SPECIMEN OF URANINITE.
FROM MINERALIZED ZONE ADJACENT TO RICH ORE BODY.
YELLOW AND BROWN SURFACE MINERALS, FLARING BLACK VEIN IN COCONINO SANDSTONE.
TYPICAL LOW GRADE ORE IN CRYSTALLINE LIMESTONE (LARGE AMOUNT NEAR NORTH MINE PROPERTY BOUNDARY).

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, SOUTH RIM, 500' LEVEL, BELOW MAIN ADIT	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	COCONINO SANDSTONE FORMATION	L 9.0, W 6.0, T 4.0 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
SCHULTZ, PAUL E.	Not Provided	11/21/1958		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/6/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY MINERALS OXIDES UNUSED	LARGE OBJECT, RADIOACTIVE BUCKET ON SHELVES NEAR LOAD	N

OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER	NUMBER
STORAGE 2000	GRCA	20081	-

DRAFT

ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
FIELD COLLECTN	FIELD COLLECTN	GRCA-00142

OBJECT/SPECIMEN NAME /SPECIMEN NAME	LOT QUANTIFICATION ITEM COUNT	STORAGE UNIT
URANINITE __URANINITE	1	EA

DESCRIPTION
URANITE SAMPLE.
JANUARY (?) 1959 TAKEN OFF EXHIBIT IN VC ON 1/16/1997.
TESTED FOR RADIATION, 06/2000. SEE ACCESSION FILE FOR SUMMARY OF SURVEY RESULTS. CONTAINED IN SEALED BUCKET AT RECOMMENDATION OF EXPERT.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, WEST RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	OLD MEAS- 6 X 6.75 X 7 IN

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
MCLAUGHLIN, JOHN S.	Not Provided	3/18/1959	/	COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
HINCHLIFFE, LOUISE 3/18/1959		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY	N.B16.01	N

	OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER
ROCKS MINERALS	STORAGE 2009	GRCA	20082

DRAFT

	ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
Oxides	FIELD COLLECTN	FIELD COLLECTN	GRCA-00142

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
URANINITE	1	EA

DESCRIPTION ONE SPECIMEN OF URANINITE.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, SOUTH RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 10.5, W 8.0, T 8.0 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
MCLAUGHLIN, JOHN S.	Not Provided	1/1/1959		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/6/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CATALOG DATA

DRAFT

CLASSIFICATION GEOLOGY ROCKS MINERALS Oxides	OBJECT LOCATION N.B16.01			CONTROLLED PROPERTY N
	OBJECT STATUS AND YEAR STORAGE 2009		PARK ACRONYM GRCA	CATALOG NUMBER 20083
	ACQUISITION TYPE FIELD COLLECTN		ACQUISITION DATE FIELD COLLECTN	ACCESSION NUMBER GRCA-00143
OBJECT/SPECIMEN NAME URANINITE			LOT QUANTIFICATION ITEM COUNT 1	STORAGE UNIT EA

DESCRIPTION ONE SPECIMEN OF URANINITE.

COLLECTION SITE ORPHAN URANIUM MINE, SOUTH RIM	PARK GRCA	TOWNSHIP/RANGE/SECTION	COUNTY COCONINO	STATE AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG. UNKNOWN	ELEVATION	DEPTH

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD UNKNOWN	DIMENSIONS/WEIGHT L 8.5, W 5.2, T 3.3 CM

COLLECTOR CASTAGNE, MAURICE, MINE SUPT.	COLLECTION NO. Not Provided	COLLECTION DATE 3/18/1959	MAINTENANCE CYCLE	CONDITION COM/GD

IDENTIFIED BY AND DATE UNKNOWN	TYPE N	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER

CATALOGER AND DATE DAVIS, SARA 8/5/2009	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS

RESTRICTION	REPRODUCTION N	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION		CONTROLLED PROPERTY
GEOLOGY ROCKS MINERALS Oxides	N.B16.01		N
	OBJECT STATUS AND YEAR: STORAGE 2009	PARK ACRONYM: GRCA	CATALOG NUMBER: 20084
	ACQUISITION TYPE: FIELD COLLECTN	ACQUISITION DATE: FIELD COLLECTN	ACCESSION NUMBER: GRCA-00143
OBJECT/SPECIMEN NAME: URANINITE		LOT QUANTIFICATION — ITEM COUNT: 1	STORAGE UNIT: EA

DRAFT

DESCRIPTION ONE SPECIMEN OF URANINITE.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN URANIUM MINE, SOUTH RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 6.0, W 4.0, T 4.0 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
CASTAGNE, MAURICE, MINE SUPT.	Not Provided	10/1/1958		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/6/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION		CONTROLLED PROPERTY
GEOLOGY ROCKS MINERALS Oxides	N.B16.01		N
	OBJECT STATUS AND YEAR: STORAGE 2009	PARK ACRONYM: GRCA	CATALOG NUMBER: 20235
	ACQUISITION TYPE: GIFT	ACQUISITION DATE: GIFT	ACCESSION NUMBER: GRCA-00739

DRAFT

OBJECT/SPECIMEN NAME /SPECIMEN NAME	LOT QUANTIFICATION ITEM COUNT	STORAGE UNIT
URANINITE	1	EA

DESCRIPTION: ONE SPECIMEN OF URANINITE.
URANATE.
TESTED FOR RADIATION IN JUNE OF 2000. SEE ACCESSION FOLDER FOR SUMMARY OF SURVEY RESULTS.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN URANIUM MINE	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 17.0, W 14.5, T 6.0 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
WESTERN GOLD & URANIUM CO.	Not Provided	9/1/1958		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
DAVIS, SARA 8/5/2009		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY	LARGE OBJECT, RADIOACTIVE BUCKET ON SHELVES NEAR LOAD	N

CLASSIFICATION (cont.)	OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER
ROCKS / MINERALS	STORAGE 2017	GRCA	21377

DRAFT

CLASSIFICATION (cont.)	ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
Oxides	FIELD COLLECTN	FIELD COLLECTN	GRCA-01560

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
URANINITE	1	EA

DESCRIPTION: ONE SPECIMEN OF URANINITE.
HORIZO: UNKNOWN. FROM THE ORPHAN MINE.
TESTED FOR RADIOACTIVITY IN JUNE 2000. SEE THE ACCESSION FOLDER FOR A SUMMARY OF THE SURVEY RESULTS.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
ORPHAN MINE, SOUTH RIM	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 27.0, W 22.0, T 15.0 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
CASTIGNE, MAURICE	Not Provided	10/1/1963		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
CASTIGNE, MAURICE 1963	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
MARTIN, CYD 1/17/1977		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY	DEACCESSIONED- RETURNED TO ORPHAN MINE	N
GEOLOGY	OBJECT STATUS AND YEAR: DEACC - VOL. DESTRUCTION 2018	PARK ACRONYM: GRCA; CATALOG NUMBER: 17091 -
MINERALS	ACQUISITION TYPE: FIELD COLLECTN	ACQUISITION DATE: FIELD COLLECTN; ACCESSION NUMBER: GRCA-01089
Carbonates		

DRAFT

OBJECT/SPECIMEN NAME /SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
MALACHITE WITH AZURITE, CHALCOCITE, CHALCOPYRITE, BORNITE	1	EA

DESCRIPTION

MALACHITE WITH AZURITE, CHALCOCITE, CHALCOPYRITE, BORNITE.
ORIGINAL CATALOG CARD SHOWS IT WAS TAKEN OFF EXHBIT IN VC ON 1/16/1997. HOWEVER, AN INVENTORY IN 1999 SHOWED IT WAS STILL ON EXHIBIT. REMOVED FROM EXHIBIT 11/2000.
TESTED FOR RADIATION, 06/2000. SEE ACCESSION FILE FOR SUMMARY OF SURVEY RESULTS.

SEE CATALOGING NOTES FOR FURTHER INFORMATION CONCERNING THE DEACCESSIONING OF THIS SPECIMEN.

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
UNKNOWN				

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	UNKNOWN	L 19.0, W 9.0,, T 3.0 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
UNKNOWN	Not Provided	UNKNOWN	/	COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
SIELAFF, GERALD W.	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
SIELAFF, GERALD W. 2/1/1957		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84

MUSEUM CATALOG RECORD-NH

REGISTRATION DATA

CLASSIFICATION	OBJECT LOCATION	CONTROLLED PROPERTY
GEOLOGY GEOLOGY MINERALS Oxides	DEACCESSIONED- RETURNED TO ORPHAN MINE	N

OBJECT STATUS AND YEAR	PARK ACRONYM	CATALOG NUMBER
DEACC - VOL. DESTRUCTION 2018	GRCA	17363

DRAFT

ACQUISITION TYPE	ACQUISITION DATE	ACCESSION NUMBER
GIFT	GIFT	GRCA-01127

OBJECT/SPECIMEN NAME	LOT QUANTIFICATION: ITEM COUNT	STORAGE UNIT
CARNOTITE	1	EA

DESCRIPTION: ONE SPECIMEN. CARNOTITE (CONTAINING URANIUM AND VARADIUM IN LOG).
HORIZON: SHINARUMP CONGLOMERATE.
TESTED FOR RADIOACTIVITY IN JUNE 2000. SEE THE ACCESSION FOLDER FOR A SUMMARY OF THE SURVEY RESULTS.
CONTAINED IN SEALED BUCKET AT RECOMMENDATION OF EXPERT.
NOTE ON ORIGINAL CATALOG CARD READS ""COLLECTOR STATED FINDING SPECIMEN IN CONGLOMERATE ABOVE DE CHELLEY SANDSTONE. CATALOGER DETERMINED HORIZON IS PROBABLY SHINARUMP ON THE BASIS THAT IN THE AREA OF

CATALOG DATA

COLLECTION SITE	PARK	TOWNSHIP/RANGE/SECTION	COUNTY	STATE
WEST SIDE OF MONUMENT VALLEY	GRCA		COCONINO	AZ

WATERBODY/DRAINAGE	UTM Z/E/N	LAT. LONG.	ELEVATION	DEPTH
		UNKNOWN		

HABITAT/DEPOSITIONAL ENVIRONMENT	FORMATION PERIOD	DIMENSIONS/WEIGHT
	SHINARUMP FORMATION	L 17.5, DIA 8.5 CM

COLLECTOR	COLLECTION NO.	COLLECTION DATE	MAINTENANCE CYCLE	CONDITION
GOULDING, HARRY	Not Provided	12/1/1944		COM/GD

IDENTIFIED BY AND DATE	TYPE	VALUE AT ACQUISITION, BASIS	CURRENT VALUE, DATE, BASIS	PHOTO NUMBER
UNKNOWN	N			

CATALOGER AND DATE	EMINENT FIGURE ASSOCIATION	OTHER NUMBERS
ROTHFUSS, E.L. 2/1/1963		

RESTRICTION	REPRODUCTION	PUBLICATION CITATION	PRESERVATION TREATMENT	CATALOG FOLDER	SIGNIFICANCE
	N				

U.S. DEPARTMENT OF THE INTERIOR

MUSEUM CATALOG RECORD CULTURAL RESOURCES

NATIONAL PARK SERVICE
FORM 10-254B
REV 7/84