# APPENDIX E
# CONSTRUCTION QUALITY ASSURANCE PLAN

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DRAFT

# CONSTRUCTION QUALITY ASSURANCE PLAN

# EAST DRAINAGE REMOVAL ACTION CONSTRUCTION WORK PLAN NORTHEAST CHURCH ROCK MINE SITE

*July 2012*

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# 1.0 INTRODUCTION

This Construction Quality Assurance Plan (CQAP) has been prepared for construction activities related to the East Drainage Time Critical Removal Action (RA) for the Northeast Church Rock Mine Site, as per the Environmental Protection Agency's (EPA) Administrative Order on Consent (AOC), CERCLA Docket No. 2012-02, dated ______ (EPA, 2012). The East Drainage area is within the area referred to as Step-out Area No. 2 in the Scope of Work (SOW) included in the AOC, which is located on the east side of Red Water Pond Rd. northeast of the Northeast Church Rock Mine site, McKinley County, New Mexico. A detailed description of the RA work and construction activities is included in the *Interim Removal Action Construction Work Plan*.

This CQAP specifies procedures to ensure that the completed RA work meets all design criteria and specifications. It explains the Construction Quality Assurance (CQA) procedures and requirements to be used during reclamation activities at the site in order to assure that the project is constructed in conformance with the specifications of the *Interim Removal Action Construction Work Plan* and applicable regulatory requirements.

This CQAP defines:

1) the individuals and parties who will be involved in reclamation activities and their respective roles, responsibilities and qualifications;

2) guidelines for the flow of information and project communication;

3) procedures for inspection activities; and

4) protocols for project documentation.

The RA scope of work will include the following:

- Conduct any additional baseline gamma surveying necessary to assess current site conditions prior to soil removal and placement on the mine site.

- Excavate impacted soil from the East Drainage area based on historical SRSE results, EPA's 2012 survey of the home site located in the area and any additional gamma measurements; place on the NECR-1 pad; and cover with six inches of clean soil.

- Conduct confirmation scanning, sampling and analysis.

- Continue excavations until confirmation scanning confirms that the impacted soil has been removed.

- Conduct interim status surveys, sampling, and analysis to confirm that soils have been sufficiently excavated in accordance with MARSSIM.

- Excavate soils containing commingled Ra-226 and diesel fuel from the area north of the NECR-1 pad, place on the NECR mine with the commingled soils currently stockpiled on the Site, and cover with six inches of clean soil or the existing synthetic cover.

- Restore the site to pre-removal conditions including backfilling excavations greater than one-foot deep as necessary, re-grading, amending surface soils, and reseeding with native species in excavation areas.

- Implement structural (e.g., erosion control blankets) and non-structural (e.g., inspection and monitoring plan) Best Management Practices for erosion and storm water control until the area achieves final stabilization.

- Provide site security to restrict access 24 hours/day to the Eastern Drainage RA Area during field operations, drive by vacated homes twice per day, and notify US EPA, as needed, of any irregularities or suspicious activity.

This CQAP describes the methods and procedure that will be used to verify that the site has been cleaned up in a manner consistent with the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) guidance (EPA, 2000), including excavation control radiological surveying and Interim and Final Status Surveys. The Status Surveys will be performed to confirm that the RA met the MARSSIM release criterion.

As part of the quality management system, a comprehensive health and safety and radiation protection program (RPP) will be implemented throughout the project. A site-specific Health and Safety Plan (HASP) was prepared for construction oversight personnel not actively involved in construction activities for implementation of the RA, including monitoring, surveying and sampling activities. The HASP was prepared in accordance with applicable sections of Code of Federal Regulations Titles 10, 29 and 40, and the New Mexico Administrative Code Titles 19 and 20. The construction contractor will prepare their own construction HASP for their workers and subcontractors, including a RPP, in accordance with applicable regulations and guidance.

In order to protect sites workers, visitors and the public, dust control will be required throughout the duration of the RA. The construction Contractor will be required to implement a dust control plan during construction. Additionally, an air monitoring program will be implemented for construction activities in order to ensure a high level of protection of the public. In order to achieve this, air monitoring will be conducted for internal and external radiation along the perimeter of the RA boundary.

# 2.0 INVOLVED PARTIES AND PERSONNEL

Each phase of the construction will undergo CQA and compliance reporting. Upon completion of all project segments, a Final Construction Report will be prepared. Following is a listing of the parties (organizations and individuals) that will be involved in the implementation of the CQAP during the Removal Action, including a discussion of each party's roles and responsibilities on the project.

## 2.1 RESPONDENTS

The Respondents of this project are General Electric Company (GE) and United Nuclear Corporation (UNC). The Respondents will have overall responsibility of ensuring that the RA objectives are met, and overseeing the execution of the RA.

## 2.2 DESIGN ENGINEERS

**Responsibility & Authority:** The Design Engineers (MWH) will be responsible for the design of the various elements of the RA and for preparing the RA Construction Work Plan. Throughout the project, the Design Engineers will interact as necessary with the Respondents, CQA staff, and the EPA's On-scene Coordinator. The Design Engineers will approve all design changes that arise during the course of the Reclamation Project, in consultation with the Respondents.

**Qualifications:** The Design Engineers shall have expertise which demonstrates significant familiarity with the design and construction of the various elements of mine site reclamation including earthwork, cover design, radiation control, public safety, and disposal.

## 2.3 CONSTRUCTION MANAGER

**Responsibility & Authority:** The Construction Manager is responsible for the conduct, direction, and supervision of all reclamation activities as detailed in the *RA Construction Work Plan* (MWH, 2012). The Construction Manager will be selected/appointed by the Respondents. The Construction Manager will interact as required with all other parties involved in implementing the reclamation including the Contractor's personnel, the Respondents, and the EPA On-Scene Coordinator. In the temporary absence of the Construction Manager, a designated representative will assume the duties of the Construction Manager. The Construction Manager will report directly to the Respondents.

The Construction Manager will also provide day-to-day, on-site oversight of the CQA activities. The Construction Manager will maintain a thorough understanding of the RA Construction Work Plan and this CQAP. Specific CQA responsibilities of the Construction Manager will include the following:

1. Attend all CQA-related meetings including Project Kickoff and Pre-Construction Meetings
2. Provide direct oversight of CQC activities
3. Assign locations for sampling
4. Observe the collection of laboratory test samples
5. Review results of field and laboratory testing and any test results provided by the Contractor and make appropriate recommendations
6. Review the calibration and condition of on-site testing equipment, and Contractor's equipment documentation

7. Report any deviations from the CQAP and *RA Construction Work Plan* to the Design Engineer and Respondents and arrange consultation with other parties as necessary to find solutions to unsolved problems

8. Prepare a daily field report for submittal to the Design Engineer and Respondents.

**Qualifications:** The Construction Manager shall have the mine reclamation and construction experience necessary to manage a reclamation project of this scale and scope.

## 2.4 RADIATION SURVEY SPECIALIST

**Responsibility & Authority:** Radiation control and execution of MARSSIM Interim and Final Status surveys will be conducted by AVM Environmental Services, Inc. (AVM). AVM will be responsible for gamma surveying during excavation activities to direct the excavators as to when an area has been cleaned and they can move on to the next area. They will also be responsible for the quality assurance of all gamma survey instruments and procedures. The Contractor will work under the direction of and report directly to the Respondents and the Design Engineer

**Qualifications:** AVM personnel shall have extensive experience in radiation survey methods, procedures and instrumentation in support of uranium mine reclamation, remediation support, verification and soil excavation activities in accordance with MARSSIM.

## 2.5 VEGETATION SPECIALIST

**Responsibility & Authority:** Baseline vegetation sampling and development of a revegetation plan will be conducted by Cedar Creek Associates. They will be responsible for implementing the methods and protocols utilized for vegetation and wildlife evaluations required for the RA, including developing site-specific protocols for monitoring and eventual success evaluations in the RA area. The Contractor will work under the direction of and report directly to the Respondents and the Design Engineer

**Qualifications:** Cedar Creek Associates personnel shall have extensive experience in rangeland sees mixes and revegetation methods in arid environments associated with surface mine reclamation in New Mexico.

## 2.6 CONTRACT LABORATORY

**Responsibility & Authority**: Analysis of soil samples from the East Drainage area for Ra-226 using EPA Method 901.1 will be conducted by Energy Laboratories in Casper, Wyoming. The will be responsible for providing laboratory analytical reports with the analytical data required for Level III and IV data validation as per the EPA's Contract Laboratory Program.

**Qualifications**: Energy Laboratories shall have extensive experience in conducting gamma spectroscopic analysis on soils samples using Method 901.1, and have an established quality assurance program that is consistent with EPA's Contract Laboratory Program and guidance (e.g., CERCLA).

## 2.7 CONSTRUCTION CONTRACTOR

**Responsibility & Authority:** The Contractor refers to an independent party or parties, contracted by the Respondents, overseeing the work in accordance with this CQAP and the *RA Construction Work Plan*. The Contractor will work under the direction of and report directly to the Respondents and the Design Engineer.

**Qualifications:** Qualifications of the Contractor are specific to the construction contract. The Contractor shall have a demonstrated history of successful construction experience as appropriate for the project. The Contractor shall maintain current state and federal licenses and bonding as appropriate.

## 2.8 SURVEYOR

**Responsibility & Authority:** The Surveyor is responsible for surveying, documenting, and verifying the location of all significant components of the work. The Surveyor is responsible for issuing Record Drawings of the completed elements of the Construction Project. The Surveyor's work is coordinated with the Contractor and Construction Manager. The Surveyor will report directly to the Contractor.

**Qualifications:** The Surveyor will be an established surveying company with at least three years of surveying experience in the State of New Mexico. All survey activities shall be performed under the direction of a Professional Land Surveyor, licensed as required by State of New Mexico regulations. The Surveyor shall be fully equipped and experienced in the use of total stations and the most recent version of AutoCAD.

# 3.0 PROJECT COMMUNICATION

## 3.1 FLOW OF INFORMATION

Effective communication is necessary to assure quality during the RA. The Communication Plan described here envisions that the Contractor, Design Engineer (MWH), Respondents (UNC/GE), and US EPA Region 9 (EPA)will coordinate their communications to the greatest extent possible in order to help in the conveyance of consistent information between the parties and by EPA to the Navajo Nation EPA (NNEPA) and public. The organizational chart showing the proposed lines of communication between the various parties is shown in Figure 1, *Project Organization*. Table 1 provides site-specific information, agency information, and contact information for EPA, NNEPA, UNC and its Contractors.

Implementation of the RA will require regular communication between the Respondents and EPA to discuss the technical elements of the construction work and schedule, as well as regular communication between EPA, NNEPA and the public to address questions and keep them apprised of the status of the work.

In addition to the periodic meetings discussed below, the Respondents' project coordinator and Respondents' onsite representative, and the Construction Manager (MWH), will be available to discuss the work with EPA's onsite representative, either in person or by telephone, in the case of the Respondents' project coordinator. Discussions will be held on the first day of each week to discuss the work proposed for that week, as well as on a daily basis to discuss any questions concerning ongoing work. At EPA's request, Respondents' onsite representative will participate in discussions between EPA's onsite representative and NNEPA's onsite representative. Respondents' onsite representative and construction staff will direct all questions and requests from the public or media to EPA's onsite representative. EPA will be responsible for coordinating and communicating the work to NNEPA, the public, and media, as required.

Specific meetings of key project personnel will take place, including a Project Kickoff Meeting, Pre-Construction Meetings, weekly Progress Meetings, and Problem or Work Deficiency Meetings. In addition, informal communication and cooperation will take place between the various parties listed in Section 2.0 above. The planned project meetings are described in the following sections.

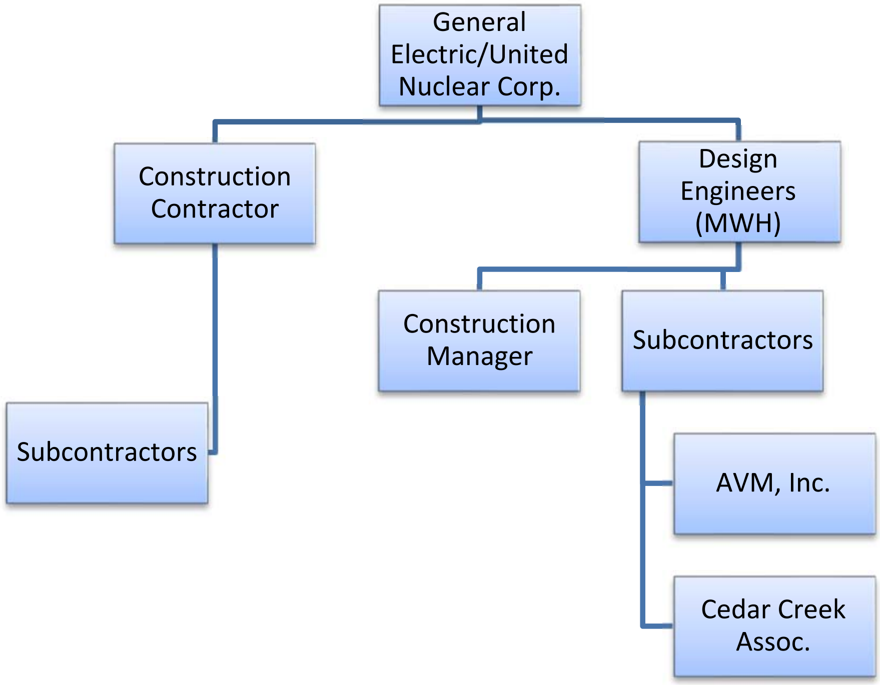


**Figure 1. Project Organization**

## 3.2 PRE-CONSTRUCTION KICKOFF MEETING

The Construction Manager will conduct a Pre-Construction kickoff meeting at the beginning of the project. This meeting will take place at the Site and will be attended by the Construction Manager, the Contractor, and the Respondents. The Construction Manager will conduct a tour of the work area to observe current conditions and to identify various areas of the Site including, equipment storage areas, soil stockpiling areas, staging areas, and other details related to the project. The Construction Manager will appoint an individual to record the discussions and decisions of the meeting and distribute meeting minutes to all attendees. Specific items for discussion at the Pre-Construction Meeting include the following:

1. The RA Construction Work Plan and CQAP and any modifications or clarifications to these documents
2. Safety procedures
3. Lines of communication and authority
4. The responsibilities of each party
5. The overall schedule
6. Acceptance and rejection criteria
7. Protocols for handling deficiencies, repairs, and re-testing
8. Documentation requirements

## 3.3 PROGRESS MEETINGS (WEEKLY TECHNICAL CALLS)

Progress meetings will be held weekly by teleconference, between the Contractor, the Construction Manager, and other concerned parties participating in project construction. This meeting will include discussions of the current project progress, planned activities for the next week, and revisions to the work plan or schedule. The Construction Manager will appoint an individual to document the meeting and send meeting minutes to all attendees for review and comment.

## 3.4 PROBLEM OR WORK DEFICIENCY MEETINGS

It is anticipated that most work deficiencies will be minor and can be resolved in the field by Construction Manager and the Contractor. The deficiency and resolution will be recorded in the daily field reports and weekly summary reports prepared by the Construction Manager.

A special meeting will be held when and if a problem or deficiency is present, or likely to occur, that cannot be easily resolved in the field. The meeting will be attended by the Contractor, the Construction Manager, and other parties as appropriate. If the problem requires a design modification, the Design Engineer should either be present at, consulted prior to, or notified immediately upon conclusion of this meeting. The Construction Manager will appoint an individual to record the meeting and send meeting minutes to all attendees for review and approval. The purpose of the work deficiency meeting is to define and resolve the problem or work deficiency as follows:

1. Define and discuss the problem or deficiency
2. Review alternative solutions
3. Select a suitable solution agreeable to all parties
4. Implement an action plan to resolve the problem or deficiency

## 3.5 DOCUMENTATION AND SUBMITTALS

### 3.5.1 Overview

The Construction Manager will be responsible for preparing documentation that demonstrates that the CQAP requirements have been addressed and satisfied. Documentation will include monitoring logs, testing data sheets, photo logs, equipment calibration forms, daily field reports, weekly summary reports, reports of design or specification changes, and a final CQA Report. All documentation will be maintained in the NECR Project files and will be available to the Respondents, Design Engineers, and the Construction Manager at all times. The Construction Manager will be responsible for preparing or approving all necessary forms that will be required throughout the Reclamation Project. These forms will be used to document CQA activities.

Documents will be submitted as prescribed in the AOC. Whenever possible, submittals will be made electronically with paper copies provided as required by the AOC. The submittal date will be the date of earliest receipt of either the electronic or paper document. All documents submitted under the AOC will be recorded on a submittal log. The submittal log will be maintained by MWH and a copy will be included in the monthly progress reports.

UNC will submit monthly progress reports to EPA and NNEPA no later than the last day of each month, summarizing the prior month's activities. The progress reports will contain the information required by the AOC and any additional information that UNC determines to be relevant and appropriate, including those items identified in this report.

As required by the AOC, a Final Construction Report will be prepared documenting activities performed under the AOC. This report will be submitted within 90 days of receipt of the final, validated laboratory data.

The distribution instructions for submittals are shown in Table 1. Deliverables will be sent to the email and/or physical addresses shown in the table. Changes to the distribution list must be communicated in writing to UNC. UNC will provide two hard copies of all Work Plan and AOC submittals to Sara Jacobs and Mark Ripperda, EPA Project Managers and On-Scene Coordinators and one hard copy to Michele Dineyahze of EPA, the NNEPA representative.

In addition, an electronic copy of monthly reports and AOC deliverables will be provided electronically to the following email addresses:

Mark Ripperda: Ripperda.Mark@epa.gov
Sara Jacobs: Jacobs.Sara@epa.gov
Michele Dineyazhe: dineyazhe.michele@epa.gov

If, however, sending the materials by email is impractical due to the size of the file, then the email shall provide notice that hard copies and electronic copies of the submission have been sent.

### 3.5.2 Contractor Evaluation

Prior to construction, the Construction Contractor will submit a summary of their proposed construction methods, equipment and protocols. The Construction Manager and Design Engineer will review the submittal and provide approval, in writing, of the Contractor's plans. The Contractor may be required to modify their proposed methods, equipment, or protocols prior to approval.

### 3.5.3 Daily Summary Reports

The Construction Manager shall prepare daily written reports that are to be included in the final CQA documentation. The daily reports shall include information about the work accomplished, and observations made, along with descriptions of the adequacy of the work completed. These reports provide a chronological framework for identifying and tracking what activities/tasks were completed and by whom. At a minimum, the daily summary reports shall include the following:

- Date, project name, location, construction observed, personnel involved in major activities, and other relevant identification information
- Description of weather conditions, including temperature, cloud cover, and precipitation
- Summaries of any meetings held and actions recommended or taken
- Specific work units and locations of construction under way during that particular day
- Equipment and personnel being utilized in each work task, including subcontractors
- Identification of areas or units of work being inspected
- Description of off-site materials received
- Calibrations or recalibrations of test equipment, including actions taken as a result of recalibration
- Decisions made regarding approval (or disapproval) of units of material or of work and/or corrective actions to be taken in instances of substandard or suspect quality
- Inspection data sheets and/or problem reporting and corrective measures used to substantiate any CQA decisions described in the previous item
- Signature of the Construction Manager
- Any other pertinent information

### 3.5.4 Daily Testing Reports

All results of field tests (e.g., gamma radiation surveys) and results of laboratory tests performed on- or off-site shall be recorded on a Field Form or data sheet. Recorded observations and test results can take the form of notes, charts, sketches, or photographs, or a combination of these. At a minimum, the testing data sheets shall include the following information:

- Description or title of the testing activity

- Location of the testing activity or location from which the sample was taken
- Type of testing activity and procedure used
- Recorded observations and/or test data
- Results of the testing activity
- In addition to the individual preparing the data sheet, identification of all personnel involved in the testing
- Signature of the testing personnel

### 3.5.5 Field Change Requests

Changes that do not alter the intent of the RA Construction Work Plan may be made during construction in order to fit field conditions. Field changes require the approval of the Construction Manager and the Respondents. Field changes are to be reported on the Field Change Request Form included in Attachment 1.

The EPA On-Scene Coordinator (OSC) may make modifications to any plan or schedule in writing or by oral direction, provided such modifications do not materially expand the scope of the Work Plan. Any oral modification will be memorialized in writing by EPA promptly and provided to Respondents and the Navajo Nation, but shall have as its effective date the date of the OSC's oral direction to the Construction Manager. Any other requirements of the AOC may be modified in writing by mutual agreement of the parties.

No informal advice, guidance, suggestion, or comment by the OSC or other EPA representatives regarding reports, plans, specifications, schedules, or any other writing submitted by Respondents shall relieve Respondents of their obligation to obtain any formal approval required by this Settlement Agreement, or to comply with all requirements of this Settlement Agreement, unless it is formally modified.

### 3.5.6 Design or Specification Changes

During construction, design or specification changes may be required. Design changes will require the written approval of the Design Engineer and will take the form of technical memorandum and/or an addendum to the RA Construction Work Pan. Design changes are to be reported on the Design Change Request Form included in Attachment 1. Design changes must be approved in writing by the EPA.

### 3.5.7 CQA Compliance Reports

At the completion of each construction phase, the Construction Manager will prepare a CQA Compliance Report. The Compliance Report will acknowledge that the work has been performed in conformance with the RA Construction Work Plan. The Compliance Report will include all supporting documentation including:

1. All daily field reports and weekly summary reports
2. Laboratory test reports
3. Field change reports
4. Construction problems and resolution data sheets
5. Documentation of design or specification changes

Compliance reports are to be completed on the Compliance Report Form included in Attachment 1.

### 3.5.8 Final Construction Report

At the conclusion of the project, the Design Engineer or a designated representative will prepare a Final Construction Report. This report will be submitted to the EPA no later than 90 days after receipt of final validated analytical results. This report will include, at a minimum:

1. A summary of the work defined in the work plan, and a description of the final design and construction demonstrating that the work was conducted in accordance with the EPA direction and approval;

2. A summary and description of any changes made to the work defined in the work plan, and an explanation of why the changes were necessary and/or beneficial;

3. A summary, descriptions and drawings showing the results of the MARSSIM Interim and Final Status Surveys;

4. Plans and drawings showing the final construction survey results documenting final site conditions; and

5. Recommendations for the overall project.

# 4.0 CONSTRUCTION MATERIALS AND METHODS

Selection of construction equipment and methods will be at the discretion of the construction contractor. This section is a general summary of the methods and procedures that will be used to monitor and document construction activities. Summaries of field observations and measurements will be recorded using the Daily Field Reports and Compliance Reports described in Section 3.0.

## 4.1 SLOPE/SITE GRADING

Final grading of the excavated surfaces will be monitored by the Construction Manager during construction. The surface condition of the excavated surfaces will be observed and documented prior to final grading to confirm that they are graded to establish positive drainage towards unnamed arroyo no. 2. The final surfaces shall be smoothed to avoid abrupt changes in grade or areas of runoff concentration.

Grading of the Soil Consolidation Pile on the existing NECR-1 pile will be monitored by the Construction Manager during construction. Grades will be checked periodically during construction using hand level and grade rod or similar methods. The final graded surface of the Soil Consolidation Pile and commingled stockpile area shall have side slopes and a top surface sloping in the directions and grades shown on the Drawings (plus or minus 0.1 percent). The side slopes and top surface shall be free from abrupt changes in grade or areas of runoff concentration. Visual observations will be made to confirm that graded surfaces are straight to concave in cross-section. Final confirmation of grades will be based on survey data.

## 4.2 COVER PLACEMENT

Cover thickness will be monitored during cover placement for material properties and thickness. Materials properties will primarily focus on documenting that borrow soil is not mixed with contaminated material. Cover thickness will be confirmed by hand excavation..

## 4.3 CHANNEL BACKFILL AND CONSTRUCTION

Backfill and channel construction in the East Drainage channel will be monitored by the Construction Manager. The Contractor will verify compaction characteristics of the subgrade, the placed and compacted sand filter material, and confirm that the riprap and sand meet the construction specifications. Visual methods will be used to confirm lift thickness, compaction means and methods, and placement of materials. Material for the East Drainage channel will consist of granular materials from approved off-site sources. Rock shall be a screened product, free from roots, branches, rubbish, and debris, and transported from an off-site source.

Consistent with the approach tested and approved by USEPA for the 2009 IRA (MWH, 2010), backfill placement and compaction will be conducted as follows:

- Compaction method specification for the John Deere 1050 bulldozer:
  - Lift thickness not greater than 18 inches
  - Four passes with the water truck, or as necessary for a moisture content approximately
  - between 8 and 14 percent
  - Four passes of the tracks (two forward and two backward) over all areas of the backfill

- Compaction method specification for the John Deere 850 bulldozer:
  - Lift thickness not greater than 12 inches
  - Four passes with the water truck, or as necessary for a moisture content approximately
  - between 8 and 14 percent

- Four passes of the tracks (two forward and two backward) over all areas of the backfill

If different equipment or equipment that is not equivalent to the above is used, a new method specification will be developed.

The channel shall be trapezoidal with a 5 foot wide bottom, 2H:1V side slopes and a channel grade of 3.2% (matching the current grade).

Erosion protection filter material shall be free from roots, branches, rubbish, and debris. The filter material will generally classify as sand containing gravel and fines. The filter layer will have a minimum thickness of 6 inches. The minimum thickness of the filter/bedding layer will be verified by spot checking of layer thickness by hand excavation in selected locations.

Riprap shall be spread in a manner to minimize segregation of the material. The Construction Manager will confirm proper gradation of riprap material at a minimum of three locations in the channel using photographic gradation techniques. Rock layer thickness will be controlled through the establishment of grade stakes placed at 200 foot intervals along the channel, at varying locations on the cross-section.

The Construction Manager will have the authority to reject filter sand or riprap that is brought to the site or has been placed. For rejected materials, the Contractor will identify the extent and will be required to excavate the material and place additional materials. If there are persistent inadequate placement methods, the Construction Manager will have the authority to stop the work until the underlying cause is determined and the Contractor can demonstrate that the materials can be placed according to the specifications.

## 4.4 CONSTRUCTION MATERIALS

The construction contractor will provide certifications of material properties for any materials they provide. This will include, but not be limited to, riprap properties, filter sand, seed certificates, and weed free mulch certificates.

Minimum riprap $D_{50}$ size for the restored East Drainage channel shall be 6 inches.

As discussed in the Removal Action Construction Work Plan, borrow areas will be sampled prior to construction to assess Ra-226 concentrations.

## 4.5 SEEDING AND PLANTING

Seeding and planting activities will be monitored for uniformity of coverage and application rate. Application rate will be calculated based on the total pounds of seed applied to a known area.

# 5.0 RADIOLOGICAL EXCAVATION CONTROL SURVEYING

## 5.1 SURVEY PROTOCOL

Excavation control surveys will be conducted to:

1) support impacted soil excavation and removal;
2) determine when an area or a survey unit is ready for Interim or Final Status Surveys; and
3) provide initial radiological data for planning the Status Surveys.

The objective of the excavation control surveying will be to screen soils at the excavated surface to evaluate whether the soils have been sufficiently excavated in accordance with MARSSIM. The excavation control survey is designed for expediency and cost effectiveness, as it needs to guide excavation activities in real-time. In order to provide real-time excavation guidance, the excavation control survey will consist of in-situ direct gamma radiation level measurements in the field, as described in Section 5.4 of MARSSIM for remedial action support surveys. The direct gamma radiation level survey for PB-214 and Bi-214 (decay products of Ra-226) is a surrogate for gamma measurement of Ra-226. The EPA Method 901.1 for laboratory analysis of Ra-226 in soil also employs the Pb-214 and Bi-214 surrogate gamma radiation measurement.

Prior to the start of excavation activities, the RA Action Level boundary will be field located and marked with pin flags using the results from the East Drainage Area SRSE and a differential global positioning system (DGPS). If needed, additional scan radiation surveys will be performed in the field to more accurately delineate the Action Level boundary prior to the start of excavation. The excavation areas may be divided into smaller subareas (such as 10-foot strips) to more efficiently control excavation, depending on the equipment used for excavation. The excavation fleet will remove the impacted soil in lifts based on the vertical extent of impacts in that area.

### 5.1.1 Site-Specific Correlation

The direct gamma radiation level (in detector count rate) estimated to be equivalent to an Ra-226 concentration of 2.24 pCi/g, 5,075 counts per minute (cpm) for the collimated detector, will be used and is based on the most recent updated site-specific correlation between gamma count rates and Ra-226 activity (Ra-226 pCi/g = 0.0013cpm - 4.3582) that was conducted for the East Drainage Supplemental RSE, as described in the *Supplemental Removal Site Evaluation Report, East Drainage Area* (MWH, 2011). The value of 5,075 cpm is consistent with the 5,214 cpm equivalent to 2.24 pCi/g Ra-226 that was determined for the Interim Status Survey of the 2009 IRA area (Step-out Area No. 1)(MWH, 2010).

The RA activities will result in changes to the concentration and distribution of Ra-226 in soil, which could change the site-specific correlation between direct gamma radiation levels and Ra-226 concentrations in soil. The correlation will be updated during construction and revised for the Interim Status Survey, as necessary, in accordance with the procedures outline in Standard Operating Procedure No. 1 (SOP-1), included in Attachment 2. Surface soil samples collected for the Interim Status Survey will be used to update the direct gamma radiation level to soil Ra-226 concentration correlation to be used for the Interim Status Survey. The soil samples will be analyzed for Ra-226 using EPA method 901.1 by an off-site vendor laboratory. A regression with an $R^2$ value of at least 0.8 will be used for converting the direct gamma radiation levels to Ra-226 soil concentrations.

### 5.1.2 Surveying Shallow Excavations

During shallow excavation, underlying soils will be scanned with a gamma radiation detector in accordance with SOP-2 (see Attachment 2) to locate areas of elevated activity. Scan radiation surveying, in combination with static radiation measurements, will be performed during construction to guide excavation in lifts until the impacted soil in each area exceeding the Action Level has been removed consistent with MARSSIM. Following an impacted soil excavation lift, a radiation scan walkthrough survey will be performed with the detector held at approximately 12 inches from the ground surface and traveling in a serpentine pattern along a transect or within the subdivided area at a rate of about two feet per second, covering 100% of the area. The excavation will be repeated in lifts as necessary until the scan radiation survey indicates that soils within the area has been sufficiently excavated consistent with MARSSIM. Following the final excavation lift and scan radiation survey, one-minute static gamma radiation level measurements will then be performed at several judgmental locations within the subdivided area to confirm that soils have been sufficiently excavated consistent with MARSSIM. Once this step is complete, excavation in that area will be considered complete and ready for the Interim Status Survey. The static radiation level measurements collected during the excavation control survey will be used as a part of the Interim Status Survey. A detailed description of the field gamma radiation survey for Ra-226 concentrations in soil is included in Appendix 2 (Attachment 2).

The instrument that will be used for direct gamma radiation level measurement during this survey will consist of a 2"x2" NaI scintillation detector (e.g., Eberline SPA-3) for detection of gamma radiation, connected to a Ratemeter/scaler (such as Ludlum 2221) for processing and counting the detected gamma radiation. The detector will be lead collimated for direct gamma radiation surveying in order to minimize radiation shine interference, and to focus on the localized area of interest under the detector. The gamma radiation survey instrumentation will be calibrated as per SOP-3. Daily function checks of the instruments will be performed in accordance with SOP-2 to assure proper operation. The direct radiation level will be measured by performing a scan gamma radiation survey and static gamma radiation measurements during the excavation control survey. The excavation control survey will be used as an interim step to guide soil removal. Areas that are determined to be clean on the basis of the excavation control survey will be surveyed during the Interim Status Survey.

The Minimum Detection Concentration (MDC) for both the static and scan gamma radiation survey will be calculated as discussed in SOP-3. Based on data collected during the SRSE surveys, the instrument MDC is expected to be below or near 50% of the $DCGL_W$ (1.24 pCi/g) and $DCGL_{EMC}$ (2.0 pCi/g) for the survey. MDCs of about 0.6 pCi/g for a one-minute static survey and about 1.1 pCi/g for a scan survey were calculated for a rate of about 2 feet per second for this instrument configuration.

### 5.1.3 Surveying Deeper Excavations

In-situ gamma radiation surveying will not be used for excavation control in the East Drainage Channel or narrow excavations greater than one foot deep due to radiation shine interferences from the channel banks or excavation sidewalls. Ex-situ field soil screening will be performed instead for excavation control in the East Drainage channel and deeper excavations. Once the excavation of impacted channel bed sediments is completed to depths based on the results of the East Drainage SRSE (MWH, 2011) and field observations, a soil sample will be collected from the base of the excavation and placed in a heavily shielded counting chamber (plastic bag lined 1.5 inch thick lead ring collimator with a 1.5 inch thick lead bottom shield) to avoid radiation shine. The ex-situ soil sample will then be screened with a 3x3 NaI detector/Ludlum 2221 single channel analyzer which is placed inside the ex-situ sample, as described in detail in SOP-4 included in Attachment 2. Excavation of the channel bed will continue until the ex-situ field soil screening indicates that the soils have been sufficiently excavated in accordance with MARSSIM.

## 5.2 DOCUMENTATION OF THE EXCAVATION CONTROL SURVEY RESULTS (MARSSIM)

Since the Ra-226 soil RA Action Level is evaluated based on the instrumentation count rate of the direct gamma radiation level (cpm) using the site-specific correlation, conversion of the scan radiation survey counts during the excavation control survey data to Ra-226 concentration in pCi/g is not necessary. The excavation and removal field decisions will be made based on the count rates observed by the instrument. The excavations will be assessed using a gamma radiation level of 5,075 cpm for the collimated detector. Following the final scan radiation survey showing that soils have been sufficiently excavated consistent with MARSSIM, the instrument count will be recorded on the Scan/Walkthrough Gamma Radiation Survey Field Form (see SOP-2).

# 6.0 INTERIM AND FINAL STATUS SURVEYS

## 6.1 STATUS SURVEY AREAS

Subsequent to completion of excavation activities, compliance with the RA objectives will be demonstrated by conducting Interim and Final Status Surveys in the East Drainage Area in accordance with MARSSIM (EPA, 2000). An Interim Status Survey will be conducted in the East Drainage flats area (e.g., all areas except the East Drainage channel). Because the areas are being addressed due to Ra-226 impacts above the RA Action Level, they are considered Class 1 Areas and will therefore require a Class 1 Final Status Survey subsequent to the final Removal Action. The Interim Status Survey is meant only to confirm that excavation activities have met the objectives of the RA. However, the data collected during the Interim Status Survey may be included in the Final Status Survey at a later date.

Within the East Drainage channel excavation, because the area will be backfilled and restored, a Final Status Survey will be conducted. The Final Status Survey will consist of the results of the ex-situ soil screening and soil samples submitted for laboratory analysis of Ra-226, as described in Section 6.3 below.

## 6.2 INTERIM STATUS SURVEY OF EAST DRAINAGE FLATS AREA

### 6.2.1 Survey Objectives and Design

The objective of the Interim Status Survey will be to demonstrate that soils containing Ra-226 have been sufficiently excavated in accordance with MARSSIM. A radiation survey was designed in Section 3.7 of the RSE Work Plan consistent with MARSSIM to support Data Quality Objectives (DQOs) for Class 1 areas. The number of data points was determined using the Wilcoxon Rank Sum (WRS) test per MARSSIM guidance with statistical parameters selected to achieve a low error rate. Since the areas undergoing the RA are Class 1 Areas, the Interim Status Survey will be conducted consistent with the RSE Work Plan for Class 1 Areas (MWH, 2006) and consistent with the 2009 IRA (MWH, 2010). Therefore, the Interim Status Survey will consist of Ra-226 soil concentration measurement by static direct gamma radiation measurements collected on an 80-foot triangular grid in each area. Soil samples will be collected for laboratory analysis for Ra-226 at a minimum of 5% of the Interim Status Survey static gamma survey locations or a minimum of 20 soil samples for laboratory analysis. The laboratory will conduct the sample analysis using gamma spectroscopy method 901.1 and will report results to a limit of 1 pCi/g.

The scan surveying conducted during excavation, which will have been conducted at 100% coverage, will be used to augment the Interim Status Survey. Any areas that were not scanned at 100% during excavation control surveying will be 100% scanned during the Interim Status Survey.

### 6.2.2 Interim Status Survey Instrumentation

The instrumentation to be used for the Interim Status Survey will the same as that used for the excavation control survey (see Section 5.0). The equipment will consist of a 2”x2” NaI scintillation detector (such as Eberline SPA-3) for detection of gamma radiation, connected to a portable ratemeter/scaler (such as Ludlum 2221). The gamma radiation levels in count rates will be converted to equivalent Ra-226 concentrations using the site-specific correlation.

### 6.2.3 Gamma Radiation Survey Protocol

The static direct gamma radiation level survey will be performed at 80-foot triangular grid nodes in each area. A triangular grid is generally more efficient for locating small areas of elevated activity compared to a square grid. The grid nodes will be determined using Visual Sampling Plan (VSP) on an 80-foot triangular grid cast on a random origin during the RA. The grid nodes will be field located using a DGPS using the grid node location coordinates generated from VSP. A daily function check of the instruments will be performed. The MDC for the static radiation survey will be calculated using the daily background count rate. A one-minute static direct gamma radiation level measurement with the collimated detector at approximately 12 inches above the ground surface will be performed at each 80-foot grid node in accordance with SOP-3. The direct gamma radiation level measurement with the location coordinates will be recorded in the Static Radiation Survey Field Form (see SOP-3).

The static gamma radiation survey results with the location coordinates will be documented in the field forms, Attachment C to SOP-3. The detector count rates obtained from the static gamma radiation survey will be converted to soil Ra-226 concentrations using the updated site-specific correlation.

### 6.2.4 Evaluation of Interim Status Survey Results

Statistical testing of Interim Status Survey results will be performed using the method specified in MARSSIM to demonstrate that the MARSSIM release criterion has been met. The statistical tests will evaluate whether or not the residual Ra-226 activity in an area exceeds the Ra-226 $DCGL_W$ (1.14 pCi/g) for an approximately uniform distribution across the survey area. In some cases, interpreting a survey's results may be straightforward when all measurement data are entirely higher or lower than the $DCGL_W$. However, in cases where measurements are neither clearly above nor entirely below the $DCGL_W$, the use of standard statistical significance tests are used, as described in Section 8.0 of MARSSIM. The comparison of measurements from the reference area and the RA survey unit is made using the Wilcoxon Rank Sum (WRS) test (also called the Mann-Whitney test). In addition, evaluation of elevated measurements is performed to evaluate if the MARSSIM release criterion has been met. The WRS test is most effective when residual Ra-226 activity is uniformly present throughout a survey unit. The test is designed to detect whether or not residual Ra-226 activity exceeds the $DCGL_W$. The hypothesis tested by the WRS test is:

> *Null Hypothesis $H_0$: The median concentration in the survey unit exceeds that in the reference area by more than the $DCGL_W$*
>
> versus
>
> *Alternative Hypothesis $H_a$: The median concentration in the survey unit exceeds that in the reference area by less than the $DCGL_W$*

The null hypothesis is assumed to be true unless the statistical test indicates that it should be rejected in favor of the alternative hypothesis. One assumes that any difference between the reference area and survey unit concentration distributions is due to a shift in the survey unit Ra-226 activities to higher values (i.e., in addition to background). Note that some or all of the survey unit measurements may be larger than some reference area measurements.

As specified in MARSSIM, in addition to the statistical test evaluation, an Elevated Measurement Comparison (EMC) will be performed against each measurement to determine if it exceeds the investigation level, $DCGL_{EMC}$ for a Class I area. If a measurement exceeds the $DCGL_{EMC}$, it will be investigated and addressed, as necessary. The $DCGL_{EMC}$ value for the Site was set at 2.0 pCi/g by EPA, as presented in the *Removal Site Evaluation Work Plan* (MWH, 2006). Consistent with MARSSIM, the purpose of the 100% scans conducted for the excavation control survey and post-excavation surface scan (see Section 5.0) is to locate areas of elevated activity. Any discrete measurement that is above the $DCGL_{EMC}$ or exceeds three standard deviations above the mean of the survey unit will be investigated further to determine if the impacts will affect achieving the MARSSIM release criterion. Further investigation may involve assessing the adequacy of the exposure pathway model used to obtain the DCGLs and area factors.

## 6.2 FINAL STATUS SURVEY OF EAST DRAINAGE CHANNEL

Within the East Drainage channel excavation, because the area will be backfilled and restored, a Final Status Survey will be conducted. The Final Status Survey will consist of the results of the ex-situ soil screening conducted during construction (see Section 5.1.2) and soil samples submitted for laboratory analysis of Ra-226. Once ex-situ field screening results indicate that impacted soils have been sufficiently excavated in accordance with MARSSIM, soil samples will be collected every 50 feet along the length of the excavation, including samples from the bottom of the excavation, as well as one sidewall sample every 50 feet alternating between the north and south sides. The soil samples will be submitted to the laboratory and analyzed for Ra-226 using EPA Method 901.1. The Final Status Survey will be conducted in segments of the excavation as it progresses along the length of the channel to facilitate backfilling of the excavation in a timely manner and to reduce safety risks.

The methods and procedures for conducting the ex-situ field screening are described in Section 5.1.2, and will consist of collection a soil samples from the excavation and placing it in a heavily shield counting chamber to avoid radiation shine. The apparatus consists of plastic bag lined 1.5-inch thick (sides and bottom) lead ring collimator. The field soil screening of the sample soils will be conducted using a 3x3 NaI detector/Ludlum 2221 single channel analyzer (field soil screening procedure SOP-4 included in Attachment A) that is placed inside the lead collimator with the soil sample surrounding the collimator. Excavation of the channel bed will continue until the field soil screening indicates that impacted soils have been sufficiently removed consistent with MARSSIM. The results of these soil sample analyses will be used to demonstrate that the channel has been cleaned and meets the MARSSIM release criterion.

# 7.0 REFERENCES

MWH, 2011. *Supplemental Removal Site Evaluation Report, East Drainage Area*, Final, Northeast Church Rock Mine Site.

MWH, 2010. *Interim Removal Action Completion Report*, Northeast Church Rock Mine Site.

MWH, 2006a. *Removal Site Evaluation Work Plan*, Northeast Church Rock Mine Site.

MWH, 2006b. *Results of Background and Radium-226 Correlation Sampling*, Northeast Churc Rock Mine Site, Technical Memorandum.

United States Environmental Protection Agency (EPA). 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, EPA 402-R-97-016.

# TABLES

# TABLE 1
# PROJECT CONTACTS

**Site Location**

Northeast Church Rock Mine Site
McKinley County, New Mexico
State Highway 566
16 miles NE of Gallup, New Mexico
End of State Highway 566 and Red Water Pond Road

**USEPA**

Voice: Office of Community Involvement: 1(800) 231-3075 9am-5pm
Fax: Office of Community Involvement: 415-947-3528 or

Mail: US EPA, Superfund Division (SFD-3)
Attn: Grace Ma
75 Hawthorne St.
San Francisco, CA 94105

**Navajo Nation EPA**

Voice: Public Information Office: (928) 871-7692
Fax: (928) 871-7996 or (928) 871-7333
Mail: Navajo Nation Environmental Protection Agency (NNEPA)
Attn: Stephen B. Etsitty
Old DNR Building - Window Rock Blvd. - (Building # W008-090)
P.O. Box 339
Window Rock, Arizona 86515

**Location of Administrative Record: US EPA Region 9**

Superfund Records Center
95 Hawthorne St.
San Francisco, CA 94105
(415) 820-4700

**Location of Information Repository/Address:**

Octavia Fellin Public Library Navajo Nation Library
115 West Hill Avenue/ PO BOX 9040
Gallup, NM 87301/ Window Rock, AZ 86515
(505) 863-1291/ (520) 871-6376

## TABLE 1
## PROJECT CONTACTS

| Position | Name | Phone Number(s) and Email Address | Mailing Address |
|---|---|---|---|
| **EPA Region 9 Contacts** | | | |
| EPA On-Scene Coordinators (OSCs) | Mark Ripperda | (415) 972-3028 (work)<br>(415) 947-3528 (fax)<br><br>Ripperda.Mark@epamail.epa.gov | U.S. EPA, Mail Code SFD-8-2<br>75 Hawthorne St.<br>San Francisco, CA 94105 |
| | Sara Jacobs | (415-972-3564 (work)<br>(415) 947-3528 (fax)<br><br>Jacobs.Sara@epamail.epa.gov | U.S. EPA, Mail Code SFD-9-2<br>75 Hawthorne St.<br>San Francisco, CA 94105 |
| EPA Community Involvement Coordinator | Grace Ma | (415) 947-4212 (work)<br>(800) 231-3075 (work)<br><br>ma.grace@epa.gov | |
| **Navajo Nation Contacts** | | | |
| Navajo Nation EPA | Michele Dineyazhe | (928) 871-7820 (work)<br><br>dineyazhe.michele@epa.gov | Same as Above |
| Department of Justice | David Taylor | 928-871-6932 (work)<br>928-871-6200 (fax)<br><br>davidataylor@navajo.org | Navajo Nation Department of Justice<br>P.O. Drawer 2010<br>Window Rock, AZ 86515 |
| Public Information Officer | TBD | | |
| **Red Water Pond Road Community Association** | | | |
| RWPR Assoc. Representative | TBD | | |
| **United Nuclear Corporation** | | | |
| UNC Project Manager | Lance Hauer | (610) 992-7972 (work)<br>(610) 992-7898 (fax)<br>(484) 213-0300 (cell)<br>Email: lance.hauer@ge.com | Corporate Environmental Programs<br>General Electric Company<br>640 Freedom Business Center<br>King of Prussia, PA 19406 |

## TABLE 1
## PROJECT CONTACTS

| Position | Name | Phone Number(s) and Email Address | Mailing Address |
|---|---|---|---|
| UNC Local Representative | Larry Bush | (505) 722-6651 (work)<br>505- 870-0338 (cell)<br>larry.bush@ae.ge.com | P.O. Box 3077<br>Gallup, NM 87305 |
| **Construction Oversight Manager – MWH** | | | |
| Project Manager & OSO | Toby Leeson | (970) 871-4361 (work)<br>(970) 367-6022 (cell)<br>Toby.Leeson@mwhglobal.com | 1475 Pine Grove Road, Suite 109<br>Steamboat Springs, Colorado 80477 |
| Construction Manager & OSO | TBD | | |
| Project Health and Safety Manager | TBD | | |
| Corporate H&S Reporting for accidents/injuries/illness | Tami Renkoski | (866) 469-4456 (work)<br>(720) 530-7274 (cell) | |
| **Construction Contractor - Company Name TBD** | | | |
| Project Director | | | |
| Construction Manager | | | |
| Site Safety Officer | | | |

# ATTACHMENTS

# ATTACHMENT 1
# CONSTRUCTION FIELD REPORT FORMS

# FIELD CHANGE REQUEST FORM
## Northeast Church Rock Mine Interim Removal Action

| | |
|---|---|
| **Task Name:**<br>**Requested By:** | **FCR No:**<br>**Date:** |
| **Task or activity description:** | |
| **Affected Plan or Procedures:** | |
| **Requested Variation:** | |
| **Justification:** | |
| **Comments:** | |
| **Approved by:** ______________________ **Date:** __________<br>MWH Construction Manager | |
| **Authorized by:** ______________________ **Date:** __________<br>UNC Project Coordinator | |

# DESIGN CHANGE REQUEST FORM

## Northeast Church Rock Mine Interim Removal Action

| | |
|---|---|
| **Task Name:**<br>**Requested By:** | **DCR No:**<br>**Date:** |

**Design Feature**:

**Change in Design:**

**Justification:**

**Comments:**

**Approved by:** ____________________ **Date:** _____
MWH Design Engineer

**Authorized by:** ____________________ **Date:** _____
MWH Construction Manager

**Approval/Concurrence:** ____________________ **Date:** _____
EPA On-Scene Coordinator

# COMPLIANCE REPORT FORM
## Northeast Church Rock Mine Interim Removal Action

| | |
|---|---|
| **Task Name:**<br>**Requested By:** | **CR No:**<br>**Date:** |

**Construction Phase**:

**Description of Completed Construction Phase**

**Comments:**

**By:** ______________________________ **Date:** __________
MWH **Construction Manager**

**Authorized by:** ______________________________ **Date:** __________
**UNC Project Coordinator**

**Approval/Concurrence:** ______________________________ **Date:** __________
**EPA On-Scene Coordinator**

# ATTACMENT 2
# STANDARD OPERATING PROCEDURES

**SOP -1**
**AVM Environnemental Services, Inc.**
**Direct Gamma Radiation Level to Ra-226 Soil Concentration Correlation**
**For UNC's NECR Mine Site**

## 1.0 Purpose

The purpose of this procedure is to update the Ra-226 concentrations in surface soil to direct gamma radiation level correlation for NECR East Drainage IRA (Step Out Area 2). A correlation was developed and used for the Step Out Area 2 SRSE in April 2011, which was reported in the September 2011 Supplemental Removal Site Evaluation Report, East Drainage Area. This correlation, for site-specific calibration of field instrumentation (2'x2' NaI scintillation detector), for determining Ra-226 concentration in surface soil by performing direct gamma radiation level survey, will be updated for Step Out Area 2 post status IRA survey to determine Ra-226 concentrations in surface soils by direct gamma radiation survey.

## 2.0 Scope

Ra-226 is primarily an alpha emitting radionuclide with a gamma radiation emission of 186 KeV at about 4% intensity. This low energy and intensity of the Ra-226 gamma radiation emission makes impractical to determine Ra-226 in the field by direct gamma radiation measurement. However Bi-214, a Ra-226 decay product, emits high energy gamma radiations (46.3 % intensity @ 609.3 keV, 15.1% intensity @ 1120.3 keV and 15.8% intensity @ 1764.3 keV) at a total of approximately 80% intensity. The gamma radiations of Bi-214 can be easily and accurately measured in the field utilizing a NaI scintillation detector, such as 2x2 NaI Scintillation detector having high gamma radiation sensitivity The Ra-226 levels in soil could be measured as a surrogate for gamma measurement of Bi-214 gamma radiation levels, as to the measurement described in Section 4.3.2 of the MARSSTM. Bi-214 is a decay product of Ra-226 through radon-222, a gaseous form, some of which emanates from soil. This phenomenon results in activity disequilibrium between Ra-226 and Bi-214 in the soil. The Rn-222 gas emanation fraction from the soil varies with different geometric characteristics of a particular soil. Therefore, a site-specific calibration is necessary. Previous studies have shown that about 30 to 40% of the Rn-222 gas decayed from Ra-226 in soil emanates out of the surface soil, indicating that significant (about 65%) of this would decay into Bi-214 in the soil matrix.

If the soil geometry and other parameters such as moisture, radon emanation fraction, contamination distribution profile, gamma ray shine from nearby sources, and land topography are consistent, the ratio of Bi-214 to Ra-226 would be consistent. This means there would be a direct correlation between Bi-214 gamma radiation levels and Ra-226 concentrations in the soil. The gamma radiation from other naturally occurring isotopes in soil, such as Th-232 decay products and $K^{40}$, may contribute to gross gamma radiation intensity. In addition, background gamma radiation from cosmic rays also contributes to gross gamma radiation intensity. However, the gamma radiation level from such naturally occurring isotopes and sources are generally at a constant level. A linear regression would identify such a constant to correct for and minimize interference with the gamma radiation level and Ra-226 soil concentration correlation.

The correlation procedure is designed to calibrate a 2"x 2" NaI scintillation detector by determining a site-specific correlation between gamma radiation level and Ra-226 concentration in soil. The gross gamma radiation intensity (count rate) will be measured at ten locations. Soil samples will be collected from these locations for Ra-226 analysis by an off-site laboratory. The locations of the soil samples and gamma radiation level measurement for correlation may be based on the predominant concentration expected in field or concentration of interest. Direct gamma radiation level or gamma radiation exposure rate measurements may be made to select sampling locations. A linear regression will be performed between gamma radiation count rate and corresponding Ra-226 concentrations in soil to determine the Correlation. The goal is to attain a correlation coefficient ($r^2$) of 0.8 or better.

Ra-226 contamination in soil at the NECR East Drainage area varies from background level to near 100 pCi/gm distributed in surface (0-6”) to subsurface soils. The removal action of the contaminated soil at the NECR is expected to change the contamination distribution and concentration to a fairly homogeneous distribution at or near the cleanup level in surface soils. Therefore, the contamination distribution assumption for correlation for remedial action support survey and final status survey will be for homogeneous distribution in surface soils near the cleanup level concentration.

## 3.0 Instrumentation

A 2”x2” NaI Scintillation detector (an Eberline SPA-3 or Ludlum 44-10 detector) and a Scaler/Ratemeter, (Eberline ESP-l/2 or Ludlum Model 2221) will be used for field gamma radiation level measurements and to select sampling locations. The Scaler/Ratemeter will be calibrated, using SOP-1 to assure that it properly counts the electronic pulse generated and sent by the detector. An optimum operating high voltage for the detector will be established by performing a high voltage plateau on the detector using SOP -1a. The input sensitivity (threshold) of the Scaler/Ratemeter will be set @ 100 mV to avoid interference from low level background radiation. The pulses generated by the detector for gamma radiation (609 KeV) from Bi-214 are significantly higher than 100 mV, as verified by using 1% uranium ore standard.

During the excavation control survey (remedial action support survey), it is likely that the Ra-226 concentration in soil near the excavated areas is elevated. Gamma radiation shine from such areas may interfere with gamma radiation level measurement at excavated areas, as the high energy gamma radiation can travel long distance in air, up to 50 feet, before ionizing. If needed, shine interference will be reduced by placing the detector in a 0.5-inch thick collimated lead shield. In addition to obtaining a correlation for a bare (uncollimated) detector, a correlation will also be developed for a lead collimated detector by obtaining gamma radiation level measurements for both collimated and uncollimated detector at each location.

## 4.0 Gamma Radiation Level Measurements and Soil Sample Collection for Updating Correlation

Gamma radiation level measurements and corresponding surface soil Ra-226 concentrations data base for the updated SRSE correlation were provided in the September 2011 *Supplemental Removal Site Evaluation Report, East Drainage Area*. Selective surface soil samples collected during excavation control and all of the IRA status survey, and corresponding one-minute static gamma radiation level measurements with 0.5 inch lead collimated detector will be used for updating the SRSE correlation. Soil samples will be collected using surface soil sampling SOP-15. Soils samples will be shipped to an off-site vendor laboratory for Ra-226 analysis using EPA gamma spectroscopy method 901.0.

## 5.0 Linear Regression Analysis

To determine the correlation between gamma radiation level counts and corresponding Ra-226 concentration in soil content, i.e. to determine a calibration equation, a liner regression analysis will be performed on the sample Ra-226 concentration in pCi/gm, Y, and the associated gamma radiation level count rate, cpm at X, from all the sample locations using a least-square liner regression and plotting the results.

Linear regression data will be summarized by the generalized equation:

$$Y = mX + b$$

where,

Y = soil concentration in pCi/gm,
m = slope, pCi/gm/cpm
X = count rate (the mean) in cpm
b = constant, y intercept

This correlation will provide a site specific calibration factor (m) in pCi/gm/cpm for the 2”x2” NaI detector, with a constant (b) to correct for any interference, specifically at lower range.

**SOP-2**
**AVM Environnemental Services, Inc.**
**Field Gamma Radiation Survey for Ra-226 Concentration in Soil**
**@ UNC's NECR Mine Site**

## 1.0 SCOPE

1.1 Purpose

This procedure will be used to determine Ra-226 concentration in surface soil by direct gamma radiation level survey for conducting Characterization, Excavation Control (Remedial Action Support) survey and status survey at uranium mill and mine sites.

1.2 Applicability

This SOP will be used by AVM Environmental Services, Inc. for performing Excavation Control survey for and as a component of the Post-IRA survey at the Northeast Church Rock Site.

## 2.0 EQUIPMENT AND MATERIALS

2.1 Ludlum 2221 or Eberline ESP Scaler/Ratemeter coupled with a Ludlum 44-10 or an Eberline SPA-3 2"x2" NaI crystal scintillation detector for direct gamma radiation detection. (SPA-3 and Ludlum 44-10 are both similar 2"x2" NaI crystal scintillation detectors).

2.2 A global positioning system (GPS) with real time differential correction capability and a data logger. Currently AVM uses a Magellan MobileMapper CX (MMCX) with TDS SOLO surveying software. The MMCX is a data logger and a DGPS system which is capable of real time differential position correction using WAAS signal.

2.3 Collimating lead shield for the 2"x2" NaI detectors, if needed to reduce gamma-ray shine interference and focus on area of interest under detector. The 0.5-inch thick collimating lead shield, which surrounds the NaI crystal, is contained within a protective marlex housing.

2.4 A vendor calibrated exposure (uR/hr) meter.

2.5 Map of survey areas with marked grid nodes and transects. Ink pen and appropriate Field Survey Forms to record survey readings and notes.

2.6 Measuring tape, pin flags and area markers.

## 3.0 INSTRUMENT CONFIGURATION & OPERATIONS

Prior to any instrument function check or the operation, the technician will read the Technical Manual for the instrument operations (Ludlum 2221 or ESP-2) and the correlation Method (SOP- 2a) for the rationale behind the gamma radiation surveys.

The field gamma radiation level survey for Ra-226 content in soil will be performed using an Eberline ESP or Ludlum 2221 Ratemeter/Scaler. The Ratemeter/Scaler is connected to a 2"x2" NaI crystal scintillation detector (SPA-3 or Ludlum 44-10) which detects gamma radiation emitted from Bi-214, a decay product of Ra-226 in the soil. The detector will be held at approximately 12 inches from the ground surface. For a survey of high energy gamma radiation of 609 to 1700 KeV, the bare (un-collimated) detector should be sensitive to at least an area of about ten feet radius under the detector. The Model 2221 Scaler/Ratemeter with external RS232 connector can be coupled to a data logger, also connected to a GPS receiver where the gamma radiation count rate in cpm would be logged with its corresponding location coordinates.

For radiation surveys where significant shine interference is present from nearby areas, the 2”x2” NaI crystal scintillation detector will be installed in a 0.5 inch collimating lead shield to reduce gamma shine interference. For a direct gamma radiation survey in the arroyos and channel, the detector will be collimated to avoid radiation shine interference from the arroyo banks. The detector shield is contained within a protective marlex housing. During the survey, the detector will be held approximately 12 inches above ground level, which should focus and be most sensitive to approximately 36 inch diameter area under the detector.

The instrumentation must be calibrated consistent with SOP-1a prior to use.

### 3.1 Instrument Function Check

An operational function check will be performed on the Scaler/Ratemeter (ESP or Ludlum 2221) and the detector (SPA-3 or Ludlum 44-10) each day prior to any field surveys. Verify calibration validity for the Scaler/Ratemeter and the detector. Calibration date for the instruments must be within one year. If not, the instrument must be calibrated with a certificate in file. The function check will be performed in field office. The following function check procedures will be used and the pertinent information recorded on the Scaler/Ratemeter-Detector Function Check Form (Attachment A).

3.1.1 Scaler/Ratemeter General Setting

If an Eberline ESP Scaler/Ratemeter is used for the instrument configuration, the calibration constant must be set @ 1.0+00; and dead time must be set @ 1.4-05 sec.

If Ludlum 2221 Scaler/Ratemeter is used for instrument configuration, the WIN toggle switch must be in the OUT position.

3.1.2 Visual inspection

Perform a visual inspection of the instrument, cables, detector and the shield, checking for signs of damage. Test for possible electrical shorts in the cable (with the instrument in the audio mode, move the cable and note for any sudden increase in counts on the Scaler/Ratemeter).

3.1.3 Calibration Due

Verify calibration validity for the Scaler/Ratemeter and the detector. Calibration date for the instruments must be within one year.

3.1.4 Battery charge

Assure that the Scaler/Ratemeter battery is functional. For ESP Scaler/Ratemeter it should not be indicating a “Low BAT” signal. For Ludlum 2221, the battery voltage digital readout must be at least 5.3 volts.

3.1.5 High Voltage

The detector high voltage must match that determined during high voltage calibration (HV Plateau) for that detector.

3.1.6 Threshold (input sensitivity)

Check and make sure that the Scaler/Ratemeter threshold is set at 100 mV. If not, set the threshold at 100 mV. Ludlum 2221 Threshold can be set by the instrument digital read out display.

3.1.7 Window

If Ludlum 2221 Scaler/Ratemeter is used for instrument configuration, the WIN toggle switch must be in OUT position.

3.1.8 C.C. Calibration Constant

If an Eberline ESP Scaler/Ratemeter is used for the instrument configuration, the calibration constant must be set @ 1.0+00; and dead time must be set @ 1.4-05 sec.

3.1.9 Background Counts

The background counts will be determined for the same time interval as the field survey count time, generally one minute. The background counts will be performed at the designated location in the field office. A location will be designated in the field office for obtaining the required daily background counts. Keep all beta/gamma radiation sources away from the detector while performing the background check. The background function check counts must be within 20% of the background counts obtained during the detector high voltage calibration.

3.1.10 Source Function Counts

Obtain the gamma radiation source, (1% $U_3O_8$ ore standard sealed in a red can marked Function Check Source"). The 1% ore standard was used to determine the acceptable count range for the detector during calibration. Place the source at the same location on the detector used to obtain the source function check counts during calibration. Count the source for one minute and note the counts in cpm. The source function check counts must be within 20% of the source counts obtained during the detector and Scaler/Ratemeter calibration.

3.1.11 Instrument Tolerance

The Scaler/Ratemeter–detector detecting and counting tolerance is expressed as percent deviation from the mean of the acceptable count range. The background counts and the source function check counts must be within 20% of the mean established following instrument calibration. If the source count is outside this range, pull the instrument from service. The instrument will be repaired or re-calibrated prior to use.

3.1.12 Technician

After completing the function check, initial in the column marked TECH of the function check form.

### 3.2 Instrument Minimum Detectable Concentration Calculation

If required, calculate Minimum Detectable Concentration (MDC) for the instrumentation using the function check background readings as described in SOP-1 (Instrument MDC Calculation). Calculate MDC for appropriate survey, i.e. Direct Measurement MDC for static (stationary) gamma radiation survey and scan MDC for scan or walkthrough gamma radiation survey. Record the MDC in the Function Check Form (Attachment A).

## 4.0 FIELD GAMMA RADIATION SURVEYS

The direct gamma radiation level survey for Ra-226 in surface soil will be conducted as either scan survey (walkthrough) or static survey (stationary) measurements.

### 4.1 Scan Radiation Survey

Scan radiation surveys (walkthrough surveys) will be performed by walking with the detector at about 12 inches from the ground surface with the scaler/Ratemeter in count RATE MODE. Scan surveys will be performed within each survey area by walking in a serpentine shape along transects to identify and locate any hot spots and contaminated area boundaries during the excavation control survey. The scan surveys may also be performed as a component of the final status survey.

A GPS based gamma radiation scan survey can be performed to log gamma radiation rate with corresponding point location coordinates in a data logger. This scan survey can be performed by walking the area with 2x2 NaI detector with ratemeter coupled with a DGPS/data logger unit. The GPS-gamma scan survey system will consist of a Ludlum 2221 Ratemeter/Scaler with SPA-3 2x2 NaI Detector coupled to a Magellan MobileMapper CX (MMCX). The MMCX is a real time DGPS with data logging capabilities using a TDS SOLO surveying software. The Ludlum 2221 will be operated in ratemeter mode, allowing a gamma count rate (cpm) to be logged with its corresponding coordinates in 2-second interval. Appropriate walk-over transect spacing based on the scan coverage rate will be used for this survey.

You can partially automate the logging process by logging points by interval. You can log points after a specified time period has elapsed. The procedure for using the Log By Interval function is described below:

1. Select **Log** > **Log by Interval**, or tap the **Log by Interval** button in the Mode Toolbar. This will open the **Select Feature to Log** screen.
2. You will be prompted to select a feature and to complete the attribute entry. When you tap on the **OK** button in the **Attributes** screen, the **Log by Interval** screen will be displayed.
3. Select between **Log by TIME interval.**
4. Enter the **2.00 Seconds** log interval in the **Log every** field.
5. Tap the **Start** button to begin logging by interval.

The first point will be logged at your current position. Once you have waited the specified time another point will be logged. This will continue until you tap the **Pause** button or close the screen. At the end of each survey day, the field data will be downloaded into a computer and processed for tabularization and mapping. Download the survey file as follow:

Select **File** > **More** > **Export** to open the **File Export** screen.

You may select the **Export Format** by tapping on the down arrow to the right of the selection box. choose Text, All exported files are stored in \My\Documents\SOLO\Export by default, otherwise. If **Prompt for filename** is selected, you can customize the names as each file is created.

Depending upon the export format selected, you may choose to export your features in two ways; a unique file for each feature layer, or one file.

With **Text *.txt** selected as the **Export Format**, tap **Options** to display the text options. You may turn these options on/off using the checkbox next to each option.

When you are satisfied with your selections, tap the **Export** button to create the file(s) in the selected format

### 4.2 Static Radiation Survey

Static radiation surveys will be performed at any point or location of interest during excavation control survey, and at specified grid nodes within survey areas for the final status survey. Also, static survey measurement will be performed at each correlation sampling point. The detector will be held at about 12 inches from the ground surface. The scaler/Ratemeter will be set in the count SCALER MODE. A one- minute count (cpm) of gamma radiation level will be obtained at each location for static gamma radiation survey.

### 4.3 Remedial Action Support (Excavation Control) Survey

Excavation control survey will be performed to guide excavation of contaminated soil exceeding the 2.24 pCi/g Ra-226 cleanup level during the IRA at the NECR, which is equivalent to the direct gamma radiation count of 5,075 cpm for the collimated detector based on the SRSE updated correlation.. This direct radiation cleanup level may change as cleanup progresses; therefore, contact your supervisor to obtain the current direct radiation cleanup level. Excavation control survey will be performed using combination of scan radiation survey and static radiation level measurements as follow:

1. Perform the function check as indicated in Section 4.1 of this procedure. In area, such as north and west of the NECR-1 near the slope, where gamma radiation shine is expected, used the collimated detector.
2. Insure that the Scaler/Ratemeter (ESP or Ludlum 2221) is set in RATE mode. Turn the Scaler/Ratemeter audio speaker to the ON position. For Ludlum 2221 Scaler/Ratemeter, set the RESP (response) toggle switch to F (fast) position. Set the audio rate toggle switch to x1, x10 or x100 position and familiarize yourself to the audio rate at the action level count rate. The audio toggle rate set at x10 is appropriate for the field survey.

3. Using the IRA Work Plan figures, area boundary location coordinates, and DGPS to field locate and mark appropriate area exceeding the cleanup level with pin flags. Radiation scanning may be necessary between the outer points to delineate the contaminated area boundaries. Coordinate the marked area with the excavation crew. The area may be divided into small subareas such as 100 square meter areas, or 10 feet strips to efficiently control excavation based on equipment used for excavation. The excavation fleet will remove the

contaminated soil in necessary thickness lift initially based on vertical extent of contamination.

Prior to performing excavation control in the field, hold a tail gate safety meeting each day with the excavation crew to coordinate safety procedures during the excavation control survey.

IT IS IMPORTANT TO COORDINATE WITH THE EXCAVATION CREW THE EXCAVATION AND SURVEY SEQUENCE FOR YOUR SAFETY. ESTABLISH NECESSARY SAFETY COORDINATION WITH THE EXCAVATION CREW. ALWAYS WEAR AN ORANGE SAFETY VEST WHILE PERFORMING SURVEY IN THE FIELD.

4. Following the initial excavation lift, assure that the excavation equipment is out of the way and the area is clear and safe, perform a radiation scan with the detector at approximately 12 inches from the ground surface by walking in a serpentine pattern along a transect or within the subdivided areas with the audio speaker ON to identify any locations that exceed the site action level count rate by audio response and digital count rate display. The scan survey for the excavation control will be performed for 100% coverage of an area. Note that the collimated detector at about 12 inches from ground is most sensitive within an area of about three feet diameter under the detector, and about 10 feet diameter under the bare detector. The gamma radiation level rates in CPM observed during the scan survey may be recorded on the field form or maps for documentation. The scan gamma radiation survey form (Attachment B) may be used to note any comments.

5. If no point or a location exceeding the action level is identified within the area by the scan, the excavation is complete and ready for the Interim Status survey.

6. If the radiation scan following the initial soil excavation lift shows portions the area above the cleanup level, or any static measurement point is above the cleanup level, mark out those areas with pin flags and coordinate with the excavation crew for the additional excavation of contaminated soil as necessary at those locations until the scan survey shows no points or location above the cleanup level and repeat step 5 at those locations.

7. If the radiation scan following the initial soil excavation lift still shows most or all of the area above the cleanup level, the contamination in entire area is deeper than the initial lift. Coordinate with the excavation crew for additional soil excavation and repeat 5 and 6 as necessary until the area is clean.

### 4.4 Interim Status Survey

The Interim Status survey includes scan radiation survey and static radiation survey. The scan radiation survey would have already been performed at 100% coverage during the excavation control survey for IRA support. This will information will be used for scan radiation survey requirement for the Interim Status Survey. The static direct gamma radiation level measurements for the Post-IRA survey will be implemented following the IRA and the remedial action support surveys. Static direct gamma radiation level survey will be performed at 80-foot triangular grid nodes in each area. The grid nodes were determined using a visual Sampling Plan (VSP) on an 80-foot triangular grid cast on a random origin during the RSE for most of the areas undergoing the interim remedial action. One-minute static gamma radiation survey will be performed at specified grid nodes or points within survey areas as a part of the Interim Status survey to demonstrate cleanup of areas. The technician will perform the static (stationary) gamma radiation survey as follows:

1. If the detector needs to be collimated for the area of interest, place the detector in the 0.5 inch lead collimator. Perform the function check as indicated in Section 4.2 of this procedure.

2. Insure that the Scaler/Ratemeter (Ludlum 2221) is set in scaler (integration) mode and the integration time is set for one minute. Turn the Scaler/Ratemeter audio speaker to the ON position.

3. Obtain the cleanup level direct gamma radiation count rate based on the correlation for the final status survey for bare and collimated detector.

4. Locate the final status survey points (grid node) using survey point location figures, the static survey point coordinate data, and the DGPS system.

5. Hold the detector at approximately 12 inches from the ground surface above the desired survey point. Obtain a one minute integrated count.

6. Record the counts in cpm and appropriate corresponding survey point information (location ID and/or coordinates etc) on the Static Gamma Radiation Survey Field Form (Attachment C).

7. If any of the reading is above the cleanup level based on the revised correlation for the final status survey, mark the survey point with a pin flag for investigation and addressing any residual contamination.

8. Repeat step 4 to 6 for additional static radiation measurements.

9. The Ra-226 concentration in the soil will be calculated from the gamma radiation survey counts (cpm) using the calibration equation established from the correlation for that detector. The results from the static gamma radiation survey and soil sampling results will be compared to the 2.24 pCi/gm Ra-226 level for demonstrating compliance with removal action of contaminated soil. If needed, data will then be evaluated using statistical method to determine if they exceed cleanup level.

## 5.0 ATTACHMENTS

| | |
|---|---|
| Attachment A | Scaler/Ratemeter-Detector Function Check Form |
| Attachment B | Scan/Walkthrough Gamma Radiation Survey Field Form |
| Attachment C | Static Gamma Radiation Survey Field Form |

**Attachment A, SOP #RAD-3a**
**Scaler/Ratemeter - 2" x 2" NaI Detector Function Check**
**UNC's NECR Mine Site**

Scaler/Ratemeter ID:__________________________________

Function Check Source ID: 1% $U_3O_8$ Ore in Sealed can

2" x 2" Detector ID:____________________________________

Acceptable background Count (cpm) Range (20%) ______________________ to ____________________

Acceptable Source Count (cpm) Range (20%) ______________________ to _______________________

| Date | Physical Check | Cal Due | Battery(1) Volts or OK | HV Volts | Threshhold mV (2) | Window In or OUT(3) | C.C.(4) | BKG Counts cpm | Source Counrts cpm | Within Acceptable Range Y or N | MDC pCi/gm | Tech |
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**Note: (1) Battery Voltage for Ludlum 2221 must be >5.3 volts; (2) Threshhold must be at 100 mV; (3) Window Position must be OUT; (4) C.C. for Eberline ESP scaler must be 1.0+00**

**Attachment B, SOP #RAD-03a**
**Gamma Radiation Survey @ UNC's NECR Mine Site**

## Scan/Walkthrough Gamma Radiation Survey Field Form

Instrumentation : Scaler/Ratemeter________________________________, Detector________________________________________

Instrument Calibration Date: ______________________________, Instrument Daily Function Check Performed: __________

2"x2" NaI Detector Collimated ______ Yes or ______ No.

Survey Area/Unit Decsription ____________________________________________________________________________

| Survey Date/Time | Survey Area-Transect ID/Description | Gamma Radiation Reading Range CPM | Comments/Notes |
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Technician Signature __________________________________, Reviewed by _____________________________________

**SOP-3**
**AVM Environmental Services, Inc.**
**CALIBRATION OF THE SCALER RATEMETER And the 2"x2" NaI DETECTOR**
**For Gamma Radiation Survey @ Uranium Mill and Mine Sites**

## 1. SCOPE

1.1 Purpose

To provide a standard procedure for calibration of the Ludlum Ratemeter, model 2221 with a 2"x2" NaI Scintillation Detector (the Ludlum 44-10 or Eberline SPA-3).

The Ludlum 2221 is a portable, battery operated, self-contained counting instrument designed for operation with scintillation, proportional or G-M detectors. When combined with a 2"x2" NaI scintillation detector, the Ludlum 2221 is used for the detection and measurement of gamma radiation. This instrument configuration is used for detection of surface soil gamma radioactivity.

1.2 Applicability

This instrument will be calibrated every twelve months, after repairs, or when the instrument function check fails. This method can be used with any Scaler/Ratemeter with a 2"x2" NaI scintillation detector configuration.

## 2. REFERENCES

2.1 Technical Manual for Scaler Ratemeter, Model 2221

## 3. REQUIREMENTS

3.1 Tools, Material, Equipment

3.1.1 Small screwdriver.

3.1.2 Ludlum Model 500 Pulser or equivalent.

3.1.3 A source of sufficient gamma radiation activity to allow a response for high voltage plateau and function check. A 1% uranium ore in a sealed can is used.

3.1.4 Efficiency calibration for Ra-226 gamma survey is performed using DOE Grants calibration site (GPL).

3.2 Precautions, Limit

3.2.1 The detector to Scaler/Ratemeter connector cable could easily be damaged if the weight of the 2"x2" NaI detector is suspended with it.

3.2.2 The NaI scintillation crystal is fragile. Shock to the crystal could cause a fracture or a crack, which could impact operation.

3.2.3 Do not leave the reading lamp on for any length of time as it will rapidly drain the battery voltage.

3.3 Acceptance Criteria

The instrument response to the calibration source should be within ±20%.

## 4. LUDLUM 2221 OPERATION CALIBRATION

Record Scaler/Ratemeter information (model and serial number) on the Scaler/Ratemeter Calibration Form. Record information about the calibration source (Pulser and/or source, 1% uranium ore standard).

4.1 Check the battery condition by pressing the “BAT” button with instrument switched on. If the meter does not indicate the battery charge above 5.3 volts, replace the four (4) D-cell batteries.

4.2 Set the threshold value as follows:

4.2.1 With the instrument turned on, press the threshold button. Read the displayed reading. If necessary adjust the **“**THR**”** adjustment screw until the threshold reads 100.

NOTE: The ‘THR” adjustment screw is located under the calibration cover

4.3 Set the WIN (window) IN/OUT to OUT.

4.4 Connect the Ludlum 500 Pulser to the 2221.

4.5 Switch SCALER/DIG RATEMETER switch to DIG RATEMETER.

4.6 Select 400 CPM on the Pulser (multiplier switch to 1 and count rate adjusted to 400 cpm).

4.7 Adjust the pulser amplitude above the set threshold (100 mV) until a steady count rate is observed.

4.8 Record the meter rate count response in AS FOUND column on the calibration form. If the meter response is not within 10% of the Pulser set count rate of 400 cpm, adjust the R40 Meter Cal (Labeled MCAL) on the processor board for 400 cpm on the meter.

4.9 Repeat steps 4.6 to 4.8 for 4000, 40,000 and 400,000 cpm pulses.

4.10 Switch the SCALER/DIG RATEMETER switch to SCALER. Select Count Time to 1 Minute.

4.11 Select 400 counts on the pulser (multiplier switch to 1 and count rate adjusted to 400)

4.12 Count the pulses on the meter for one minute by pressing COUNT switch.

4.13 Record the meter response counts in AS FOUND column on the calibration form. If the meter count is not within 10% of the pulser set counts of 400 cpm, adjust the R40 Meter Cal (Labeled MCAL) on the processor board and repeat step 5.12 until a count of 400 is observed on the meter.

4.14 Repeat steps 4.11 to 4.13 for 4000, 40,000 and 400,000 pulses.

If the meter reading could not be set within 10% of the pulses generated by the pulser, the meter requires repair and calibration prior to use.

The Ludlum 2221 is ready for detector calibration and operation.

## 5. DETECTOR HIGH VOLTAGE AND BACKGROUND CALIBRATION

Record Scaler/Ratemeter (Ludlum 2221) and 2”x2” NaI detector (Eberline SPA-3 or Ludlum 44-10) information (model and serial number) on the Scaler/Detector Calibration Form. Record information about the calibration source (1% uranium ore standard).

5.1 Connect the calibrated Ludlum 2221 to the 2”x2” NaI detector.

5.2 Turn the Ludlum 2221 ON. Set WIN ON/OFF to OFF.

5.3 Check Threshold setting. Should be at 100 mV.

5.4 Switch SCALER/DIG RATEMETER switch to SCALER. Select Count Time to 1 Minute.

5.5 Set HV to 500 VDC.

5.6 Expose the detector to the 1% uranium ore can by placing directly under the detector.

5.7 Obtain one-minute counts with the detector exposed to the source at every 50-volt increment until voltage plateau is passed and sudden increase in the counts is observed. (Usually the for the 2”x2” NaI detector, the high voltage plateau maximum voltage is about 1300 to 1400 VDC.). Record the counts under the READING CPM SOURCE in the calibration form.

5.8 Return HV setting back to 500 VDC.

5.9 Remove the source away from the detector. Obtain one-minute background counts with the detector shielded from the source at every 50-volt increment until similar voltage to the source high voltage plateau reading. Record the counts under the READING CPM BACKGROUND in the calibration form.

5.10 Plot voltage versus cpm reading for both the source and background high voltage data. From the plot, select the optimum operating high voltage, which is usually at least about 50 volts above the knee of the plateau curve for a greater counting stability. The optimum high voltage should be also within the background plateau curve for background counting stability.

5.11 Set the Ludlum HV at the optimum operating voltage determined above.

The Ludlum 2221 and the 2”x2” NaI detector configuration is ready for efficiency calibration and establishing the operating background and source function check.

## 6. OPERATING BACKGROUND AND SOURCE FUNCTION CHECK DETERMINATION

6.1 Set the Ludlum 2221 to Scaler mode, Count Time at 1 minute, with WIN OUT and THR at 100.

6.2 Remove any type of sources away from the detector. Obtain five one-minute background counts. Record the background counts in the calibration form. Average the five one-minute background counts. Record the average background counts in the calibration form. The daily function check background counts should be within 20% of this average.

6.3 Expose the 1% uranium ore source (in the sealed can). Note the exact location of the source to the detector. Obtain five one-minute background counts with the detector exposed to the source. Record the source counts in the calibration form. Average the five one-minute source counts. Record the average source counts in the calibration form. The source position to the detector for the function check should be exactly the same as this calibration, and the source counts for the daily source function check counts should be within 20% of this average.

## 7. EFFICIENCY CALIBRATION

7.1 Using the Map in the DOE Field Calibration Report (DOE/ID/12584-179) go to the Grants calibration site. Locate GPL pad (87.78 pCi/gm Ra-226, 0.50 pCi/gm Th-232 and 15.58 pCi/gm K-40) as shown in the Grants Calibration Site layout in the DOE report.

7.2 Set the Ludlum 2221 to Scaler mode, Count Time at 1 minute, with WIN OUT and THR at 100.

7.3 Obtain five one-minute counts with detector at the center of the pad at about 12 inches from the pad surface. Record the counts on the Calibration Form. Also obtain five one-minute counts with detector collimated at same height and record the counts on the Form.

7.4 Average the five calibration counts (cpm) and record on the form and calculate efficiency for collimated and uncollimated (bare) detector.

Efficiency (cpm/pCi/gm) = Cal Pad average one-minute counts (cpm)/87.78 pCi/gm

This efficiency may be used for calculating instrument Minimum Detectable Concentration (MDC).

## 8. MINIMUM DETECTABLE CONCENTRATION CALCULATION

8.1 MDC for Static Gamma Radiation Measurement (for 0.05 probability for both false positive and false negative errors)

$$MDC = C \times [3 + 4.65\sqrt{B}]$$

Where

C = Detector calibration factor, pCi/gm/cpm (for this survey as determined above).
B = Number of background counts that are expected to occur while performing a sample measurement.

Example: If the background count from the function check for the detector is 7862 cpm, and the detector efficiency is 0.001418 pCi/gm/cpm (705 cpm/pCi/gm), then the MDC for a one minute static measurement would be:

MDC = 0.0014 pCi/gm/cpm x [3 + 4.65√ (7862 cpm ] = 0.59 pCi/gm

8.2 MDC for Scan Gamma Radiation survey

The scan MDC is assumed for a scan rate of about 3 feet per second and a one second interval (based on a detector that is focused on about 36 inches diameter area at about 12 inches from ground surface). Also, a surveyor efficiency (p) of 0.5 is assumed. First calculate the Minimum Detectable Count Rate (MDCR) as follow:

MDCR = d’ x √(bi x (60/i)

Where:

d’ = value for true positive and false positive proportion. A value of 1.38 will be used for 95% true and 60% false positive proportion.
bi = number of background counts in the interval i (cpm/60 sec/min for one second interval).

For a detector background count of 7820 cpm, the MDCR for one second interval would be:

MDCR cpm = (1.38) x √(7820 cpm x 1 sec x 1 min/60 sec) x 60 sec/min = 945 cpm.

Then calculate the $MDCR_{surveyor}$ using surveyor efficiency (p) of 0.5 as follow:

$MDCR_{surveyor}$ = MDCR/$\sqrt{p}^5$ = 945 cpm/√0.5 = 1,337 cpm.

From the $MDCR_{surveyor}$, calculate the scan MDC using the following:

Scan MDC = $MDCR_{surveyor}$, cpm x C, pCi/gm/cpm

Where: C = Detector calibration factor, pCi/gm/cpm (for this survey as determined above).

For a C of 0.0014 pCi/gm/cpm (705 cpm/pCi/gm), the Scan MDC would be:

Scan MDC = 1,337 cpm x 0.0014 pCi/gm/cpm = 1.87 pCi/gm

The integration count time for static measurement may be increased, and the scan rate for radiation scan survey may be reduced to lower MDCs to desired levels. The Ludlum 2221/2”x2” NaI detector configuration is ready for a site-specific soil Ra-226 to gamma radiation level calibration (SOP-2) and performing field gamma radiation survey (SOP-3). A daily function check must be performed prior to use.

[redacted]

[redacted]

[redacted]