# Standard Operating Procedures

## Excavation Control & Verification Surveys
## St. Anthony Mine Closeout

Prepared by

AVM Environmental Services, Inc.

Grants, New Mexico

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**SOP-1**
**AVM Environmental Services, Inc.**
**Calibration of Gamma Radiation Survey Instruments**
**St. Anthony Mine Closeout**

## 1. SCOPE

1.1 Purpose

To provide a standard procedure for calibration of the Ludlum Scaler/Ratemeter, model 2221 with a 2"x2" NaI Scintillation Detector (the Ludlum 44-10 or Eberline SPA-3) for gamma radiation surveys during St. Anthony Mine Site (site) closeout activities.

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 radiations. This instrument configuration is used for detection of the soil Ra-226 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 flat head 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 Detector response factor for Ra-226 gamma survey is performed as described in Section 7

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.

3.2.4 The meter firmware affects the measurements outputted via the RS-232 communication port. Based on the selected integrated count output for specific scan survey, verify appropriate firmware version installed for the Model L2221. The L2221 should have firmware version 261-02-N11 for one second integrated count output, and the firmware version 26106n03 two second integrated count output. The firmware version will appear on the L2221 display after turning it ON.

3.3 Acceptance Criteria

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

## 4. LUDLUM 2221 OPERATION CALIBRATION

If the Ludlum 2221 has been calibrated by the vendor within 12 months, skip this procedure in this section and start with detector calibration in Section 5. Record Scaler/Ratemeter information (model and serial number, and calibration date) 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, and calibration date) on the Scaler/Detector Calibration Form. Record information about the radiation 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 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 calibration 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 source response plateau curve for greater counting stability. The optimum high voltage should be also within 50 volts of the background plateau curve for background counting stability.

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

5.12 Record the HV voltage setting on the Scaler/Detector Calibration Form.

The Ludlum 2221 and the 2”x2” NaI detector configuration are ready for determining the detector response factor 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 of radioactivity 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. DETECTOR RESPONSE FACTOR AND FIELD OF VISION

### 7.1 Filed Vision

A detector field of vision (FOV) is used for determining observation interval of gamma scan survey for scan MDC calculations, and for transects spacing calculations for scan gamma survey coverage. Detection range of a photon from a particular source by a detector is related to FOV for that detector. The detection range is dependent on the energy of radiation (photon) being detected since it is a characteristic of photon energy, not a detector. Detection range will be longer for a photon with higher energy than a photon of lower energy. FOV is a circular area with the detection range as radius. A minimum FOV of 6.0 feet for bare and 3.0 feet for collimated 2x2 NaI detectors for Ra-226 (uranium ore) photons will be used for observation interval for MDC calculations. If a different FOV is used, it will be verified by conducting a FOV test.

### 7.2 Detector Response Factor

For the calculation of minimum detectable concentrations (MDCs), the detector response factor, a.k.a detector efficiency, which is a conversion constant in units of cpm per pCi/g is required. There are several methods for determining the detector response factor, such as using calibration pads, source modeling or a concentration to gamma radiation level correlation study. Since final gamma radiation level to Ra-226 surface soil concentration correlations for bare and collimated detectors have been established for the site, the appropriate detector response factor from these correlations will be initially used for MDC calculations for gamma surveys during the St. Anthony mine site field gamma survey activities. The correlations were developed for the ground surface assumptions similar to what is expected at the St. Anthony mine site, i.e. fairly homogeneous and distribution of Ra-226 concentration in surface soils by using sampling data from appropriate conditions. These correlations meet the statistical acceptance criteria and the project data quality objectives.

The slope of the regression represents the relationship between the field gamma measurement in cpm and the Ra-226 surface soil concentration in pCi/g. Thus, the slope is in units of pCi/g/cpm. The derivations of the correlations are described in the Attachment 1 to the Attachment C.1 to Appendix C of the Closure Plan, Excavation Control Plan. The final correlations yielded a regression slope of 0.0005 pCi/gm/cpm ( or 2000 cpm/pCi/g) for bare 2x2 NaI Detectors, and 0.0013 pCi/gm/cpm (or 970 cpm/pCi/g) for 0.5-inch lead collimated 2x2 NaI detectors.

Response factor for all 2x2 NaI scintillation detectors are fairly comparable. However, if a detector is repaired, replaced or new one is used, the comparability of the response factor should be verified by cross measurement against the original calibrated detector using a constant uranium ore source with sufficient activity, or preferably at the DOE uranium ore calibration pad. The response should be within ±20%.

## 8. DETECTOR MINIMUM DETECTABLE CONCENTRATION CALCULATION

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

The calculation below is an example for illustrative purposes and the static MDC will be calculated in the field based on actual field background measurements from function checks. It is important to note that these MDC calculations necessarily depend on several assumptions of consistent conditions in the field such as homogeneous distributions of contamination in soil, infinite plane geometry, consistent thickness of the contaminated layer of material, and consistent detector to soil surface relationship. Those conditions will not be ideal when field measurements are performed and the MDC will likely be greater than the value calculated below.

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

Where,

C = Detector response factor, cpm/pCi/g

B = Background count rate in cpm.

Example:

- For the bare 2x2 NaI detector, estimated background count rate of 10,000 cpm from previous function checks at the site, detector response of 0.0005 pCi/g/cpm from Section 7.2 above, then the MDC for a one minute static measurement would be:

$$MDC = 0.0005 \text{ pCi/g/cpm} \times [3 + 4.65\sqrt{(10{,}000 \text{ cpm}}] = 0.23 \text{ pCi/gm}$$

- For the 0.5-inch lead collimated 2x2 detector, estimated background count rate of 3,000 cpm from previous function checks at the site, detector response of 0.0013 pCi/g/cpm from Section 7.2 above, then the MDC for a one minute static measurement would be:

MDC = 0.0015 pCi/g/cpm x [3 + 4.65√ (3,000 cpm] = 0.63 pCi/gm

The integration count time for static measurement may be changed to attain MDCs to required levels. Tolerable maximum instrument background count rate to attain a specified MDC can be calculated by solving the above equation using other accepted parameters (integration time and detector response factor). A daily function check must be performed prior to use.

The total propagated uncertainty will be calculated for the static survey measurement and reported with the static MDC values in all reports, tables, and figures.

### 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 2 second interval. For a single component scan, such as GPS based gamma scan for St. Anthony mine site soil excavation action, the scan CPM is recorded using DGPS and Data logger for later evaluation of data with no pausing for stationary survey investigation needed in the field during the scan, and variability in the actual scan speed due to human inconsistencies in scan rate and detector height, a surveyor efficiency (p) of 0.8 is appropriate. For a dual component where a surveyor may pause during a scan survey for investigation, a surveyor efficiency of 0.5 will be used. The calculation below is an example for illustrative purposes and the scan MDC will be calculated in the field based on actual field conditions (based on the actual detector response factor, surveyor efficiency, field of view, scan rate to meet the scan MDC requirements, and background; d' is fixed as indicated below).

First calculate the Minimum Detectable Count Rate (MDCR) as follows:

MDCR = (d' x √bi) x (60/i)

Where:

d' = value for true positive and false positive proportion. A value of 1.38 (MARSSIM Table 6.5) will be used for 95% true and 60% false positive proportion.

bi = number of background counts in the interval i [(background rate in cpm/60 sec/min) x 2 for two second interval].

Example: For the bare 2x2 NaI detector background count of 10,000 cpm estimated from previous function checks at the site, the MDCR for two second observation interval (6.0 feet FOV/3.0 feet per second scan rate) would be:

bi (2 sec) = (10,000 cpm) x (1 min/60 sec) x (2 sec) = 333 counts

MDCR cpm = (1.38) x √[333 counts] x (60 sec/min)/(2 sec) = 756 cpm.

The MDCR $_{surveyor}$ using surveyor efficiency (p) of 0.8 would be:

MDCR $_{surveyor}$ = MDCR/√p = 756 cpm/√0.8 = 845 cpm.

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

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

Where: C = Detector response factor, 0.0005 pCi/g/cpm (from Section 7.2 above)

Scan MDC = 756 cpm x 0.0005 pCi/g/cpm = 0.42 pCi/gm

For the 0.5-inch lead collimated detector with a background of 3,000 cpm, C of 0.0015 pCi/g/cpm, observation interval of one second (3.0 feet FOV/3.0 feet per second scan rate), the scan MDC would be 0.98 pCi/g.

A daily function check must be performed prior to use. The scan rate for radiation scan survey may be changed to attain MDCs to required levels. The tolerable maximum instrument background count rate to attain a specified scan MDC can be calculated by solving the above equation using the other approved instrument and survey parameter values, such as survey sensitivity (d'); detector response factor; scan rate; observation interval; and surveyor efficiency. Likewise, maximum scan rate for scan survey to attain a specified scan MDCs can be calculated by solving the above equation with using other instrument and survey parameter values, such as survey sensitivity (d'); instrument background count rate; detector response factor;  detector FOV for Ra-226; and surveyor efficiency factor.

## Attachment A

### Scaler/Ratemeter Calibration Form

Model______________________________ S/N _____________________

Calibration Source__________________________________________________________

Threshold (input sensitivity), Found at_________________mV Left or Set at __________mV

Window, In/Out__________ Window _________________mV

Pulser Amplitude Set @______________________________mV

| Range/Mode | Calibration Point (Pulser Setting) cpm x multiplier | As Found Reading | Left or Set Reading |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
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| | | | |

HV Set @________________ VDC

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Date __________________________ Calibrated By _________________________________________

## Attachment B

**AVM Environmental Services Inc.**
**Scaler/Ratemeter - Detector Calibration Form**

Scaler/Ratemeter : Ludlum 2221, SR #
Detector: 0.5 Inch Lead Collimated SPA-3, #

Source: ____________________________ Strength: ________________

Scaler/Ratemeter Threshhold set @ 100 (10mV); Window IN/OUT: OUT; Window: N/A mV

| HV | Reading, CPM (Source) | Reading, CPM (Background) |
|---|---|---|
| 500 | | |
| 550 | | |
| 600 | | |
| 650 | | |
| 700 | | |
| 750 | | |
| 800 | | |
| 850 | | |
| 900 | | |
| 950 | | |
| 1000 | | |
| 1050 | | |
| 1100 | | |
| 1150 | | |
| 1200 | | |
| 1250 | | |
| 1300 | | |
| 1350 | | |
| 1400 | | |

**at designated function check location in office.**

| Count # | Reading (CPM) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| Average | |

**Count Readings with 1 percent $U_3O_8$ can directly under collimated detector on designated function check location in office.**

| Count # | Reading (CPM) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| Average | |

HV Set @_______________________ VDC (Instrument) __________________ VDC (DVM Fluke 8020B)

Input Sensitivity (THR), mV ________________

Function Check with 1 percent $U_3O_8$ ore in can. Can Directly under the detector.
Acceptable Function check range is: ______________________ to ___________________ CPM

**Count Readings for Calibration Pad GPL (87.78 pCi/gm Ra-226)**

#1 ______________ cpm
#2 ______________ cpm Average ______________ cpm
#3 ______________ cpm
#4 ______________ cpm Efficiency ______________ cpm/pCi/gm
#5 ______________ cpm Efficiency ______________ pCi/gm/cpm (1/cpm/pCi/gm)

Date ____________________________ By _____________________________________

# SOP -2
# AVM Environnemental Services, Inc.
# Direct Gamma Radiation Level to Ra-226 Soil Concentration Correlation Update
# St. Anthony Mine Closeout

## 1.0 Purpose

The purpose of this procedure is to update the Site specific Ra-226 concentrations in surface soil to direct gamma radiation level correlations for St. Anthony Mine Closeout. Site specific correlations were initially developed for both bare and collimated 2x2 NaI detectors during the 2018 Supplemental Radiologic Characterization as discussed in Attachment 1 to Appendix C.1. Although these correlations meet or exceed the appropriate acceptable statistical criteria (correlation coefficient, p-value and low MSEs), the correlations may be updated to improve the statistical parameters.

## 2.0 Scope

The Ra-226 levels in soil could be measured as a surrogate by measuring Pb-214 and Bi-214 gamma radiation levels, as to the measurement described in Section 4.3.2 of the MARSSIM. Pb-214 and Bi-214 are decay products of Ra-226 through radon-222 (Rn-222), a gaseous form, some of which emanates from soil. This process results in activity disequilibrium between Ra-226 and PB-214/Bi-214 in the soil. The Rn-222 gas emanation fraction from the soil varies with different characteristics of a particular soil. Therefore, a site-specific calibration of the detector is necessary. Studies at the Site have shown that about 20 percent of the Rn-222 gas decayed from Ra-226 in soil emanates out of the surface soil, indicating that a significant percentage (about 80 percent) of Ra-226 will decay into Pb-214 and Bi-214 in the soil matrix. If the soil characteristics 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 Pb-214/Bi-214 to Ra-226 will be consistent. This results in a direct correlation between Pb-214/Bi-214 gross 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 site specific correlations for both the bare and collimated 2x2 NaI detectors were developed with primary assumption of contamination distribution in surface soil. Any lateral gamma radiation shine from the nearby elevated areas would skew gamma radiation level. A collimator detector mitigates the lateral shine interference. The collimated detector correlation was updated with sampling data from locations that fit this assumption during previous investigations and removal actions. A correlation with this assumption is most appropriate for excavation control and final status surveys during removal actions because the contamination distribution is expected to be fairly homogeneous and in surface soils following the removal action. Only gamma radiation level measurements and soil sample Ra-226 data from corresponding locations with this correlation assumption will be used to update the correlations.

## 3.0 Instrumentation

Instrumentation to collect gamma radiation level measurements will be the same as used during the development of previous correlations. A 2”x2” NaI Scintillation detector (an Eberline SPA-3 or Ludlum 44-10 detector) and a Scaler/Ratemeter, (Ludlum Model 2221 or 2241) will be used for field gamma radiation level measurements and to select sampling locations. A 2x2 NaI detector with 0.5-inch thick lead collimator will also be used for gamma radiation level measurement for the collimated detector correlation update. The

Scaler/Ratemeter will be calibrated consistent with SOP-1 to assure that it properly counts the electronic pulses generated and sent by the 2x2 NaI 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 Ra-226 gamma radiations (primarily from the Pb-124 and Bi-214 decay products) are significantly higher than 100 mV, as verified by using 1% uranium ore standard.

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

If any surface soil sampling is performed during excavation control with a co-located static gamma radiation level measurement, the data may be used to update the correlation. One minute static gamma radiation level measurements will be performed consistent SOP-1. The co-located surface soil sample will be collected consistent with SOP-5, and will be analyzed for Ra-226 by an offsite vendor laboratory using EPA Method 901.1.

## 5.0 Linear Regression Analysis

The relationship between gamma radiations from Ra-226 to detector response is linear. To determine the correlation between gamma radiation level counts and corresponding Ra-226 concentration in surface soil, 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. A linear regression is the only statistical approach determined to be appropriate because the 2x2 NaI detector response to gamma radiation detection is linear, specifically at the levels emanating from uranium ore and tailings impacted soil. The liner regression will be performed by augmenting the appropriate correlation data included in Attachment 1 of Appendix C.1. Prior to augmenting and updating the correlation, review the data to make sure that the data meets appropriate QA/QC requirements and the collected data fits the correlation assumption, i.e. fairly homogeneous Ra-226 distribution in only surface soil for bare detector, and in area with any lateral shine is mitigated with collimated detector.

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. The purpose of the update is to increase correlation sample numbers to improve statistical parameters (correlation coefficient, confidence level, p-value and low MSEs). If the update does not improve the statistical parameters, investigate the data to see if they meet the correlation assumptions or are outliers.

**SOP-3**
**AVM Environnemental Services, Inc.**
**Field Gamma Radiation Survey for Ra-226 Concentration in Soil**
**St. Anthony Mine Closeout**

## 1.0 SCOPE

1.1 Purpose

This procedure will be used for direct gamma radiation surveys to detect Ra-226 in surface soil for performing investigation surveys, excavation control (Remedial Action Support) surveys, and as a component of the Verification Survey (VS) at the St. Anthony Mine Site (site) site during closeout.

## 2.0 EQUIPMENT AND MATERIALS

2.1 A Ludlum model 2221 or 2241 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 and data logging capability

2.3 A 0.5 inch lead Collimator for use with 2”x2” NaI detectors, if needed to mitigate nearby lateral gamma-ray shine interference and focus on the area of interest under detector. The 0.5-inch thick collimator, which surrounds the NaI crystal, is contained within a protective marlex housing.

2.4 A vendor calibrated Exposure Rate (uR/hr) meter.

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

2.6 Measuring tape, pin flags, area markers and marking paint.

## 3.0 INSTRUMENT CONFIGURATION & OPERATIONS

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

The field gamma radiation level surveys for Ra-226 in surface soil will be performed using a Ludlum 2221 Scaler/Ratemeter connected to a 2”x2” NaI crystal scintillation detector (SPA-3 or Ludlum 44-10) which detects gamma radiation emitted from radium-226 decay products (primarily Pb-214 and Bi-214) in the soil. The detector will be held at approximately 12 inches from the ground surface. The bare (uncollimated) detector should be sensitive to an area at least six feet in diameter under the detector. The Model 2221 Scaler/Ratemeter with external RS232 or a Bluetooth connector can be coupled to a DGPS/data logger where the gamma radiation count rate in CPM would be logged with its corresponding location coordinates.

For gamma 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 thick lead collimator to reduce gamma shine interference. During the survey, the detector will be held approximately 12 inches above ground level, which should focus and be most sensitive to an approximate 36 inch diameter area under the detector.

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

### 3.1 Instrument Function Check

An operational function check will be performed on the Scaler/Ratemeter (L2221) and the detector (SPA-3 or Ludlum 44-10) configuration each day prior to any field surveys. The operator will verify calibration validity for the Scaler/Ratemeter and the detector. The calibration date for the instruments must be within one year. If not, the instrument must be removed from service and calibrated with a certificate in file. The function check will be performed in the 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 Visual Inspection

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

#### 3.1.2 Calibration Due

Verify calibration validity for the Scaler/Ratemeter and the detector. Calibration date for the instruments must be within one year and have a current Calibration Certificate on file.

#### 3.1.3 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.

#### 3.1.4 High Voltage

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

#### 3.1.5 Threshold (input sensitivity)

Check and make sure that the Scaler/Ratemeter threshold is set at 10.0 mV. If not, set the threshold to 10.0 as all gross gamma measurements are performed with 10 mV (equivalent to 100 setting on instrument) threshold. Ludlum 2221 Threshold can be set by the instrument digital read out display.

3.1.6 Window

If Ludlum 2221 Scaler/Ratemeter is used for instrument configuration, the WIN (window) toggle switch must be in the OUT position for gross gamma measurements.

3.1.7 Background Counts

The background counts will be determined for the same time interval as the field static 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 at the field office must be within 20% or lower than the background counts obtained during the detector high voltage calibration.

3.1.8 Source Function Counts

Obtain the gamma radiation function check source, (1% $U_3O_8$ ore standard sealed in a can marked "Function Check Source"). The 1% ore standard was used to determine the acceptable count range for the detector following 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.

3.1.9 Instrument Tolerance

The Scaler/Ratemeter and detector counting and detecting tolerance are 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 must be repaired and/or re-calibrated prior to use.

3.1.10 Technician

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

3.2 Instrument Minimum Detectable Concentration Calculation

When required, calculate Minimum Detectable Concentration (MDC) for the instrumentation using the function check background readings as described in SOP-1 (Instrument MDC Calculation). Acceptable MDCs are below the specified investigation or Action Levels. The acceptable Ra-226 MDC limit for the site soil excavation action for static gamma survey is 3.3 pCi/g (50% of the 6.6 pCi/g RAL) and scan MDC limit for scan gamma survey is 3.4 pCi/g (50% of the 6.84 pCi/g SALemc). 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 instrument background information. Record in the Function Check Form (Attachment A) if the instrument MDC is less than the acceptable limit.

The integration count time for static measurement and the scan rate for scan survey may be changed to attain MDCs at acceptable levels

## 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 Gamma Radiation Survey

Scan gamma 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 to identify and locate any hot spots and contaminated area boundaries for investigations and excavation control during the site soil removal action. Scan surveys will also be performed as a component of the VS. A 0.5 inch lead collimator for 2”x2” NaI detectors will be used if needed to reduce lateral gamma-ray shine interference and focus on an area of interest under the detector. The scan rate and walking speed depends on the desired scan MDC for the survey. For this instrument configuration, a scan walking rate of 3 feet per second (fps) results in a Ra-226 scan MDC of 1.52 pCi/g. For a different san MDC, the scan walking rate may be modified.

A GPS based gamma radiation scan survey can be performed to log a gamma radiation rate with corresponding point location coordinates in a data logger. A GPS based scan survey paired with a scaler/ratemeter and a bare 2”x2” detector will be used for VS scan surveys. This scan survey can be performed by walking along the specified transects in the areas using a 2x2 NaI detector with a ratemeter coupled with a DGPS/data logger unit. The GPS-gamma scan survey system will consist of a Ludlum 2221 Scaler/Ratemeter/ with SPA-3 2x2 NaI Detector coupled to a DGPS/data logger system. Where terrain allows, the VS scan survey may also be performed using an all terrain vehicle (ATV) mounted scan survey system. The Ludlum 2221 will be operated in Ratemeter mode, allowing a gamma count rate (cpm) to be logged with its corresponding coordinates in one or two second intervals. Appropriate walk-over transect spacing based on the scan coverage rate and the detector FOV for Ra-226 will be used for this survey, as discussed in SOP-1.

The logging process can be partially automated 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 in SoloField mapping software 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 Gamma Radiation Survey

Static gamma radiation surveys will be performed at any point or location of interest during surface soil investigation surveys, excavation control surveys, and at specified grid nodes within survey units for the VS. 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 integrated count (CPM) of gamma radiation level will be obtained at each location for a static gamma radiation survey. A DGPS integrated with a data logger may be used to log the gamma counts and location for static surveys. A 0.5 inch lead collimator for the 2"x2" NaI detectors will be used if needed to reduce lateral gamma-ray shine interference and focus on the area of interest under detector. Static surveys for the VS will be conducted using a collimated detector. For this instrument configuration, a one-minute integrated count results into a Ra-226 MDC of about 0.3 pCi/g for bare detectors and 0.4 pCi/g for collimated detectors. For a different MDC, the integrated count period may be modified.

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

Excavation control surveys will be performed to guide the excavation of contaminated soil exceeding the Ra-226 RAL of 6.6 pCi/g during the site soil excavation action. Obtain field action level in CPM (for either bare or collimated detector) for the site Soil Action Level (SAL) concentration (pCi/g) based on the site specific correlation. This direct radiation level CPM may change as soil excavation progresses and the correlation is updated; therefore, contact the Radiation Safety Officer (RSO) to obtain the current direct radiation level CPM. Excavation control surveys will be performed using a combination of scan gamma radiation surveys and static radiation level measurements as follow:

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.

1. Perform the function check as indicated in Section 4.1 of this procedure. In area where gamma radiation shine is expected, use the collimated detector.

2. Ensure that the Scaler/Ratemeter 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 based on radiation level of the area and familiarize yourself to the audio rate at the action level

count rate. The audio toggle rate set at x10 or x100 is appropriate for the field survey.

3. Using appropriate maps, area boundary location coordinates and a DGPS if needed, field locate and mark any area exceeding the SAL with pin flags. Radiation scanning may be necessary to delineate the contaminated area boundaries. Coordinate the marked area with the excavation crew. The area may be divided into smaller subareas such as about 100 square meter areas, or 10 feet strips to help efficiently control excavation based on the type of excavation equipment used for excavation. The excavation fleet will remove the contaminated soil in necessary thickness lifts initially based on vertical extent of contamination.

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 within the 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 six feet diameter under the bare detector. The scan gamma radiation survey form (Attachment B) may be used to note any comments.

   If no point or a location exceeding the action level is identified within the area by the scan, the removal action in the area would be considered complete, and the area will be ready for the final status survey.

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

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

### 4.4 Investigation Survey

Gamma radiation surveys for Ra-226 contamination investigations will be used to identify hot spots and contamination boundaries. Static gamma radiation surveys will be conducted at any points of interest that are above the appropriate investigation level of an area. Obtain appropriate investigation level in CPM since they are different for different type of areas as described in the VS Plan. Follow the scan and static survey procedure as described in Section 4.1 and 4.2 above. Scan gamma radiation surveys will be performed by walking around with the detector at about 12 inches from the ground surface with the scaler/ratemeter in count RATE MODE. Scan surveys will be performed at necessary coverage rates, as specified in the CVS Plan for investigations, within areas of interest in a serpentine shape along transects. The investigation scan and static gamma survey data may be recorded in the DGPS/data logger and/or in field forms that are included in Attachments B and C.

### 4.5 Verification Survey

The final Status Survey will be implemented following excavation control surveys indicating that the contaminated soil an area or a survey unit exceeding the RAL has been removed and is ready for VS. Both, the scan and static gamma radiation surveys are components of the VS. The scan gamma radiation survey would have already been performed at very dense coverage during the excavation control survey for soil excavation action support. This information will be used for the scan gamma radiation survey requirements for the status survey.

**VS Scan gamma radiation survey**

Systematic VS scan gamma radiation surveys will be conducted prior to the static gamma radiation survey in survey units. The technician will perform the static gamma radiation survey as follows:

1. The scan survey coverage in each class survey unit is different. Obtain appropriate scan coverage for the survey unit from the VS Plan.
2. Calculate Transect spacing for the VS systematic gamma scan using the detector field of view (FOV) for the Ra-226 gamma radiations:

   transect spacing = FOV/Required % scan coverage.

   For example, for FOV of 6.0 feet for 2x2 NaI detectors, a 20 percent scan coverage requires a transect spacing of 30 feet.
3. Field locate and mark the specified transects in a survey unit using a GPS and appropriate marking material.
4. Conduct the VS scan survey along transects as described in Section 4.1
5. Download the scan survey data as described in Section 4.1.

A QA/QC review of the scan data will be performed. The scan data will be reviewed to determine if the survey unit is ready for the static gamma survey.

**VS Static gamma radiation survey**

The static gamma radiation survey will be implemented following the VS scan gamma survey. One minute static direct gamma radiation survey will be performed using a 0.5 inch lead collimated detector at triangular grid nodes in each survey unit casted on a random origin. The technician will perform the static gamma radiation survey as follows:

1. Place the detector in the 0.5 inch lead collimator. Perform the function check as indicated in Section 4.2 of this procedure.
2. Verify that the Scaler/Ratemeter (Ludlum 2221) is set in scaler (integration) mode and that the count time is set for one minute. Turn the Scaler/Ratemeter audio speaker to the ON position.
3. Obtain coordinates of each grid node in the survey unit.

4. Locate VS static points (grid node) using the static survey point coordinate data, and a DGPS system.

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

6. Log the survey point ID, coordinates and counts in the DGPS/data logger. The technician may also 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 measurement is above the counts for SAL or SALemc based on the correlation, mark the survey point with a pin flag for investigation.

8. Repeat steps 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 linear regression equation established from the correlation for that detector. The static gamma survey data will be reviewed for QA/QC. The results from the static gamma survey will be used for demonstrating compliance with SAL.

## 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-03**
**Scaler/Ratemeter - 2" x 2" NaI Detector Function Check**

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)**

**Attachment B, SOP-03**

**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 ____________________________________

**Attachment C, SOP-03**
**Static 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 Point ID/Description | Survey Point Coordinate Northing | Survey Point Coordinate Easting | Gamma Radiation Reading, CPM | Comments/Notes |
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Technician Signature ___________________________________, Reviewed by ______________________________________

# AVM SOP-4
# AVM Environmental Services, Inc.
# Field Soil Gamma Radiation Screening Procedure
# St. Anthony Mine Closeout

## 1.0 Introduction

This field soil screening procedure for Ra-226 consists of measuring 609 KeV gamma radiations of Bi-214, a decay product of Ra-226 through Rn-222. The 609 KeV gamma radiation counts of the sample soil is compared to a reference soil from the site with a known Ra-226 concentration for field screening. Although the Rn-222 is a gas and the soil is not sealed, the soil retains over 80 % of Rn-222 gas within the soil matrix, resulting in a significant amount of Bi-214 decay product and its gamma radiations. Bi-214 609 KeV gamma radiation is at fairly high intensity (46%) and isolated, which mitigates interference from other energy gamma radiations. A single channel analyzer (SCA), such as Ludlum L221 integrated with Ludlum 44-20 3x3 NaI scintillation detector will be used to measure radiation of a particular energy of Bi-214. The heavily shielded counting chamber lowers the background counts without lowering the counting efficiency for that geometry and sample size, thus lowers the detectable concentration. For a quick estimate of Ra-226 in soil, a reference soil with a known Ra-226 concentration (similar to screening level), which is not previously sealed, the 609 KeV gamma radiation level of Bi-214 can be measured (pulse height analysis) for field screening. The sample in a plastic bag is placed in a counting chamber (1.5 inch thick x 7.5 Inch ID x 12 inch tall lead ring collimator with a 1.5 inch thick lead bottom shield) around the 3x3 NaI detector and 609 KeV gamma radiation counts are obtained and compared to the reference soil and sample soil for field screening. The soil screening results are estimated for confirmation of gamma survey results during excavation control, and are not used for Verification Survey (VS) confirmation of removal actions at specified limits. If the soil screening result is used for confirmation of VS and indicate that the sample concentration is at or below the Soil Action Level (SAL), the sample must be sent off site vendor laboratory analysis for confirmation.

## 2.0 L2221/44-20 Window Operation and Energy Calibration Procedure

The following procedure calibrates threshold directly in keV.

1. Setup the counting chamber shield system with L 44-20 detector inside the chamber and connected to L2221 scaler/ratemeter. The L44-20 3x3 NaI detector is situated in the shielded counting chamber with the detector crystal facing up.

2. Place RATEMETER multiplier switch to LOG position.

3. Unscrew and remove instrument calibration cover.

4. Press HV pushbutton. The HV should read out on the display directly in volts. While depressing the HV pushbutton, turn HV potentiometer maximum counterclockwise. The HV should be less than 50 volts.

5. Depress the THR pushbutton. Turn the THR potentiometer clockwise until 652 displays.

6. With WIN IN/OUT switch IN, depress the WIN pushbutton. Turn the WIN potentiometer until 20 appears on the display.

7. Switch WIN IN/OUT to OUT.

8. Connect the detector (Ludlum 44-20) and expose to Cs-137 source.

9. Increase HV (if HV potentiometer is at minimum, it will take approximately 3 turns before any change is indicated). While increasing the HV, observe the log scale of the ratemeter. Increase HV until ratemeter indication occurs.

10. Switch WIN IN/OUT switch to IN.

11. Turn the HV control until maximum reading occurs on the log scale. Increase HV until reading starts to drop off, and then decrease the HV for maximum reading.

12. Turn RATEMETER selector switch to the X1K position.

13. Press ZERO pushbutton and release. If meter does not read, switch to a lower range until a reading occurs.

14. Carefully adjust HV potentiometer until maximum reading is achieved on the range scale. The instrument is now peaked for Cs137 on both the LOG and Linear scales. Record HV for energy calibration.

    NOTE: When the THR control is adjusted, the effective window width remains constant. As an example, if the THR is set at 559, the WIN at 100, a 609 KeV peak +559 (100 divided by 2) will be centered in the window. Then the threshold point is equivalent to 559 KeV with a 100 KeV window and calibrated for 100 KeV per turn. Now if the thresh hold is reduced to 250, the threshold is equivalent to 250 KeV, but the window (100) is still equal to 100 KeV. Proportionally, this represents a broader window.

15. Set THR at 559 and window at 100 for Bi-214 609 KeV (559 to 669 KeV ROI) gamma radiation measurement. Expose the detector with a 1% Uranium ore function check source and obtain a one minute counts. Remove the function check source and obtain a one minute background counts.

16. Record the energy calibration data in the L2221SCA/L44-20 Energy Calibration Form (Attachment A).

## 3.0 Minimum Detectable Concentration

The calculation below is an example for illustrative purposes for minimum detectable concentration (MDC), and the actual MDC will be calculated in the field based on actual field background measurements from function checks. The MDC, for 0.05 probability for both false positive and false negative errors, is calculated using equation 6-7 in Section 6.7.1 of the MARSSIM Guidance,

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

Where,

C = Detector response factor, pCi/g/cpm

B = Background count rate in cpm.

Example:

For the 3x3 NaI detector of the soil screening system, estimated background count rate of 80 cpm from previous function checks and the detector response during 2018 Characterization of about 86 cpm/pCi/gm (570 net cpm for 3,000 gm reference soil @ 6.6 pCi/g of Ra-226) sample , then the Ra-226 MDC for a 3,000 gm screening sample for a one minute measurement is calculated to be:

$$MDC = (0.0116\ pCi/g/cpm) \times [3 + 4.65 \cdot \sqrt{(80\ cpm)}] = 0.79\ pCi/gm$$

The required MDC for the St. Anthony Mine Closeout is <3.3 pCi/g (50% of the 6.6 pCi/g SAL). The soil screening counting system will meet the required MDC limit of with one minute background counts of less than about 1000 cpm

Note: The MDC calculation assumes the weight of reference soil and screening soil to be same, 3000 grams, and the background and sample counting time be the same, least one minute. The measurement (integration) time of background and sample may be changed to attain desired MDC.

## 4.0 Field Soil Screening Procedure

1. Setup the L2221 parameters (HV, Threshold and Window) obtained during energy calibration above and connect the 44-20 detector. Make sure the window toggle switch is in the IN position.

2. Setup the counting chamber shield system in back of pick-up truck.

3. The L44-20 3x3 NaI detector is situated in the shielded counting chamber with the detector crystal facing up.

4. Perform background and source (1% Uranium ore) function checks and record in the Function Check Form (Attachment B).

5. Insert a clean plastic bag in the counting chamber for lining detector and counting chamber to avoid cross contamination. Obtain 3,000 grams of appropriate reference soil, not previously sealed, and place in the plastic bag so that the sample is around the detector without any void, similar to the Marinelli Beaker geometry to provide the best counting efficiency. Cover the chamber opening with lead lid.

6. Obtain an integrated count for specified time period, generally one minute, with L2221 in Scaler mode and record in the soil screening Field Form (Attachment C). The reference soil counts may be used for efficiency calculation (pCi/g/com) for MDC calculation.

7. Remove the plastic bag with soil. Insert new plastic bag in the chamber for liner. Homogenize sample in stainless steel bowl and weigh 3000 grams of sample. Repeat step 5 and 6 for next soil sample. Change counting chamber liner between every sample.

8. Compare the reference soil counts to the sample soil counts to determine the sample Ra-226 concentration at above or below the reference soil concentration.

9. Following completion of soil screening, split a sample aliquot if needed for confirmatory analysis using EPA Method 901.1 by vendor laboratory. Return the unused sample at the location collected from.

**QA/QC Procedure**

1. The instrumentation, L2221 must be calibrated at least annually. Although the operating HV for the 3x3 NaI detector for soil screening is established during energy calibration discussed above, an HV plateau should be performed at least annually to verify proper detector operation throughout the HV range.
2. The background and source (with uranium ore check source to verify 609 KeV ROI calibration) function checks must be performed daily prior to use.
3. The reference soil material concentration must be determined from vendor laboratory analysis, or prepared using a certified reference material.
4. Duplicate measurement will be performed for 5% of the samples.
5. For verification survey soil screening, any soil sample screening result less than SAL will be sent to a vendor laboratory for confirmation.

**Attachment A**

**AVM Environmental Services Inc.**
L2221 SCA/L44-20 Energy Calibration Form

SCA: L2221, SR #68782 Detector: Ludlum 44-20 (3x3 NaI Scintillator)

Calibration Source: Cs-137 Check Source, 5 uCi (August 2008) For 662 KeV Peak Cal

Threshold (input sensitiv **652**

Window, In/Ou **IN** Window **20**

HV Initial ____________, At Peak ______________

Maximum CPM: __________________________ Background CPM: __________________

HV Set @_______________ VDC

For Bi-214 609.2 KeV Peak (559 - 659 KeV ROI), Set Threshold @ 559, Window @ 100

CBi-214 609 KeV ROI Calibration Check: 1% U3O8 Ore Check Source: ________________ CPM
Background count (empty chamber) _____________ CPM

Date _________________________ Calibrated By _______________________________________

# Attachment B

**AVM Environmental Services, Inc.**
**Ludlum SCA L2221 - 44-20 3x3 NaI Detector Function Check**
**559 - 659 KeV Gamma Radiation Soil Screening**

L2221 #68782

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

Ludlum 44-20 3x3 NaI Detector, #PR295573

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

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

| Date | Physical Check | Cal Date | Battery[1] Volts or OK | HV Volts | Threshhold mV [2] | Window mV | Window In/Out | 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 220 mV; (3) Window @ 440, must be IN**

# Attachment C

## AVM Environmental Services, Inc.

## Field Soil Sample Gamma Radiation Screening Form

Instrumentation : Scaler/Ratemeter________________________, Detector __________________________________

Instrument Calibration Date: ___________________________, Instrument Function Check Performed: _________

Survey Area/Unit Decsription _________________________________________________________________

| Date/Time | Soil Sample ID | Sample Weight Grams | 609 (559-669) Kev Gross Counts | Weight Corrected Counts | CPM | Estimated Ra-226 pCi/g | Comments |
|---|---|---|---|---|---|---|---|
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Technician Signature ______________________________, Reviewed by _________________________________

# AVM SOP-5
# AVM Environnemental Services, Inc.
# Surface Soil Sampling
# St. Anthony Mine Closeout

## 1.0 Introduction

This standard operating procedure (SOP) describes methods and equipment commonly used for collecting environmental surface soil samples for radiologic analyses during the soil excavation action at the St. Anthony Mine Site (Site). The information presented in this SOP is generally applicable to the collection of all surface soil samples, except where the analyte(s) may interact with the sampling equipment. This SOP defines sample collection procedures using hand augers and shovels/trowels samplers. This document focuses on methods and equipment that are readily available and typically applied in collecting surface soil samples. It is not intended to provide an all-inclusive discussion of sample collection methods.

The objective of surface soil sampling is to characterize radiologic and chemical properties of the soil. Details pertaining to sample locations, number of samples, and type of analyses required, are presented in the Excavation Control (Appendix C.1) and Cleanup Verification Survey Plan (Appendix C.2).

## 2.0 Scope

This SOP describes procedures for surface soil sampling using hand tools for Ra-226, total uranium and metals analysis as required during the St. Anthony Mine Closeout.

## 3.0 Sample Type

Surface soil samples are typically collected from the ground surface to 6 inches below ground surface. Samples collected from greater than 6 inches below ground surface are referred to as subsurface soil samples. Soil sampling includes samples for confirmation of in-situ gamma radiation level and ex-situ gamma radiation soil screening, and for site-specific correlation Surface soil samples may be collected as grab samples or as composite samples. The sample method is determined based on the physical characteristics of the sample location and soil matrix.

- Grab sample: A sample taken from a particular location. Grab samples are useful in determining discrete concentrations, but also provide spatial variability when multiple samples are collected. Grab samples will be collected from sampling locations for the final status survey and during excavation control.

- Composite sample: A number of samples that are individually collected then combined (homogenized) into a single sample for subsequent analysis. Composite samples are useful when averaged or normalized concentration estimates of a waste stream or an area are desired. Also, multi-point composite samples may be collected for correlation sampling location.

## 4.0 Sampling Equipment and Technique

The following materials will be available, as required, during soil sampling activities:

- Personal protective equipment (PPE), as specified by the site HASP
- Stainless steel bowls
- Stainless steel spoons
- Stainless steel spatulas
- Stainless steel trowel
- Stainless steel spades
- Stainless steel hand augers
- Rock pick
- Permanent Indelible ink pens
- Tape measure or a ruler
- Sealable plastic bags (e.g., Ziploc®)
- Appropriate sample location coordinates and/or area maps or figures
- Equipment decontamination materials
- Transport container such as cooler (if sampling for laboratory analysis)
- Appropriate Field Sampling Data forms

A grab surface soil sample may consist of a single scoop or core, or the sample may be a composite of several individual samples. Surface soil samples shall be obtained using hand augers, shovels/trowels, or soil core samplers.

**Hand Auger:** A hand auger consists of a stainless steel tube with two sharpened spiral wings at the tip. The auger typically cuts a 2-inch to 3-inch diameter boring and works better in consolidated or slightly moist soils. Because the auger is hand-driven, penetration in dense or rocky/gravelly soil may be difficult. For surface soil sample collection, the procedures outlined below shall be followed.

1. Advance the auger by hand into the soil, to the desired depth (6 inches or less for surface soil samples), by turning in a clockwise direction with down force applied.

2. Retrieve the auger by pulling straight up until completely out of the hole, preferably without any rotation.

3. Fill the sample container, generally a Ziploc bag for Ra-226 and/or other container, using clean stainless steel spatulas or spoons. Repeat step 1 and 2 until a sufficient amount of sample is collected for specified analysis. For Ra-226 analysis by Method 901.1, about 400 grams in a quart size Ziploc bag is sufficient. For on-site ex-situ soil screening, about 3000 grams in a gallon size Ziploc bag will be required. Affix label on the sample container with appropriate sample information.

**<u>Shovel/Trowel:</u>** Various shovel/trowel designs and sizes are commercially available for a variety of sampling applications. These devices are hand-driven and are typically used for sampling relatively soft, unconsolidated surface soils. Some designs (e.g., the sharpshooterTM) can be driven into hard, rocky soil by opening a deep, narrow hole. All shovels or trowels used for soil sampling shall be made of stainless steel. The procedures outlined below shall be followed while collecting samples with shovels or trowels.

1. Drive the shovel/trowel into the soil six inches deep.

2. Retrieve the shovel/trowel being careful to not spill sample.

3. Fill the sample container, generally a Ziploc bag for Ra-226 and/or other type sample container for metals using clean stainless steel spatulas or spoons. Repeat step 1 and 2 until sufficient amount of sample is collected for specified analysis. For Ra-226 analysis by Method 901.1, about 400 grams in a quart size Ziploc bag is sufficient. For on-site ex-situ soil screening, about 3000 grams in a gallon size Ziploc bag will be required. Affix label on the sample container with appropriate sample information.

This procedure can also be used for collecting soil samples collected for ex-situ gamma radiation soil screening for subsurface soil investigation from the base of shallow test holes, pits or trenches excavated by hand tool such as a shovel or by a backhoe. Any soil sample collected for on-site ex-situ gamma screening may require sending to off-site vendor laboratory for Ra-226 analysis based on the ex-situ soil screening results. Split an aliquot for the off-site vendor laboratory from the ex-situ sample, which would had been already homogenized and of ample quantity.

## 5.0 Sample Equipment Decontamination

All sampling tool and equipment used for soil sampling will be clean prior to any soil sample collection. Sampling tools and equipment that are reusable will be decontaminated in between sample collection at different locations to avoid sample cross contamination. Hand tools, such as trowels, shovels, spoons, mixing bowls, etc. will be decontaminated at the sample locations. Any large equipment may be decontaminated at the designated decontamination area at the Site to for appropriate disposal of residual soil and rinsate. Since the sampling involves soil that may be potentially impacted by the COCs, Ra-226, uranium, and the COPC metals from uranium ore, which are mostly insoluble, the following procedure will be used to decontaminate soil sampling tools and equipment:

1. Brush off any loose soil from the sampling tool.
2. Wash the sampling tool with water and a residue free detergent, such as Alconox, in a bucket using a brush.
3. Rinse the sampling tool in a bucket with fresh water.
4. Rinse the sample tool with de-ionized water.

## 6.0 Investigation Derived Waste

The surface soil sampling is not expected to generate any Investigation Derived Waste (IDW) other than PPE (disposable gloves) and paper towels. Any excess soil from soil sample will be backfilled into the hole created from sample collection. Sampling tool decontamination rinse water will be poured on top of the backfilled sample hole for compaction. This method does not create any additional contamination or waste. If it is not feasible to put the excess sample back in the sample location, the excess soil will be contained and placed in the Pit which already contains elevated level of material, and will eventually be remediated.

## 7.0 Sampling Data Recording, Handling and

Field sampling documentation will be completed to provide sample information. Fill out sample information in the Field Soil Sample Log Form, included in Attachment A. Any additional information may be included in the log book. Sample handling requirements, such as storage, shipping and chain of custody, are specified in the Excavation Control (Appendix C.1) and Cleanup Verification Survey Plan (Appendix C.2). The soil samples collected for the COCs and CPOC metals do not require any specific preservatives. Complete sample chain of custody provided by laboratory. The field supervisor will retain all site documentation while in the field and add to project files when the field mobilization is complete.

## 8.0 QA/QC Requirements

Quality assurance quality control (QA/QC) includes following the SOP as discussed above, which includes proper decontamination to avoid cross contamination and sampling data recording and handling. Field QA/QC samples will be collected at the frequency specified in the work plan as listed below:

- Sampling equipment rinsate sample as discussed above in the section 5.0.
- Field QA/QC soil sample duplicate at a frequency of 10% of the samples collected.

Other applicable QA/QC requirements for laboratory, such as blanks, duplicate analyses, matrix spike are specified in the Cleanup Verification Survey Plan (Appendix C.2).

# Attachment A
# Field Soil Sample Log Form
# St. Anthony Mine Closeout

| Sample ID | Sample Date and Time | Sample Location (Coordinates) | Sample collection method/container/preservative | Analyses | Sample Type/Description | Comments/Notes | Sample Tech |
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Please include other applicable information, such as sampling activity/event, COC#, sampling depth, soil description, sample sub-location, etc in sample description or comments/notes