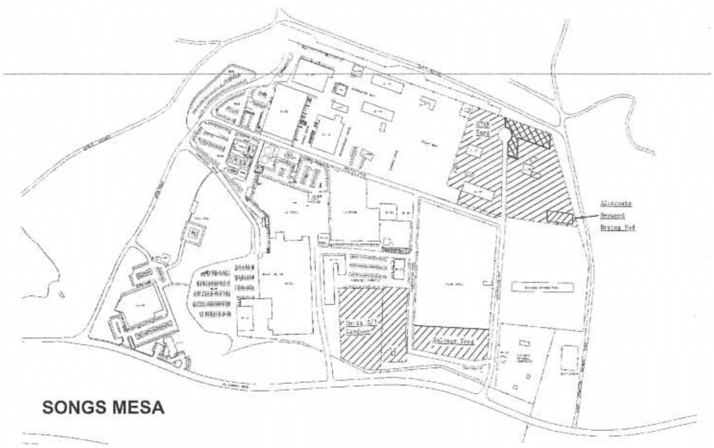
Upper Bound Radiation Dose Evaluation

San Onofre Nuclear Generating Station

Mesa Facility

San Clemente, CA



Upper Bound Radiation Dose Evaluation

This report provides an evaluation of the upper bound for radiation dose of a member of the public assuming the individual is exposed to radioactive contamination at the level of detection of the instrumentation used to survey the Mesa property. **It should be stressed that no contamination distinguishable from background was detected such that this estimation is hypothetical and does not represent actual conditions.**

UPPER BOUND RADIATION DOSE EVALUATION
Mesa Facility
San Onofre Nuclear Generating Station, San Clemente, CA

OBJECTIVE:

To provide an upper bound radiation dose estimate to a member of the public who occupies the Mesa property assuming residual radioactivity is present at the detection limits of the surveys conducted.

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A. INTRODUCTION

The Southern California Edison Company (SCE) leased land from the Department of the Navy (DoN) on the landward (east) side of Interstate 5 for San Onofre Nuclear Generating Station (SONGS) construction equipment/material staging and plant operational support and a small parcel on the west side of Interstate 5 that housed a security kiosk and access gate leading to the leased land on the east side of Interstate 5. The leased property was known as the Mesa. Much of the raised land consisted of spoils from the excavation of the SONGS Units 2 and 3 site that was transported to the Mesa during the late 1970's. A variety of facilities were eventually built at the Mesa including laydown areas for construction of SONGS Units 2 and 3, training facilities, the Emergency Operations Facility, engineering offices, a campground for outage workers, warehouses, medical building, paint shop, and other support buildings. Beginning in 1980, there were a number of events where radioactively contaminated items or materials were inadvertently transported from the plant to the Mesa where they were discovered. Reference 1 reviewed available records and determined that 11 events that occurred between December 1980 and November 2003 required additional consideration for radiological surveys. That document, essentially a Historical Site Assessment, followed the graded radiation survey and site investigation guidance of MARSSIM (Reference 2). Of those 11 events, 6 locations were identified as needing confirmatory surveys and 2 were identified as needing further evaluation of prior surveys (Reference 1 Recommendations). No other locations were deemed to require further investigation. Attachment 1 shows the SONGS Mesa map with cross-hatched areas identified as requiring further investigation.

B. PROBLEM STATEMENT

SCE no longer needs to use the Mesa Lease lands described above. In an August 20, 2015 letter, the DoN requested that SCE show that these lands "achieve a release criteria of no more than 12 mrem/year," or background. Since the Mesa property and land areas were never the subject of a Nuclear Regulatory Commission (NRC) radioactive materials license (other than a State-issued small sealed source training license terminated many years ago), a formal NRC license termination process does not apply. There are no levels of acceptable residual radioactivity because the endpoint of the lease termination process is essentially no detectable plant-related radioactivity remaining. That translates into no radioactivity distinguishable from background and therefore no radiation dose above background, a condition that has been shown by surveys on the Mesa Lease area. However, for comparison purposes, an upper bound of radiation dose to a hypothetical member of the public can be estimated by calculating the dose that would be accrued if residual radioactivity were present at the detection level of the instrumentation used in the surveys. This memorandum documents an upper bound evaluation such that comparisons to NRC license termination criteria may be made.

C. SURVEY TECHNIQUES

Three primary survey techniques were employed at the Mesa Facility (Reference 3) to validate that no residual radioactivity remained behind after historical remediation efforts (see Reference 1 for a history of the events, remediation, and follow-up surveys at the Mesa).

The three techniques employed were:

- For land areas, samples of soil were obtained in a process guided by MARSSIM (statistically based surveys) that provide a high level of confidence that no residual plant-related radioactivity remains at the Mesa. Reference 3 describes the implementation of MARSSIM principles into the survey plan for soil sampling, such as numbers of sample locations, laboratory equipment detection requirements, etc.

- Land areas were scanned using MARSSIM techniques to ensure that no areas of elevated radiation levels were present. Reference 3 describes the scanning requirements and how they align with MARSSIM guidance. These included audible signals, pause-and-count for elevated indications, maximum permissible scan speed, distance above grade, etc.
- Building surfaces were surveyed using MARSSIM based techniques to ensure that no residual radioactivity was present on structures that may have contained items in the past. As above, Reference 3 describes the survey requirements such as the use of a floor monitor for efficient operations.

Each of those techniques is reviewed below with an upper bound of sensitivity that can then be correlated to a conservatively estimated radiation dose to a hypothetical member of the public. As a foundation for these estimations, a discussion of the potential contaminants and sensitivity must first be presented to provide a basis for the survey techniques.

D. RADIONUCLIDE DISTRIBUTION

Previous analyses determined that Cs-137 is the dominant plant-related radionuclide and is probably the only potential plant related radionuclide that could be present. This is due to the length of time between the events that occurred at the Mesa and the present. A detailed evaluation of the radionuclide distributions (Reference 3), from both Unit 1 where the majority of the events originated, and from Units 2/3, is included in Attachment 2. The conclusion that Cs-137 is the predominant potential radioactive contaminant validates the proper instrument selection.

E. SENSITIVITY DETERMINATION

The three techniques used in Mesa surveys have the following sensitivities (see Attachment 3 for details):

1. The typical laboratory analysis demonstrated detection capability of about 0.11 pCi/g (see Reference 7 and attachments). This is sufficiently sensitive to detect environmental levels of Cs-137 that may be present due to long-term atmospheric weapons fallout, Chernobyl, or Fukushima. These sources have all been implicated in the presence of Cs-137 in environmental media over the years, particularly in surface soils. For the SONGS site, the Annual Radiological Environmental Operating Reports (Reference 9) document the detection of Cs-137 in surface soil both near the plant and at distant control locations.
2. Scan surveys with gamma-sensitive scintillation detectors have the capability of detecting Cs-137 contaminants in soil down to about 4 pCi/g (see Reference 3 and Attachment 3 to this document for detailed survey requirements necessary to achieve this sensitivity). This technique was used primarily to identify any locations in a survey area that could have elevated radiation levels due to the presence of plant-related radioactive contamination. If elevated levels were not identified, the randomly prescribed

soil sampling described in MARSSIM Table 5.9 for Class 3 areas provided a sufficiently high confidence (5% decision errors as described in MARSSIM Section 5.5.2.3) that there is no contamination present. It is noteworthy that the scan surveys using scintillation detectors were conducted on 100% of the accessible affected land areas, greatly exceeding Class 3 guidance in MARSSIM (crosshatching on the Attachment 1 map identifies the affected areas). A dose assessment based on this survey technique is not necessary since the sampling plan (#1 above) provides a high level of confidence (as above, consistent with MARSSIM Section 5.5.2.3 and Table 5.9) that there is no plant-related radioactivity present that is distinguishable from background.

3. Scan surveys of building surfaces along with disk smears to assess removable contamination were employed to determine if any contamination was detectable on building surfaces, particularly floors, in areas where events occurred or where contaminated items were discovered. The sensitivity of the floor monitor that was used, was about 500 – 600 dpm/100 cm^2 total contamination (note that the monitors provided an audible signal assuring sensitive indication by the operators). Again it is noteworthy that the floor monitor is efficient and provides consistency greater than typical Geiger-Muller pancake probe field instruments, supporting surveys of 100% of the accessible floor surfaces. Wall surfaces were surveyed using industry standard field instruments, the "pancake" Geiger-Muller probe and count rate meter. Those G-M field instruments have a sensitivity of 5000 dpm/100 cm^2 total contamination and 1000 dpm/100 cm^2 for removable contamination. Note that smear surveys for removable contamination is a technique beyond MARSSIM guidance and provides addition confirmation of the absence of radioactive contamination.

F. DOSE EVALUATION

The next step in the process is to convert instrument sensitivities to dose. The simplest and most conservative approach is to equate the NRC screening values (Reference 6) with their respective annual dose in the license termination process. That is, uniform Cs-137 soil contamination at 11 pCi/g is equivalent to 25 mrem/yr assuming a very conservative model in which the critical group (most highly exposed) lives on the property, grows and eats crops from the property, and drinks water from the property. For NRC purposes, this scenario equates to an unrestricted use of the property.

With that said, the radiation dose due to possible soil contamination may be assessed as follows:

- The extensive soil surveys conducted at the Mesa determined that no detectable contamination was present down to a Minimum Detectable Activity (MDA) of 0.11 pCi/g (laboratory analysis).

- Hypothetically, if uniform Cs-137 contamination existed in Mesa soil at 0.11 pCi/g, the resultant conservatively calculated dose to a member of the public would be:

- $$\frac{0.11\, pCi/g}{11\frac{pCi}{g}\ /\ 25\frac{mrem}{yr}}$$ = **0.25 mrem/yr**

Note that this value is very conservative since it is based on the resident farmer scenario in which a resident of the property grows and consumes all of his/her crops on the land and is exposed to direct radiation from residual contamination. The likelihood of such a scenario at the Mesa property is remote because the land is reserved for military activities, not farming nor public residence. Nevertheless, the eventual use will be unrestricted from a radiological perspective.

All of the buildings that were surveyed were found to have no detectable radioactivity and subsequent to those surveys, some buildings have been demolished. Two buildings remain: the W-50 warehouse and E-50 Training and Education Center. The E-50 building had only one very small location where a radioactive source was stored and that location was verified free of any radioactive contamination. The warehouse was also surveyed extensively, and since it was empty, large floor surfaces were available for the sensitive floor monitor to confirm no radioactive contamination was present. Similar to the soil contamination assessment above, the radiation dose due to possible floor contamination may be assessed as follows:

- The extensive floor surveys conducted in the Mesa buildings determined that no detectable contamination was present down to an MDA between 500 and 600 dpm/100 cm^2.

- Hypothetically, if uniform Cs-137 contamination existed on Mesa building floors at 600 dpm/100 cm^2, the resultant conservatively calculated dose to a member of the public would be (using the NRC screening value of 28,000 dpm/100 cm^2 for building surface Cs-137 contamination equivalent to 25 mrem/yr, Reference 6):

  - $$\frac{600\, dpm/100\, cm2}{28{,}000\frac{dpm}{100\, cm2}\ /\ 25\frac{mrem}{yr}}$$ = **0.54 mrem/yr**

Again, note that this is very conservative since most of the buildings under consideration have been demolished and only a few remain for Marine Corps use. As these do include the Warehouse that was surveyed, this dose scenario is relevant.

G. CONCLUSION

Based upon the detection level of the instruments used to survey for radiation at the Mesa, the dose to a hypothetical member of the public who might occupy Mesa properties (live as a resident, grow crops, etc.) could not be more than about 0.8 mrem/yr, the sum of the two hypothetical dose pathways. This value is exceedingly conservative since it is based on an assumption of uniform contamination of both soil and building floors that were determined to have no contamination distinguishable from natural background, and on the assumption that a resident lives on the property full-time and is exposed to these sources concurrently, a situation that may not be plausible but is very conservative for this analysis.

For comparison purposes, the detection level dose of 0.8 mrem/yr may be compared to (Reference 4):

- natural background from sources other than radon – approximately 100 mrem/yr
- average radon and progeny dose to Americans – approximately 200 mrem/yr
- a chest x-ray – 10 mrem

H. REFERENCES:

1. Memorandum for File, Assessment of Radiological Events at the Mesa, T Cooper, April 10, 2014
2. NUREG-1575, Revision 1, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), August 2000
3. Mesa Survey Plan, EM Goldin and TL Cooper, April 30, 2014
4. National Council on Radiation Protection and Measurements, Report No. 160 - Ionizing Radiation Exposure of the Population of the United States, 2009
5. Memorandum for File, Survey Sensitivity for Unconditional Release – Foundation for Program Requirements, EM Goldin, December 12, 2013.
6. NUREG-1757, Vol. 2, Revision 1, "Consolidated Decommissioning Guidance, Characterization, Survey, and Determination of Radiological Criteria," September 2006
7. Memorandum for File, Results of Confirmatory Radiological Survey of the Mesa, T Cooper, July 2, 2014
8. Scanning Sensitivity – Soil/Area Scans of Remediated Areas, SONGS Unit 1 - Revision 1, E.M. Goldin to J.M. Sills, January 11, 2005
9. Annual Radiological Environmental Operating Report, 2014 San Onofre Nuclear Generating Station, License Numbers: DPR-13, NPF-10, NPF-15, May 2015.

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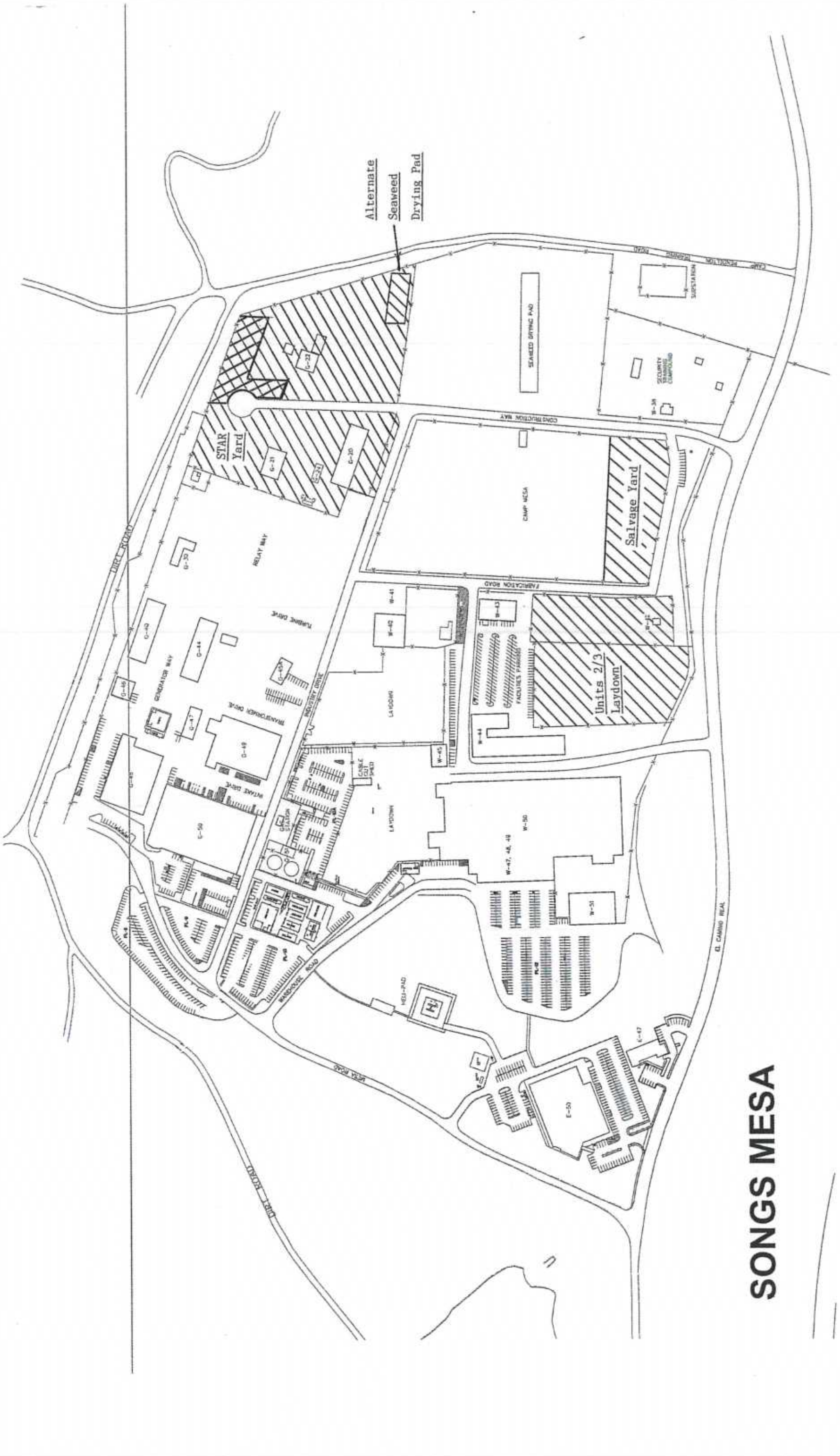
Alternate
Seaweed
Drying Pad
STAR
Yard
Salvage Yard
Units 2/3
Laydown
SONGS MESA

I.1 RADIONUCLIDE DISTRIBUTION

The radionuclides that may be present along with their relative abundances were discussed in Reference 3. The relevant section of that evaluation is presented below:

> One key objective for planning an appropriate and defensible survey is to identify the radionuclide distribution most suitable for the contaminated items/equipment and account for hard-to-detect radionuclides, if necessary.
>
> A second key objective is to provide guidance on survey methods that will be adequate to determine if the removal of radioactivity from the building or area was satisfactory to a prescribed level of "indistinguishable from background."
>
> The levels of contamination found on each piece of equipment were low but detectable using standard field instrumentation such as a G-M pancake probe and scaler ("frisker.") This industry standard instrument is sensitive to beta-gamma emitting radionuclides, typically the cesium isotopes and cobalt isotopes associated with fission products and activated corrosion products. Reference 3 *{Reference 5 above}* provided an evaluation that demonstrated frisker sensitivity to the radionuclide distribution associated with both Unit 1 and Units 2/3 contamination during plant operation and at varying times after permanent unit retirement. The frisker is approximately 10% or more efficient for the detection of these radionuclides, taking into account hard-to-detect radionuclides such as common electron-capture nuclides. Therefore, for all of the events, the industry standard field instruments, frisker and portable scintillation detector will be adequate for surveying. This is true now and was true when the items were discovered at the Mesa as well, when the contaminant mix was "fresh" with short-lived radionuclides present. It should be noted that a detailed analysis of the instrument capability to detect a specified fraction of the Derived Concentration Guideline Level (DCGL) as required by MARSSIM is not necessary because any contamination above instrument background is unacceptable.
>
> The Unit 1 profile evaluated in Reference 3 contained the following relative abundances of radionuclides:
> Co-60: 44%, Ni-63: 12%, Fe-55: 31%, and Cs-137: 10% as of year 2000 (Reference 3.)
>
> Items discovered at the Mesa that originated from Unit 1 were released between 1977 and the early to mid-1980's (Reference 1) *{Reference 1 above}*. At that age of greater than 30 years, Reference 3 demonstrated that frisker efficiency is well over 10% and, in fact, close to 20% due to the domination of Cs-137. Co-60 and other short-lived fission and activation products will have decayed to negligible amounts. Hard-to-detect radionuclides were accounted for in that evaluation and frisker efficiency included their contribution to reduced total efficiency. In addition to the analysis in Reference 3, twelve Dry Active Waste profiles were evaluated in a spreadsheet that showed the following distribution:

Co-60: 22%, Ni-63: 11%, Fe-55: 14%, Cs-134: 9%, and Cs-137: 41%. For these data, representing over 97% of the radioactivity, decay over the years leaves Cs-137 as the predominant radionuclide.

It is also noteworthy that the majority of the tools and items discovered at the Mesa originated at Unit 1 where, at the time of discovery, Co-60 dominated the radionuclide distribution making detection by field instruments relatively easy and sensitive.

Hence, for contamination due to radioactivity originating in Unit 1, standard field instruments were adequate during the time of discovery at the Mesa and remain adequate for confirmatory surveys in the present.

For potential contamination derived from Units 2/3, the analysis in Reference 3 contained the following relative abundances of radionuclides:
Cr-51: 33%, Ni-63: 11%, Fe-55: 14%, Co-58: 28%, Cs-137: 3% as of year 2013 (Reference 3.)

Items discovered at the Mesa that originated from Units 2/3 were released no later than 1990, greater than 20 years ago (Reference 1). At that age, Reference 3 demonstrated that the frisker efficiency remains about 10%. Again, like Unit 1, Co-60 in these events and other short-lived fission and activation products will have decayed to negligible amounts. In addition, hard-to-detect radionuclides were accounted for in that evaluation and frisker efficiency included their contribution to reduced total efficiency.

In conclusion, the radionuclide distribution from either Unit 1 or Units 2/3 contamination yields sufficient beta-gamma radiation emissions such that standard field instruments are adequately sensitive with appropriate detection efficiency. Note that both of the above conclusions accounted for hard-to-detect radionuclides that form a fraction of each of the distributions. This conclusion applies to historical surveys as well, confirming that surveys completed in the past (such as those conducted in the early 1980's to support recovery of contaminated tools) were adequately sensitive. Also, note that tritium was not present in the radionuclide distributions because it is not present in the dry active waste profiles that form the basis for those analyses. Therefore, no analysis for tritium is required because it was not present on any tools or equipment brought to the Mesa from the plant.

Lastly, one location, "k" in Room 105 of Building G-48, involved a specific exempt quantity source that was compromised. Chlorine-36 emits sufficiently high energy betas (709 keV max, 251 keV average, 98% abundance) such that a follow-up survey of that location with standard field instruments will have adequate efficiency and meets the requirements above for sensitivity.

The conclusion drawn was that standard field instruments were adequate to detect the contaminants that may have been present on tools and equipment found at the Mesa. Soil from land areas surveyed by gamma spectrometry is also represented by the same radionuclide distribution and those radionuclides are readily detected by the laboratory instruments used.

This discussion supports the position that the proper instruments were used and had adequate sensitivity to detect low levels of potential contaminants.

I.2 SENSITIVITY DETERMINATION

The three techniques used in Mesa surveys have the following sensitivities:

- Laboratory analyses of soil samples are reported automatically with a Minimum Detectable Activity or MDA. The MDA for the dominant Cs-137 radionuclide was typically about 0.11 pCi/g.

  For license termination (that is not applicable at the Mesa), the Nuclear Regulatory Commission provides "screening levels" that, under the most conservative scenarios, equate to 25 mrem/yr. Those levels are found in NUREG 1757, Table H.2 (Reference 6). The most relevant screening values for this evaluation are 11 pCi/g for Cs-137 and 3.8 pCi/g for Co-60. MARSSIM generally requires (Section 4.7.1) that surveys should be sensitive enough to detect between 10% and 50% of the Derived Concentration Guideline Level or DCGL. When screening values are used, the DCGL equals the screening value. Therefore the laboratory instrumentation for soil samples needed to be able to detect down to about 1.1 pCi/g. As noted above, the typical laboratory analysis demonstrated detection capability at a small fraction of this requirement, typically about 0.11 pCi/g (or equivalent to about 0.25 mrem/yr based on the above mentioned screening levels).

- Scan surveys have a sensitivity determined by a calculation of Minimum Detectable Count Rate or MDCR. Scans conducted at the Mesa utilized Eberline ASP-1/SPA-3 detectors, a 2" x 2" sodium iodide scintillation detector. Reference 6 Table 6.7 shows that such a detector is capable of detecting about 237 Bq/kg Cs-137. This equates to:

  $$\frac{237\ Bq/kg}{3.7E10\ Bq/Ci}\ x\ \frac{1E12\ pCi/Ci}{1000\ g/kg} = 6.4 \text{ pCi/g}$$

  In practice the sensitivity is greater because the background count rates were lower (Reference 7 showed background was typically 8000 cpm compared to the assumed 10,000 cpm).

  Following the guidance in MARSSIM Section 6.7.2.1, pages 6-43 through 6-46 and Reference 8, and using the same desired level of performance as in the MARSSIM example, (i.e. 95% correct detection, 60% false positive rate), *d'* = 1.38. With the background level of 8000 cpm and using a 1 second interval time (see Reference 3 for detailed survey requirements that included a specified maximum scan speed sufficient to meet this criterion and an audible signal that ensures a pause-and-count for increased count rates):

  $$bi = 8000\ cpm\ x\ 1\ sec\ \frac{1}{60\ sec/min} = 133\ counts$$

$$MDCR = 1.38\ x\ \sqrt{133}\ x\ \frac{60\ sec}{min} = 956\ cpm$$

$$MDCRsurveyor = 956\ x\ \frac{956\ cpm}{\sqrt{0.5}} = 1352\ cpm$$

The Technical Manual for the SPA-3 detector (http://www.thermoscientific.com/content/tfs/en/product/spa-3-high-sensitivity-gamma-detector.html) indicated 1.2 Mcpm/(mR/hr) for Cs-137. This is equivalent to 1200 cpm/(μR/hr). The minimum detectable count rate is the $MDCR_{surveyor}$ divided by the ratio of count rate to exposure rate or 1352/1200 = 1.13 μR/hr.

Following the example in MARSSIM and assuming the same modeling results for μR/hr above background as a function of residual radioactivity in soil (5 pCi/g yielding 1.307 μR/hr):

$$scan\ MDC = \frac{(5\,pCi/g)(1.13\ \mu R/hr)}{1.307\ \mu R/hr} = 4.3\text{ pCi/g}$$

This value, 4.3 pCi/g is well below the screening value of 11 pCi/g for Cs-137 pointed out above (note there is no "elevated measurement concentration" as described in MARSSIM). Similarly, for the periods in which an elevated count rate might have occurred (during perceived increase in audible signal), the increased monitoring period of 5 seconds adequately compensated for the higher background counts and the MDC_{scan} remained well below 11 pCi/g.

Note that MARSSIM guidance (in Table 5.9) recommends that scan surveys of Class 3 land areas should be "judgmental," focusing on the locations of highest potential such as corners, ditches, and, drains. In the Mesa surveys, land areas were scanned with considerably greater detail and coverage than required for a Class 3 area (Mesa land surveys covered 100% of accessible areas, see Reference 3 for detailed requirements for land area survey scans). While a scan MDC is not required for Class 3 land area surveys, this evaluation ensured that the instruments used were sensitive enough to detect down to, and below the screening levels.

- Lastly, the sensitivity of scan surveys of building surfaces along with disk smears to assess removable contamination may be estimated using MARSSIM recommendations. Drawing from MARSSIM and previous evaluations:

  Scan and static building surface surveys were conducted with instrumentation that has improved sensitivity over industry standard field instruments. In the case of a potentially contaminated floor, an instrument such as the FLM-3B floor monitor was employed. Previous studies have shown that these detectors are capable of detecting very low levels of contamination. In fact the scan MDC falls within the range of 500 - 1400 dpm/100 cm^2 depending on the instrument utilized and the conditions (such as uniformity of contamination). The MARSSIM-based determination of scan MDCs for the floor monitor follows. The bounding surface contamination, using Cs-137 as the dominant radionuclide was 28,000 dpm/100 cm^2 based on Table H.1 in Reference 6.

MARSSIM (Section 6.7) requires that a detector used for scanning surveys have sufficient sensitivity to detect radioactive contamination at a fraction of the acceptance criterion (or DCGL). The suggested guidance is that the Minimum Detectable Concentration (MDC) should be as far below the DCGL as possible, with values less than 10% of the DCGL being preferred and up to 50% of the DCGL being acceptable.

MDCs for surface scans for structure surfaces for beta- and gamma-emitters may be computed as follows (MARSSIM equations 6-8, 6-9, and 6-10.

$$s_i = d' \sqrt{b_i}$$

where s_i	=	net source counts per interval
d'	=	sensitivity index (MARSSIM Table 6-5)
b_i	=	expected background counts during time period i

$$MDCR = s_i\ (60/i)$$

where s_i	=	minimum number of net source counts per interval
i	=	time interval (seconds) of the observation while the probe passes over the source
$MDCR$	=	Minimum Detectable Count Rate (per minute)

$$MDC_{structure,scan} = \frac{MDCR}{\sqrt{p}\varepsilon_i \varepsilon_s\ (\frac{A}{100})}$$

where p	=	surveyor efficiency,
ε_i	=	instrument efficiency for the emitted radiation (cpm/dpm),
ε_s	=	source efficiency (intensity) in emissions per disintegration,
A	=	sensitive area of the detector (cm^2),

A value of 1.38 used for the sensitivity index corresponds to a 95% confidence level (5% false negative rate) for detection of a concentration at the scanning MDC with a false positive rate of 60% (MARSSIM Table 6.5 for a "first stage" scan). For a second stage scan where the operator holds the detector for twice as long (4 seconds), the sensitivity index increases to 2.48 (20% false positive rate). As before, details regarding the survey requirements and sensitivities are described in Reference 3. The numerator represents the minimum detectable count rate that the observer would "see" at the performance level represented by the sensitivity index. The surveyor efficiency (p) is set at 0.5 as recommended in MARSSIM also. The factor of 100 corrects for probe areas that are not 100 cm^2. In the case of a scan measurement, the counting interval is the time the probe is actually over the source of radioactivity. This time depends on scan speed, the size of the source, and the fraction of the detector's sensitive area that passes over the source; with the latter depending on the direction of probe travel. The source efficiency term (ε_s) may be adjusted to account for effects such as self-absorption, as appropriate. A specific survey documented the efficiency calculation – survey #040730-007.

Applying these equations to two of the advanced detectors available for large area surface surveys we find for a ^{137}Cs radionuclide potential contaminant:

^{137}Cs

	FLM-3B		Electra+ / BP-19		
Scanning Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	2nd Stage
Distance From Surface	1"	1"	1/2"	1/2"	Contact
Background (cps)	40	40	8	8	8
i (sec.)	2	4	1	4	4
d'	1.38	2.48	1.38	2.48	2.48
b_i	80	160	8	32	32
MDCR (cps)	6.2	7.8	3.9	3.5	3.5
p	0.50	0.50	0.50	0.50	0.50
ε_i	0.34	0.34	0.46	0.46	0.54
ε_s	0.50	0.50	0.50	0.50	0.50
Probe size (cm^2)	600	600	100	100	100
Scan MDC (dpm / 100 cm^2)	513	652	1,440	1,294	1,102

Note that the Scan MDC for the FLM-3B, the instrument used for floor surveys at the Mesa, was well below the MARSSIM recommendation that Scan MDC's fall below 10% of the 28,000 dpm/100 cm^2 screening value for Cs-137.