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AN AERIAL RADIOLOGICAL SURVEY OF THE DOUBLE TRACK SITE AND SURROUNDING AREA

CENTRAL NEVADA

DATE OF SURVEY: DECEMBER 1993

MASTER

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AN AERIAL RADIOLOGICAL SURVEY OF THE DOUBLE TRACK SITE AND SURROUNDING AREA

CENTRAL NEVADA

DATE OF SURVEY: DECEMBER 1993

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1.0 INTRODUCTION

An aerial radiological survey of the Double Track Site was conducted in December 1993. An interim report entitled "An Aerial Radiological Survey of the Double Track Site and Surrounding Area," EGG 11265-1086, was issued. That report described survey procedures and presented terrestrial exposure rate and wide-area-averaged plutonium isopleth plots. This letter report presents additional plutonium plots and some "rule-of-thumb" calculations which should help the reader to properly interpret the data presented.

Attached to this report are three isopleth plots produced from the Double Track data. No one processing method provides all the answers regarding a particular surveyed area. Where peak values are most important, Figure 1, created from the original unsmoothed data, is the presentation of choice. Figure 2, from smoothed data, is superior for the detection of areas of widespread low-level contamination. Figure 3, also smoothed data, satisfied a particular early mission goal but is not as useful for cleanup operations as the other two. Figure 3 is presented for historical completeness only.

2.0 DATA

2.1 Unsmoothed (Original) Data

The isopleth presented in Figure 1 was generated from the as-measured data using the original second-by-second position and concentration values. Nominal line spacing for the data set was 150 feet, nominal along-track spacing was 120 feet, and nominal altitude was 100 feet. No averaging, smoothing, or gridding was done.

Data processed in this manner gives the best possible spatial resolution and best possible determination of concentration in small areas. This latter point is very important. If a contaminated area is small with respect to the detector's field-of-view, then the maximum concentration in that area (peak value) is averaged with surrounding lower values, which results in underestimation of the actual concentration. It also causes the contaminated area to appear larger than it should.

Smaller detector footprints minimize this characteristic, but at a significant cost to sensitivity. The second-by-second acquisition time yields rather poor counting statistics; therefore, the method does not have good sensitivity for low-level, wide-area contamination.

It should be noted that even the as-measured data of Figure 1 does not necessarily produce an accurate representation of ground-level conditions. Simple relationships describe the effect that a given detector spatial response will have on a given input. While the relationships are exact only for Gaussian-shaped functions, actual functions approximate the Gaussian well enough that the relationships are applicable for most estimate purposes.

The first equation relates widths of the involved functions:

$$OW = ((IW)^2 + (RW)^2)^{1/2} \quad (1)$$

where

OW = observed full width at half max (FWHM)
IW = input (ground deposition) FWHM
RW = detector point source response FWHM

The second equation relates peak and width relationships:

$$OP/IP = IW/OW \quad (2)$$

where

OP = observed peak amplitude
IP = input (ground deposition) peak amplitude

As an illustration, consider the following set of parameters:

Assume a detector response FWHM = 200 feet
(approximate value for 100 foot altitude)

Assume a ground deposition (input) FWHM = 300 feet

From (1), the observed FWHM will be:

$$OW = ((300)^2 + (200)^2)^{1/2} = 361 \text{ feet}$$

From (2), the observed peak value multiplier will be:

$$OP/IP = IW/OW = 300/361 = 0.831$$

The following table was generated using (1) and (2) with an assumed detector response (RW) of 200 feet (assumed altitude 100 feet).

INPUT (GROUND DEPOSITION) FWHM (IW IN FEET)	OBSERVED FWHM VALUE (OW IN FEET)	RELATIVE PEAK VALUE (OP/IP)	PEAK CORRECTION (IP/OP)
2	200.0	0.0100	100.0
5	200.1	0.0250	40.02
10	200.2	0.0500	20.02
20	201.0	0.0995	10.05
50	206.2	0.2425	4.124
100	223.6	0.4472	2.236
200	282.8	0.7071	1.414
500	538.5	0.9285	1.077
1000	1020.	0.9806	1.020
2000	2010.	0.9950	1.005

Note that for narrow input FWHM, the observed FWHM is essentially that of the detector response function. Within normal field measurement tolerances (about +/- (5%)), virtually no information exists in such observed data to define the input width other than that it appears to be equal to or less than 50 feet FWHM and that the peak correction value is greater than 4.124. For a source of extent less than one inch, the peak correction value could exceed three orders of magnitude! Only for input FWHM in excess of 500 feet can the detector spatial response function be considered negligible.

For observed widths differing by a reasonable amount from the detector response function width, estimates can be made of the true input width and peak correction factor. From the data used to generate Figure 1, over the area of peak activity, the measured FWHM was 270 feet and the peak value was 1443 pCi/gm. Rearranging (1) and (2), and solving for the apparent input parameters gives:

Estimated input width is:

$$\begin{aligned}
 IW &= ((OW)^2 - (RW)^2)^{1/2} & (1a) \\
 IW &= ((270)^2 - (200)^2)^{1/2} \\
 IW &= 181 \text{ feet}
 \end{aligned}$$

and estimated input peak is:

$$\begin{aligned} \text{IP} &= (\text{OW/IW}) * \text{OP} & (2a) \\ \text{IP} &= (270/181) * 1443 \\ \text{IP} &= 2152 \text{ pCi/gm} \end{aligned}$$

One may also calculate the uncertainty of the estimate. As previously mentioned, the uncertainty of the observed FWHM is approximately +/- (5%), so that the observed width becomes 181 +/- (5%) or 172 to 190 feet. Using (2a) to calculate corresponding peak values gives:

$$\begin{aligned} \text{min FWHM} &= 172 \text{ feet, max peak} = 2265 \text{ pCi/gm (round to 2300)} \\ \text{max FWHM} &= 190 \text{ feet, min peak} = 2050 \text{ pCi/gm (round to 2000)} \end{aligned}$$

NOTE: Four digits were carried in parameters of the examples to precisely illustrate changes and relative values associated with the estimation technique. This does not imply four-digit accuracy in any real value. The estimated peak ground deposition is appropriately stated to only two digits as "2000 to 2300 PCI/GM."

2.2 Smoothed Data: Sample Grid of 150-foot Elements, 9-point Neighbor Averaging

The isopleth presented in Figure 2 was created using a new analysis algorithm. This algorithm averages data over a region significantly larger than the detector's field-of-view. This substantially increases the measurement sensitivity, but at a cost of reduced spatial resolution and aggravated underestimation of the peak value.

The original second-by-second data were resampled to create a grid with 150-foot elements. This grid matches the nominal original line spacing and is reasonably close to the nominal along-track point spacing. The gridded data are averaged so that each element of the grid is the average of the nine nearest neighbors. Isopleths were generated using this averaged data within the 150-foot grid elements.

Use of the averaging technique greatly improves low-level statistical uncertainty and allows setting of lower-level detection limits for areas of widespread low-level contamination. Spatial resolution is degraded, but the location of peak values is reasonably well preserved. Peak values from areas of contamination which are small with respect to the sampling neighborhood are underestimated more strongly than peak values from unsmoothed/averaged data.

2.3 Smoothed Data: Sample Grid of 450-foot Elements

The isopleth presented in Figure 3 is a reproduction of the one informally distributed earlier and is essentially the same as that presented in the preliminary report. It was created utilizing the data smoothing algorithm which was the predecessor of that described above. This algorithm was designed to map widespread contamination associated with atmospheric nuclear testing with optimal sensitivity.

The algorithm assumes that the contamination is so widespread that it is relatively uniform over many times the detector's field-of-view. The original second-by-second data were resampled to create a grid of 450-foot elements. Approximately 11 original points are averaged within each 450-foot grid element. As previously discussed, such averaging improves detectability for widespread contamination areas. Isopleths were generated using the averaged data projected on the 450-foot grid.

As with Figure 2, low-level detection limits are improved by this technique. However, peak values are not well preserved and an additional uncertainty exists in the location of the peak, because the spatial resolution can be no better than the resampled point spacing (450-foot).

The data set for Figure 3 was the first distributed because it generally is very conservative, showing contamination where there is even the slightest possibility of its presence. This was the perceived short-term goal of the surveys done at the Clean Slates and at Double Track. Later discussions led to the understanding that spatial resolution and improved determination of peak values were also very important.

3.0 COMMUNICATION

There are many useful other data products that can be generated from the aerial survey data. It is essential that communications exist between RSL scientific personnel and Double Track principals so that proper products may be provided and that proper interpretations may be applied to existing and future products.

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AN AERIAL RADIOLOGICAL SURVEY OF
DOUBLE TRACK SITE
AND SURROUNDING AREA
CENTRAL NEVADA
EGG 11265-1146

DATE OF SURVEY: DECEMBER 1993
DATE OF REPORT: JULY 1995

0

1000

200

FIGURE
DOUBLE TRACK
UNSMOOTHED (C)

4947 T

4985

4 173 000m N

4000

PLUTONIUM CONTAMINATION ISOPLETH (FROM MEASURED AM-241) FOR THE DOUBLE TRACK SITE. THE EXCLUSION FENCE IS SHOWN IN GREEN.

NO SPATIAL FILTERING WAS DONE ON THE MEASURED DATA. THIS GIVES THE BEST POSSIBLE SPATIAL RESOLUTION AND PEAK VALUE DETERMINATION FOR SMALL AREAS AT THE EXPENSE OF DEGRADING SENSITIVITY FOR LOW-LEVEL LARGE AREAS.

~~Radioactive Area~~

Area

50000

E

LETTER LABEL	PLUTONIUM pCi/gram
D	< 100
E	100 - 158
F	158 - 250

Target

D

4 171 000m N

4857T

501 000m E

E

LETTER LABEL	PLUTONIUM pCi/gram
D	< 100
E	100 - 158
F	158 - 250
G	250 - 400
H	400 - 630
I	630 - 1000
J	1000 - 1580

Data were taken at 100 feet above ground at 70 knots ground speed. The detector array consisted of 8 - 2 x 4 x 16 inch NaI(Tl) detectors.

Conversion assumptions were:

cosine detector response

3 cm relaxation depth

2.5 cm sample depth

Pu Am ratio = 10

Photopeak cts = window cts x 1.6

502 000m E

1000

2000

1000

FIGURE 2
DOUBLE TRACK
SMOOTHED D.
SAMPLE GRID 150
9 POINT NEIGHBOR

4947T

4985T

4 173 000m N

3000

4000

E 2
ACK SITE
DATA
150 FOOT
OR AVERAGE

PLUTONIUM CONTAMINATION
ISOPLETH (FROM MEASURED AM-
241) FOR THE DOUBLE TRACK
SITE. THE EXCLUSION FENCE IS
SHOWN IN GREEN.

NINE-POINT-NEIGHBOR SPATIAL
FILTERING WAS DONE ON THE
MEASURED DATA. THIS
IMPROVES SENSITIVITY FOR
LOW-LEVEL LARGE AREAS AT
THE EXPENSE OF DEGRADING
PEAK VALUE DETERMINATION
AND SPATIAL RESOLUTION OF
SMALL AREAS.

*Radioactive
Area*

4918AT A

4925T

4977

4 172 000m N

Target

LETTER LABEL	PLUTONIUM pCi/gram
A	<25
B	25 - 40
C	40 - 63
D	63 - 100

Target

4 171 000m N

4857T

LETTER LABEL	PLUTONIUM pCi/gram
A	<25
B	25 - 40
C	40 - 63
D	63 - 100
E	100 - 158
F	158 - 250
G	250 - 400
H	400 - 630
I	630 - 1000
J	1000 - 1580

Data were taken at 100 feet above ground at 70 knots ground speed. The detector array consisted of 8 - 2 x 4 x 16 inch NaI(Tl) detectors.

Conversion assumptions were:

cosine detector response

3 cm relaxation depth

2.5 cm sample depth

Pu Am ratio = 10

Photopeak cts = window cts x 1.6

0

1000

2000

FEET

FIGURE 3
DOUBLE TRACK
SMOOTHED D.
SAMPLE GRID 450

4947T

4 173 000m N

4985T

A

E

F

G

F

E

D

C

B

4918AT

A

3000

4000

E 3
ACK SITE
DATA
450 FOOT

PLUTONIUM (MEASURED AM-241)
CONTAMINATION ISOPLETH FOR
THE DOUBLE TRACK SITE. THE
EXCLUSION FENCE IS SHOWN IN
GREEN. NOTE CONTAMINATION
OUTSIDE THE EXCLUSION
FENCE.

Radioactive
Area

5000

F

E

D

C

B

A

B

C

B

A

B

C

D

E

4925T

4918AT

4917T

4 172 000m N

Target

Target

4 171 000m N

LETTER LABEL	PLUTONIUM pCi/gram
A	< 25
B	25 - 30
C	30 - 40
D	40 - 60
E	60 - 100
F	100 - 130
G	130 - 200

Data were taken at 100 feet above ground at 70 knots ground speed. The detector array consisted of 8 - 2 x 4 x 16 inch NaI(Tl) detectors. A 450 x 450 foot pixel was used for summing data.

Conversion assumptions were:
cosine detector response
3 cm relaxation depth
2.5 cm sample depth
Pu/Am ratio = 10
Photopeak cts = window cts x 1.6

501 000m E