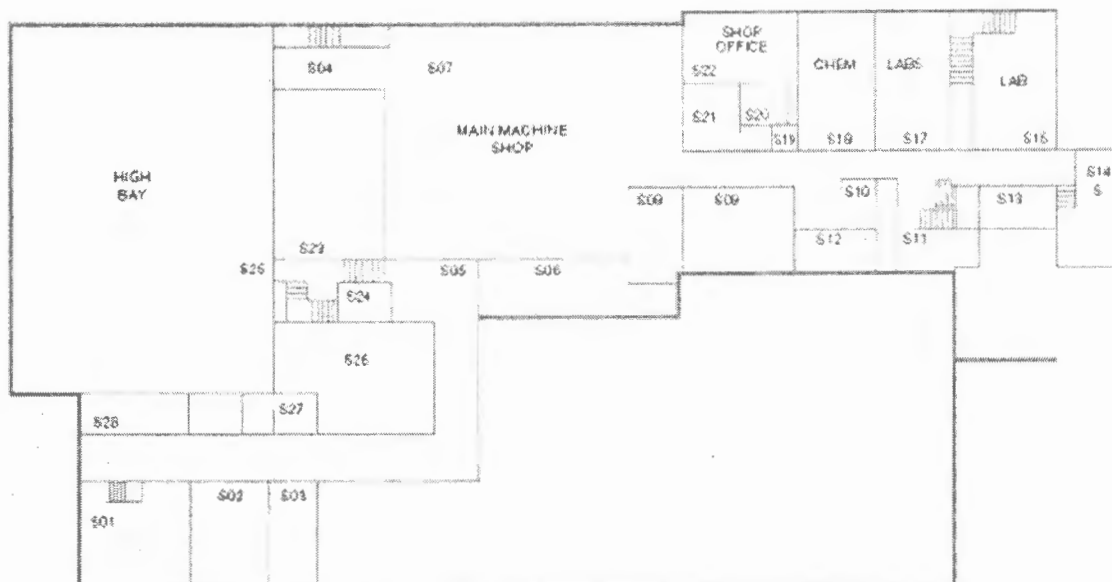
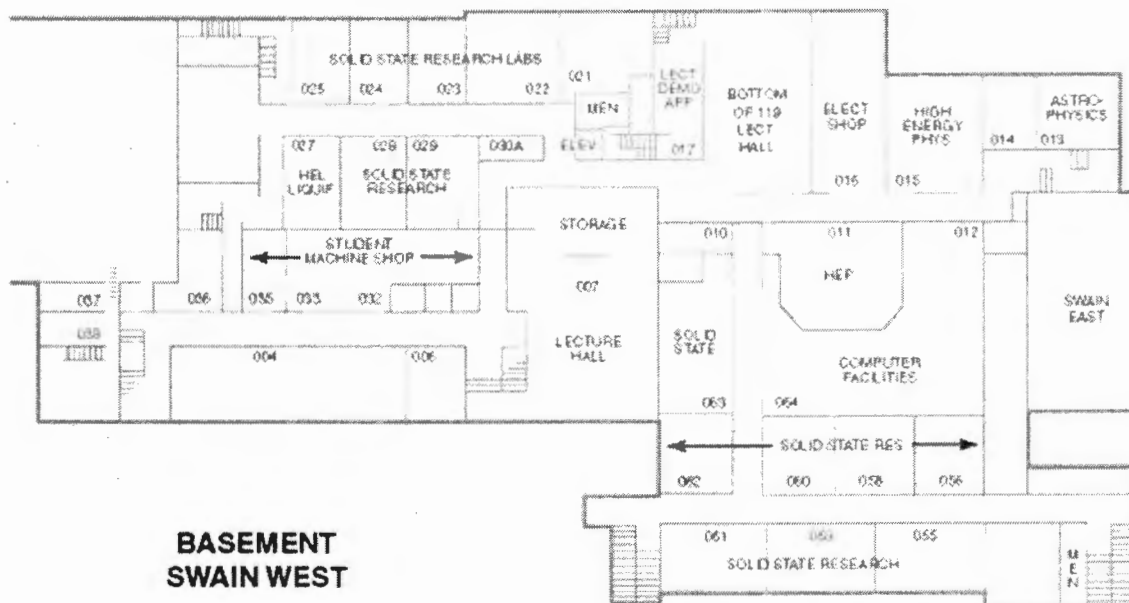


Attachment 1

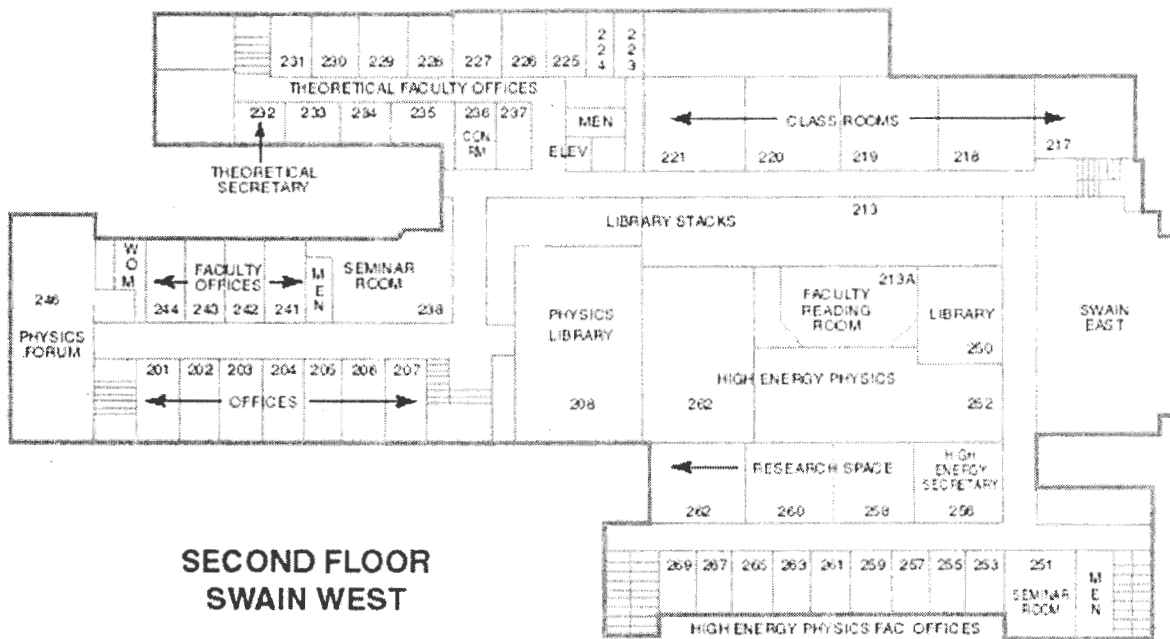
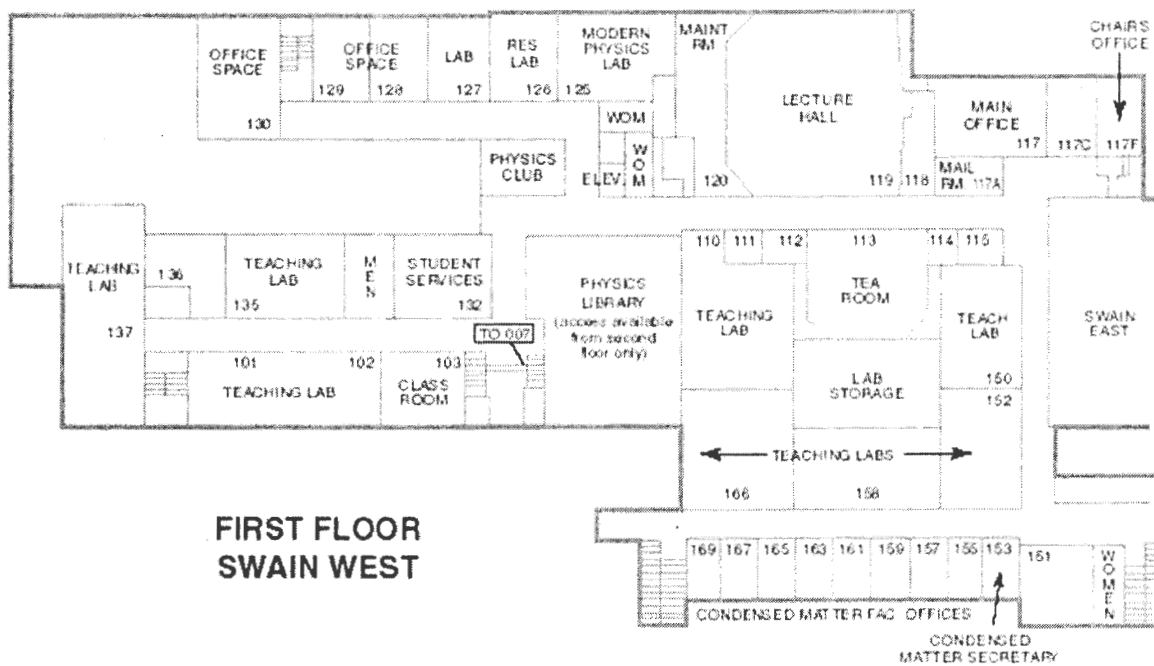
Floor Layout of Swain Hall West

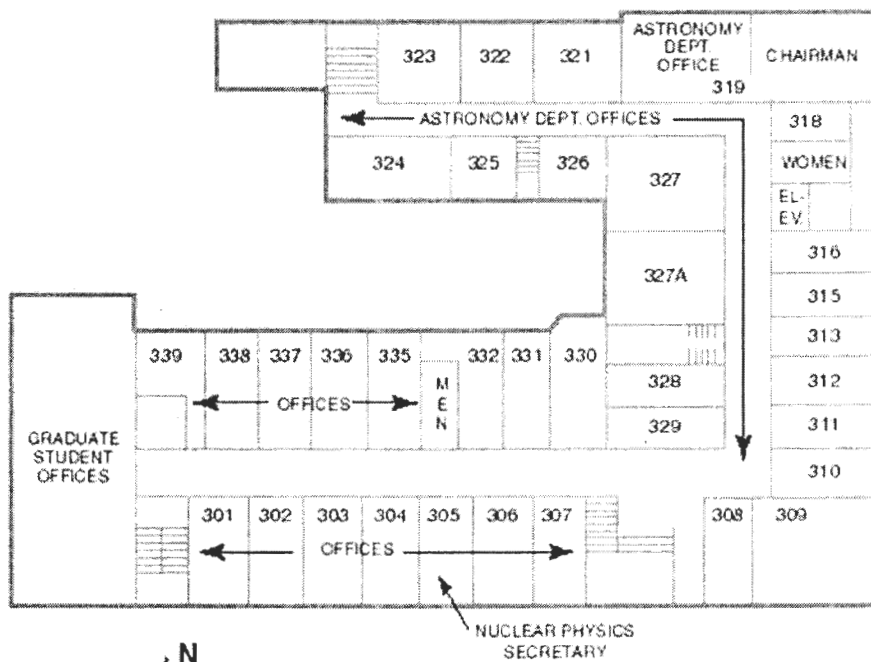


**SUB - BASEMENT
SWAIN WEST**



**BASEMENT
SWAIN WEST**





**THIRD FLOOR
SWAIN WEST**

Attachment 2

RESRAD-BUILD DCGL_{surface} Modeling for Radionuclides of Concern

Title : Bi-207

Input File : sitel.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : Bi-207

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime | Inhalation [m3/day] | Ingestion(Dust) [m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : Bi-207

Input File : site1.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion | Inhalation | Submersion |
|--------|-----------|------------|------------|------------------------|
| | [dpm/m2] | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| BI-207 | 3.400E+06 | 2.468E-06 | 9.009E-06 | 3.967E-03 |

Title : Bi-207

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

=====

Assessment for Time: 1

Time =0.00E+00 yr

=====

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | BI-207 | 3.400E+06 |

Evaluation Time: 0.00000000E+00 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

```
[mrem]
```

| Source | Total |
|--------|-------|
|--------|-------|

1

| | | | |
|----------|---|----------|----------|
| Receptor | 1 | 2.46E+01 | 2.46E+01 |
|----------|---|----------|----------|

| | | |
|-------|----------|----------|
| Total | 2.46E+01 | 2.46E+01 |
|-------|----------|----------|

Title : Bi-207

Input File : site1.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 2.24E+01 | 1.73E+00 | 1.83E-02 | 2.73E-01 | 0.00E+00 | 1.99E-01 |
| Total | 2.24E+01 | 1.73E+00 | 1.83E-02 | 2.73E-01 | 0.00E+00 | 1.99E-01 |

Title : Bi-207

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| BI-207 | 2.46E+01 | 2.46E+01 |

Title : Bi-207

Input File : sitel.bld

Evaluation Time: 1.00000000 years

=====

Assessment for Time: 2

Time =1.00E+00 yr

=====

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 0.000E+00

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration [dpm/m2] |
|-----------------|---------|---------------------------|
| | BI-207 | 1.669E+06 |

Title : Bi-207
Input File : sitel.bld
Evaluation Time: 1.00000000 years

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses

[mrem]

| Source | | Total |
|----------|---|-------------------|
| 1 | | |
| Receptor | 1 | 1.46E+01 1.46E+01 |
| Total | | 1.46E+01 1.46E+01 |

Title : Bi-207

Input File : site1.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 1.46E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Total | 1.46E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Title : Bi-207

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| BI-207 | 1.46E+01 | 1.46E+01 |

Title : Bi-207

Input File : sitel.bld

Full Summary

RESRAD-BUILD Dose (Time) Tables

Receptor Dose Received for the Exposure Duration

(mrem)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.46E+01 1.46E+01

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.46E+01 1.46E+01

Title : Eu-152

Input File : site1.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : Eu-152

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime | Inhalation [m3/day] | Ingestion(Dust) [m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Title : Eu-152

Input File : sitel.bld

===== Building Information =====

Building Air Exchange Rate: 8.00E-01 1/hr

| Height[m] | Air Exchanges [m3/hr] | |
|-------------|-----------------------|------------------|
| Area [m2] | ***** | |
| | * | * |
| | * | * |
| | * | <=Q01: 7.20E+01 |
| H1: 2.500 | * Room 1 | * Q10 : 7.20E+01 |
| | * LAMBDA: 8.00E-01 | * |
| Area 36.000 | * | * |
| | * | * |
| | ***** | |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : Eu-152

Input File : sitel.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion | Inhalation | Submersion |
|--------|-----------|------------|------------|------------------------|
| | [dpm/m2] | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| GD-152 | 0.000E+00 | 7.252E-05 | 1.095E-01 | 0.000E+00 |
| EU-152 | 4.000E+06 | 2.919E-06 | 9.955E-05 | 2.973E-03 |

Title : Eu-152

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

```
=====
|                                     |
|                                     |
|===== Assessment for Time: 1      |=====
|                                     |
|===== Time =0.00E+00 yr          |=====
|                                     |
|=====
|                                     |
|=====
```

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | GD-152 | 0.000E+00 |
| | EU-152 | 4.000E+06 |

Title : Eu-152

Input File : site1.bld

Evaluation Time: 0.00000000E+00 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

Source Total

1

Receptor 1 2.45E+01 2.45E+01

Total 2.45E+01 2.45E+01

Title : Eu-152

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 1.94E+01 | 1.44E+00 | 1.53E-02 | 3.36E+00 | 0.00E+00 | 2.62E-01 |
| Total | 1.94E+01 | 1.44E+00 | 1.53E-02 | 3.36E+00 | 0.00E+00 | 2.62E-01 |

Title : Eu-152

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| GD-152 | 1.24E-11 | 1.24E-11 |
| EU-152 | 2.45E+01 | 2.45E+01 |

Evaluation Time: 1.00000000 years

```

Assessment for Time: 2
Time =1.00E+00 yr

```

Source Information

Pathway ::

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration [dpm/m2] |
|-----------------|---------|---------------------------|
| | GD-152 | 1.251E-08 |
| | EU-152 | 1.898E+06 |

Title : Eu-152

Input File : sitel.bld

Evaluation Time: 1.00000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

| Source | Total |
|--------|-------|
|--------|-------|

1

| | | |
|------------|----------|----------|
| Receptor 1 | 1.22E+01 | 1.22E+01 |
|------------|----------|----------|

| | | |
|-------|----------|----------|
| Total | 1.22E+01 | 1.22E+01 |
|-------|----------|----------|

Title : Eu-152

Input File : site1.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 1.22E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Total | 1.22E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Title : Eu-152

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| GD-152 | 0.00E+00 | 0.00E+00 |
| EU-152 | 1.22E+01 | 1.22E+01 |

Title : Eu-152

Input File : sitel.bld

Full Summary

RESRAD-BUILD Dose (Time) Tables

Receptor Dose Received for the Exposure Duration

(mrem)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.45E+01 1.22E+01

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.45E+01 1.22E+01

Title : Eu-154

Input File : site1.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : Eu-154

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime [m3/day] | Inhalation [m2/hr] | Ingestion(Dust) [m2/hr] |
|----------|------|----------|----------|----------|----------------------|-----------------------|----------------------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Title : Eu-154

Input File : sitel.bld

===== Building Information =====

Building Air Exchange Rate: 8.00E-01 1/hr

| Height[m] | Air Exchanges [m3/hr] | |
|-------------|-----------------------|------------------|
| Area [m2] | | |
| | ***** | |
| | * | * |
| | * | * |
| | * | <=Q01: 7.20E+01 |
| H1: 2.500 | * Room 1 | * Q10 : 7.20E+01 |
| | * LAMBDA: 8.00E-01 | * |
| Area 36.000 | * | * |
| | * | * |
| | ***** | |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : Eu-154

Input File : site1.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion | Inhalation | Submersion |
|--------|-----------|------------|------------|------------------------|
| | [dpm/m2] | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| EU-154 | 3.700E+06 | 4.302E-06 | 1.288E-04 | 3.230E-03 |

Title : Eu-154

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

```
=====
|                                     |
|                                     |
|===== Assessment for Time: 1      |=====
|                                     |
|===== Time =0.00E+00 yr          |=====
|                                     |
|=====
|                                     |
|=====
```

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [l/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | EU-154 | 3.700E+06 |

Title : Eu-154

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

| | Source | Total |
|--|--------|-------|
|--|--------|-------|

1

| | | | |
|----------|---|----------|----------|
| Receptor | 1 | 2.46E+01 | 2.46E+01 |
|----------|---|----------|----------|

| | | | |
|-------|--|----------|----------|
| Total | | 2.46E+01 | 2.46E+01 |
|-------|--|----------|----------|

Title : Eu-154

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 1.90E+01 | 1.37E+00 | 1.48E-02 | 3.87E+00 | 0.00E+00 | 3.43E-01 |
| Total | 1.90E+01 | 1.37E+00 | 1.48E-02 | 3.87E+00 | 0.00E+00 | 3.43E-01 |

Title : Eu-154

Input File : site1.bld

Evaluation Time: 0.00000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| EU-154 | 2.46E+01 | 2.46E+01 |

Title : Eu-154

Input File : site1.bld

Evaluation Time: 1.00000000 years

Assessment for Time: 2

Time =1.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 0.000E+00

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | EU-154 | 1.710E+06 |

Title : Eu-154

Input File : sitel.bld

Evaluation Time: 1.00000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

| Source | Total |
|--------|-------|
| 1 | |

| | | |
|------------|----------|----------|
| Receptor 1 | 1.17E+01 | 1.17E+01 |
| Total | 1.17E+01 | 1.17E+01 |

Title : Eu-154

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 1.17E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Total | 1.17E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Title : Eu-154

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| EU-154 | 1.17E+01 | 1.17E+01 |

Title : Eu-154

Input File : sitel.bld

Full Summary

RESRAD-BUILD Dose (Time) Tables

Receptor Dose Received for the Exposure Duration

(mrem)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.46E+01 1.17E+01

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.46E+01 1.17E+01

Title : Pb-210

Input File : sitel.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : Pb-210

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime | Inhalation [m3/day] | Ingestion(Dust) [m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Title : Pb-210

Input File : site1.bld

===== Building Information =====

Building Air Exchange Rate: 8.00E-01 1/hr

| Height[m] | Air Exchanges [m3/hr] | |
|-------------|-----------------------|------------------|
| Area [m2] | | |
| | ***** | |
| | * | * |
| | * | * |
| | * | <=Q01: 7.20E+01 |
| H1: 2.500 | * Room 1 | * Q10 : 7.20E+01 |
| | * LAMBDA: 8.00E-01 | * |
| Area 36.000 | * | * |
| | * | * |
| | ***** | |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : Pb-210

Input File : sitel.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion | Inhalation | Submersion |
|--------|-----------|------------|------------|------------------------|
| | [dpm/m2] | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| PB-210 | 2.200E+05 | 2.422E-03 | 6.214E-03 | 4.698E-06 |

Title : Pb-210

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

```
=====
=====
Assessment for Time: 1
Time =0.00E+00 yr
=====
=====
```

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | PB-210 | 2.200E+05 |

Title : Pb-210

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses

{mrem}

| Source | | Total |
|----------|---|-------------------|
| 1 | | |
| Receptor | 1 | 2.43E+01 2.43E+01 |
| Total | | 2.43E+01 2.43E+01 |

Title : Pb-210

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 6.18E-03 | 4.72E-04 | 1.38E-06 | 1.19E+01 | 0.00E+00 | 1.24E+01 |
| Total | 6.18E-03 | 4.72E-04 | 1.38E-06 | 1.19E+01 | 0.00E+00 | 1.24E+01 |

Title : Pb-210

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| PB-210 | 2.43E+01 | 2.43E+01 |

```

=====
Assessment for Time: 2
Time =1.00E+00 yr
=====

```

Source Information

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | PB-210 | 1.066E+05 |

Title : Pb-210

Input File : sitel.bld

Evaluation Time: 1.00000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

| | Source | Total |
|--|--------|-------|
|--|--------|-------|

| | | |
|--|---|--|
| | 1 | |
|--|---|--|

| | | | |
|----------|---|----------|----------|
| Receptor | 1 | 3.99E-03 | 3.99E-03 |
|----------|---|----------|----------|

| | | | |
|-------|--|----------|----------|
| Total | | 3.99E-03 | 3.99E-03 |
|-------|--|----------|----------|

Title : Pb-210

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 3.99E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Total | 3.99E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Title : Pb-210

Input File : site1.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| PB-210 | 3.99E-03 | 3.99E-03 |

Title : Pb-210

Input File : sitel.bld

Full Summary

RESRAD-BUILD Dose (Time) Tables

Receptor Dose Received for the Exposure Duration

(mrem)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.43E+01 3.99E-03

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.43E+01 3.99E-03

Title : Ra-226

Input File : site1.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : Ra-226

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime | Inhalation [m3/day] | Ingestion(Dust) [m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : Ra-226

Input File : sitel.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Radon Release Fraction: 1.000E-01

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion | Inhalation | Submersion |
|--------|-----------|------------|------------|------------------------|
| | [dpm/m2] | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| RA-226 | 4.110E+05 | 5.950E-04 | 3.871E-03 | 4.663E-03 |
| PB-210 | 0.000E+00 | 2.422E-03 | 6.214E-03 | 4.698E-06 |

Title : Ra-226

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

```
=====
|                                     |
|                                     |
|===== Assessment for Time: 1      |=====
|                                     |
|===== Time =0.00E+00 yr          |=====
|                                     |
|=====
|                                     |
|=====
```

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration [dpm/m2] |
|-----------------|---------|---------------------------|
| | RA-226 | 4.110E+05 |
| | PB-210 | 0.000E+00 |

Title : Ra-226

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses

[mrem]

| Source | | Total |
|----------|---|-------------------|
| 1 | | |
| Receptor | 1 | 2.50E+01 2.50E+01 |
| Total | | 2.50E+01 2.50E+01 |

Title : Ra-226

Input File : site1.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 3.02E+00 | 2.39E-01 | 2.68E-03 | 1.49E+01 | 4.37E-01 | 6.34E+00 |
| Total | 3.02E+00 | 2.39E-01 | 2.68E-03 | 1.49E+01 | 4.37E-01 | 6.34E+00 |

Title : Ra-226

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| RA-226 | 2.43E+01 | 2.43E+01 |
| PB-210 | 6.94E-01 | 6.94E-01 |

Title : Ra-226

Input File : sitel.bld

Evaluation Time: 1.00000000 years

```
=====
|                                     |
|                                     |
|===== Assessment for Time: 2      |=====
|                                     |
|===== Time =1.00E+00 yr          |=====
|                                     |
|=====                             |=====
```

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 0.000E+00

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration [dpm/m2] |
|-----------------|---------|---------------------------|
| | RA-226 | 2.054E+05 |
| | PB-210 | 6.288E+03 |

Title : Ra-226

Input File : sitel.bld

Evaluation Time: 1.00000000 years

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses

[mrem]

| Source | | Total |
|----------|---|-------------------|
| 1 | | |
| Receptor | 1 | 2.31E+00 2.31E+00 |
| Total | | 2.31E+00 2.31E+00 |

Title : Ra-226

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

(mrem)

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 2.02E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.91E-01 | 0.00E+00 |
| Total | 2.02E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.91E-01 | 0.00E+00 |

Title : Ra-226

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| RA-226 | 2.31E+00 | 2.31E+00 |
| PB-210 | 3.55E-04 | 3.55E-04 |

Title : Ra-226
Input File : site1.bld
Full Summary

| | |
|---------------------------------|--|
| RESRAD-BUILD Dose (Time) Tables | |
|---------------------------------|--|

Receptor Dose Received for the Exposure Duration

(mrem)

| | |
|----------------------|-------------------|
| Evaluation Time [yr] | |
| 0.00E+00 | 1.00E+00 |
| 1 | 2.50E+01 2.31E+00 |

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

| | |
|----------------------|-------------------|
| Evaluation Time [yr] | |
| 0.00E+00 | 1.00E+00 |
| 1 | 2.50E+01 2.31E+00 |

Title : Tl-204

Input File : sitel.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : Tl-204

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime [m3/day] | Inhalation [m2/hr] | Ingestion(Dust) |
|----------|------|----------|----------|----------|----------------------|-----------------------|-----------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Title : T1-204

Input File : sitel.bld

===== Building Information =====

Building Air Exchange Rate: 8.00E-01 1/hr

| Height[m] | Air Exchanges [m3/hr] | |
|-------------|-----------------------|------------------|
| Area [m2] | ***** | |
| | * | * |
| | * | * |
| | * | <=Q01: 7.20E+01 |
| H1: 2.500 | * Room 1 | * Q10 : 7.20E+01 |
| | * LAMBDA: 8.00E-01 | * |
| Area 36.000 | * | * |
| | * | * |
| | ***** | |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : TL-204

Input File : sitel.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion Inhalation Submersion | | |
|--------|-----------|---------------------------------|------------|------------------------|
| | | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| TL-204 | 5.800E+08 | 1.514E-06 | 1.086E-06 | 2.941E-06 |

Title : TL-204

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Assessment for Time: 1

Time =0.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | TL-204 | 5.800E+08 |

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses
[mrem]

| Source | | Total | |
|----------|---|----------|----------|
| 1 | | | |
| Receptor | 1 | 2.47E+01 | 2.47E+01 |
| Total | | 2.47E+01 | 2.47E+01 |

Title : Tl-204

Input File : site1.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 3.96E+00 | 2.55E-01 | 1.81E-03 | 4.38E+00 | 0.00E+00 | 1.61E+01 |
| Total | 3.96E+00 | 2.55E-01 | 1.81E-03 | 4.38E+00 | 0.00E+00 | 1.61E+01 |

Title : Tl-204

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| TL-204 | 2.47E+01 | 2.47E+01 |

Title : Tl-204

Input File : sitel.bld

Evaluation Time: 1.00000000 years

```
=====
|                                     |
|                                     |
|===== Assessment for Time: 2      |=====
|                                     |
|===== Time =1.00E+00 yr          |=====
|                                     |
|=====
|                                     |
|=====
```

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 0.000E+00

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | TL-204 | 2.414E+08 |

Title : T1-204

Input File : sitel.bld

Evaluation Time: 1.00000000 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

| | Source | Total |
|--|--------|-------|
|--|--------|-------|

| | | |
|--|---|--|
| | 1 | |
|--|---|--|

| | | | |
|----------|---|----------|----------|
| Receptor | 1 | 2.17E+00 | 2.17E+00 |
|----------|---|----------|----------|

| | | | |
|-------|--|----------|----------|
| Total | | 2.17E+00 | 2.17E+00 |
|-------|--|----------|----------|

Title : Tl-204

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 2.17E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Total | 2.17E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Title : Tl-204

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| TL-204 | 2.17E+00 | 2.17E+00 |

Title : T1-204

Input File : sitel.bld

Full Summary

| | |
|---------------------------------|--|
| RESRAD-BUILD Dose (Time) Tables | |
|---------------------------------|--|

Receptor Dose Received for the Exposure Duration

(mrem)

Evaluation Time [yr]

| | | |
|---|----------|----------|
| | 0.00E+00 | 1.00E+00 |
| 1 | 2.47E+01 | 2.17E+00 |

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

Evaluation Time [yr]

| | | |
|---|----------|----------|
| | 0.00E+00 | 1.00E+00 |
| 1 | 2.47E+01 | 2.18E+00 |

Title : U-235

Input File : sitel.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : U-235

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime | Inhalation [m3/day] | Ingestion(Dust) [m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Title : U-235

Input File : sitel.bld

===== Building Information =====

Building Air Exchange Rate: 8.00E-01 1/hr

| Height[m] | Air Exchanges [m3/hr] | |
|-------------|-----------------------|------------------|
| Area [m2] | | |
| | ***** | |
| | * | * |
| | * | * |
| | * | <=Q01: 7.20E+01 |
| H1: 2.500 | * Room 1 | * Q10 : 7.20E+01 |
| | * LAMBDA: 8.00E-01 | * |
| Area 36.000 | * | * |
| | * | * |
| | ***** | |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : U-235

Input File : sitel.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion | Inhalation | Submersion |
|--------|-----------|------------|------------|------------------------|
| | [dpm/m2] | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| U-235 | 4.800E+04 | 1.204E-04 | 5.541E-02 | 4.063E-04 |
| PA-231 | 0.000E+00 | 4.775E-03 | 5.766E-01 | 9.049E-05 |
| AC-227 | 0.000E+00 | 6.665E-03 | 3.029E+00 | 9.734E-04 |

Title : U-235

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

=====

Assessment for Time: 1

Time =0.00E+00 yr

=====

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [l/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration |
|-----------------|---------|---------------|
| | | [dpm/m2] |
| | U-235 | 4.800E+04 |
| | PA-231 | 0.000E+00 |
| | AC-227 | 0.000E+00 |

Title : U-235

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses

[mrem]

| Source | | Total |
|------------|----------|----------|
| 1 | | |
| Receptor 1 | 2.46E+01 | 2.46E+01 |
| Total | 2.46E+01 | 2.46E+01 |

Title : U-235

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 3.74E-02 | 2.96E-03 | 2.73E-05 | 2.44E+01 | 0.00E+00 | 1.42E-01 |
| Total | 3.74E-02 | 2.96E-03 | 2.73E-05 | 2.44E+01 | 0.00E+00 | 1.42E-01 |

Title : U-235

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| U-235 | 2.46E+01 | 2.46E+01 |
| PA-231 | 2.68E-03 | 2.68E-03 |
| AC-227 | 1.38E-04 | 1.38E-04 |

Title : U-235

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Assessment for Time: 2

Time =1.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 0.000E+00

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration [dpm/m2] |
|-----------------|---------|---------------------------|
| | U-235 | 2.400E+04 |
| | PA-231 | 5.072E-01 |
| | AC-227 | 7.978E-03 |

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses

[mrem]

| Source | | Total |
|------------|----------|----------|
| 1 | | |
| Receptor 1 | 2.50E-02 | 2.50E-02 |
| Total | 2.50E-02 | 2.50E-02 |

Title : U-235

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 2.50E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Total | 2.50E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Title : U-235

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| U-235 | 2.50E-02 | 2.50E-02 |
| PA-231 | 2.20E-07 | 2.20E-07 |
| AC-227 | 4.29E-08 | 4.29E-08 |

Title : U-235

Input File : sitel.bld

Full Summary

| |
|---------------------------------|
| RESRAD-BUILD Dose (Time) Tables |
|---------------------------------|

Receptor Dose Received for the Exposure Duration

(mrem)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.46E+01 2.50E-02

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.46E+01 2.50E-02

Title : U-238

Input File : sitel.bld

RESRAD-BUILD Table of Contents

| | |
|------------------------------------|----|
| RESRAD-BUILD Input Parameters..... | 2 |
| Building Information..... | 3 |
| Source Information..... | 4 |
| For time = 0.00E+00 yr | |
| Time Specific Parameters..... | 5 |
| Receptor-Source Dose Summary..... | 6 |
| Dose by Pathway Detail..... | 7 |
| Dose by Nuclide Detail..... | 8 |
| For time = 1.00E+00 yr | |
| Time Specific Parameters..... | 9 |
| Receptor-Source Dose Summary..... | 10 |
| Dose by Pathway Detail..... | 11 |
| Dose by Nuclide Detail..... | 12 |
| Full Summary..... | 13 |

Title : U-238

Input File : sitel.bld

RESRAD-BUILD Input Parameters

Number of Sources : 1
 Number of Receptors: 1
 Total Time : 3.650000E+02 days
 Fraction Inside : 5.000000E-01

Receptor Information

| Receptor | Room | x [m] | y [m] | z [m] | FracTime | Inhalation [m3/day] | Ingestion(Dust) [m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1 | 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.80E+01 | 1.00E-04 |

Receptor-Source Shielding Relationship

| Receptor | Source | Density [g/cm3] | Thickness [cm] | Material |
|----------|--------|--------------------|-------------------|----------|
| 1 | 1 | 2.40E+00 | 0.00E+00 | Concrete |

Title : U-238

Input File : site1.bld

===== Building Information =====

Building Air Exchange Rate: 8.00E-01 1/hr

| Height[m] | Air Exchanges [m3/hr] | |
|-------------|-----------------------|------------------|
| Area [m2] | ***** | |
| | * | * |
| | * | * |
| | * | <=Q01: 7.20E+01 |
| H1: 2.500 | * Room 1 | * Q10 : 7.20E+01 |
| | * LAMBDA: 8.00E-01 | * |
| Area 36.000 | * | * |
| | * | * |
| | ***** | |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-07 [1/s]

Title : U-238

Input File : sitel.bld

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00[m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [l/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

Radon Release Fraction: 1.000E-01

Contamination::

Nuclide Concentration Dose Conversion Factor (Library: FGR 13 Morbidity)

| | | Ingestion | Inhalation | Submersion |
|--------|-----------|------------|------------|------------------------|
| | [dpm/m2] | [mrem/dpm] | [mrem/dpm] | [mrem/yr/ (dpm/m3)] |
| U-238 | 5.080E+04 | 1.210E-04 | 5.317E-02 | 7.191E-05 |
| U-234 | 0.000E+00 | 1.275E-04 | 5.946E-02 | 4.014E-07 |
| TH-230 | 0.000E+00 | 2.468E-04 | 1.468E-01 | 9.155E-07 |
| RA-226 | 0.000E+00 | 5.950E-04 | 3.871E-03 | 4.663E-03 |
| PB-210 | 0.000E+00 | 2.422E-03 | 6.214E-03 | 4.698E-06 |

Title : U-238

Input File : site1.bld

Evaluation Time: 0.00000000E+00 years

Assessment for Time: 1

Time =0.00E+00 yr

Source Information

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 5.000E-01

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration [dpm/m2] |
|-----------------|---------|---------------------------|
| | U-238 | 5.080E+04 |
| | U-234 | 0.000E+00 |
| | TH-230 | 0.000E+00 |
| | RA-226 | 0.000E+00 |
| | PB-210 | 0.000E+00 |

Title : U-238

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

RESRAD-BUILD Dose Tables

Source Contributions to Receptor Doses

[mrem]

| | Source | Total |
|--|--------|-------|
|--|--------|-------|

| | | |
|--|---|--|
| | 1 | |
|--|---|--|

| | | | |
|----------|---|----------|----------|
| Receptor | 1 | 2.50E+01 | 2.50E+01 |
|----------|---|----------|----------|

| | | | |
|-------|--|----------|----------|
| Total | | 2.50E+01 | 2.50E+01 |
|-------|--|----------|----------|

Title : U-238

Input File : sitel.bld

Evaluation Time: 0.00000000E+00 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 7.64E-03 | 6.05E-04 | 5.11E-06 | 2.48E+01 | 1.98E-17 | 1.51E-01 |
| Total | 7.64E-03 | 6.05E-04 | 5.11E-06 | 2.48E+01 | 1.98E-17 | 1.51E-01 |

Title : U-238

Input File : sitel.bld

Evaluation Time: 0.0000000E+00 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| U-238 | 2.50E+01 | 2.50E+01 |
| U-234 | 3.86E-05 | 3.86E-05 |
| TH-230 | 2.79E-10 | 2.79E-10 |
| RA-226 | 1.26E-15 | 1.26E-15 |
| PB-210 | 1.48E-17 | 1.48E-17 |

Title : U-238

Input File : sitel.bld

Evaluation Time: 1.00000000 years

```
=====
|                                     |
|                                     |
|===== Assessment for Time: 2      |=====
|                                     |
|===== Time =1.00E+00 yr          |=====
|                                     |
|=====
|                                     |
|=====
```

===== Source Information =====

Source: 1

Location:: Room : 1 x: 0.00 y: 0.00 z: 0.00 [m]

Geometry:: Type: Area Area:3.60E+01 [m2] Direction: x

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E-01

Removable fraction: 0.000E+00

Time to Remove: 3.650E+02 [day]

| Contamination:: | Nuclide | Concentration [dpm/m2] |
|-----------------|---------|---------------------------|
| | U-238 | 2.540E+04 |
| | U-234 | 7.186E-02 |
| | TH-230 | 3.234E-07 |
| | RA-226 | 4.670E-11 |
| | PB-210 | 3.607E-13 |

Title : U-238

Input File : sitel.bld

Evaluation Time: 1.00000000 years

| | |
|--------------------------|--|
| RESRAD-BUILD Dose Tables | |
|--------------------------|--|

Source Contributions to Receptor Doses

[mrem]

| | Source | Total |
|------------|----------|----------|
| | 1 | |
| Receptor 1 | 5.10E-03 | 5.10E-03 |
| Total | 5.10E-03 | 5.10E-03 |

Title : U-238

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Pathway Detail of Doses

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1 | 5.10E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.48E-16 | 0.00E+00 |
| Total | 5.10E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.48E-16 | 0.00E+00 |

Title : U-238

Input File : sitel.bld

Evaluation Time: 1.00000000 years

Nuclide Detail of Doses

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| U-238 | 5.10E-03 | 5.10E-03 |
| U-234 | 9.77E-10 | 9.77E-10 |
| TH-230 | 6.59E-15 | 6.59E-15 |
| RA-226 | 1.96E-15 | 1.96E-15 |
| PB-210 | 8.45E-20 | 8.45E-20 |

Title : U-238

Input File : sitel.bld

Full Summary

| | |
|---------------------------------|--|
| RESRAD-BUILD Dose (Time) Tables | |
|---------------------------------|--|

Receptor Dose Received for the Exposure Duration

(mrem)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.50E+01 5.10E-03

Receptor Dose/Yr Averaged Over Exposure Duration

(mrem/yr)

Evaluation Time [yr]

0.00E+00 1.00E+00

1 2.50E+01 5.10E-03

Site Specific Work Plan

IUB Swain Hall West Radiological Remediation

November 2016



Prepared by:



AMERIPHYSICS

9111 Cross Park Drive, Suite D200
Knoxville, TN 37923
800.563.7497

RECORD OF REVISIONS

| Change Number | Date | Description of Change | Approval |
|---------------|------|-----------------------|----------|
| 0 | | Initial Distribution | |
| | | | |
| | | | |

APPROVALS

Prepared By

Paul A. Jones and Timothy Pratt

Date

Review and Approval

Date

Contents

| | | |
|--------|---|----|
| 1. | SCOPE | 5 |
| 2. | HISTORICAL RADIONUCLIDES OF CONCERN | 5 |
| 3. | FACILITY DESCRIPTION | 5 |
| 3.1. | Site Location and Description | 6 |
| 4. | PROJECT APPROACH | 6 |
| 4.1. | Characterization Surveys | 6 |
| 4.2. | Remediation | 7 |
| 4.3. | Air Sampling and Concrete Dust Control | 8 |
| 4.4. | Health and Safety Program | 8 |
| 4.5. | Final Status Survey | 9 |
| 5. | PROJECT RELEASE CRITERIA | 9 |
| 6. | SURVEY INSTRUMENTATION | 11 |
| 6.1. | Instrument Calibration | 11 |
| 6.2. | Daily Response Checks | 11 |
| 6.3. | Determination of Counting Times and Minimum Detectable Concentrations | 11 |
| 6.3.1. | Static Counting | 12 |
| 6.3.2. | Ratemeter Scanning | 12 |
| 6.3.3. | Removable Contamination Measurement Counting | 14 |
| 6.4. | Counting Uncertainty | 14 |
| 6.5. | Uncertainty Propagation and Confidence Interval | 15 |
| 6.6. | Instrumentation Specifications | 15 |
| 6.7. | Background Determination | 16 |
| 7. | FINAL STATUS SURVEY DESIGN | 16 |
| 7.1. | Data Quality Objectives | 17 |
| 7.2. | Area Classification | 17 |
| 7.3. | Survey Unit Identification | 18 |
| 7.4. | Surface Scans | 19 |
| 7.5. | Determining the Number of Sample Locations | 19 |
| 7.6. | Determination of Sampling Locations | 20 |
| 7.7. | Total Surface Activity Measurements | 21 |
| 7.8. | Removable Contamination Measurements | 22 |
| 7.9. | Survey Investigation Levels | 22 |
| 7.10. | Survey Documentation | 22 |
| 7.11. | Data Validation | 23 |
| 7.12. | Evaluating Survey Results | 23 |
| 8. | FINAL REPORT | 23 |
| 9. | RADIOACTIVE WASTE MANAGEMENT PROGRAM | 24 |
| 9.1. | Waste Characterization | 24 |
| 9.2. | Waste Shipment | 24 |
| 10. | REFERENCES | 24 |

Attachments

Attachment 1: Floor Layout of Swain Hall West

Attachment 2: RESRAD-BUILD DCGL_{surface} Modeling for Radionuclides of Concern

Abbreviations and Acronyms

| | |
|-------------|---|
| ALARA | As Low As Reasonably Achievable |
| Ameripysics | Ameripysics, LLC |
| cpm | counts per minute |
| DCGL | Derived Concentration Guideline Level |
| dpm | disintegration per minute |
| DQO | Data Quality Objective |
| NIST | National Institute of Standards and Technology |
| LBGR | Lower Bound of the Gray Region |
| MARSSIM | Multi-Agency Radiation Survey and Site Investigation Manual |
| MDC | Minimum Detectable Concentration |
| NRC | Nuclear Regulatory Commission |
| RAM | Radioactive Material |
| TEDE | Total Effective Dose Equivalent |

1. SCOPE

The purpose of this Site Specific Work Plan is to provide the concise work instructions necessary to support the removal of residual radioactive contamination from the identified locations within Swain Hall West in order to meet the requirements for release of these locations for unrestricted use in accordance with 10 CFR 20 Subpart E. All work will be accomplished using the Ameripysics Nuclear Regulatory Commission (NRC) radioactive materials license number 41-35264-01.

2. HISTORICAL RADIONUCLIDES OF CONCERN

Table 2-1 includes a listing of all the radionuclides known to be possessed in Swain Hall West. This listing is based on what might have been authorized (such as by the old AEC license) and more recent (1970 to present) facility records.

Table 2-1 – Potential Radionuclides

| Radionuclide | Half Life |
|---------------------|------------|
| Bi-207 ² | 32.9 y |
| C-14 ¹ | 57E3 y |
| Cl-36 ¹ | 3.01E5 y |
| Co-60 ¹ | 5.2713 y |
| Cs-137 ¹ | 30.1671 y |
| Eu-152 ² | 13.537 y |
| Eu-154 ² | 8.593 y |
| H-3 ¹ | 12.32 y |
| Ni-63 ¹ | 100.1 y |
| Pb-210 ² | 22.2 y |
| Ra-226 ² | 1600 y |
| Sr-90 ¹ | 28.79 y |
| Th-232 ² | 1.41E+10 y |
| Tl-204 ² | 3.78 y |

Based on the radionuclides that were possessed in unsealed form, a comprehensive radiological survey of the impacted areas within the scope of this plan is required. The methodology described in NUREG-1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), is used to design these surveys.

3. FACILITY DESCRIPTION

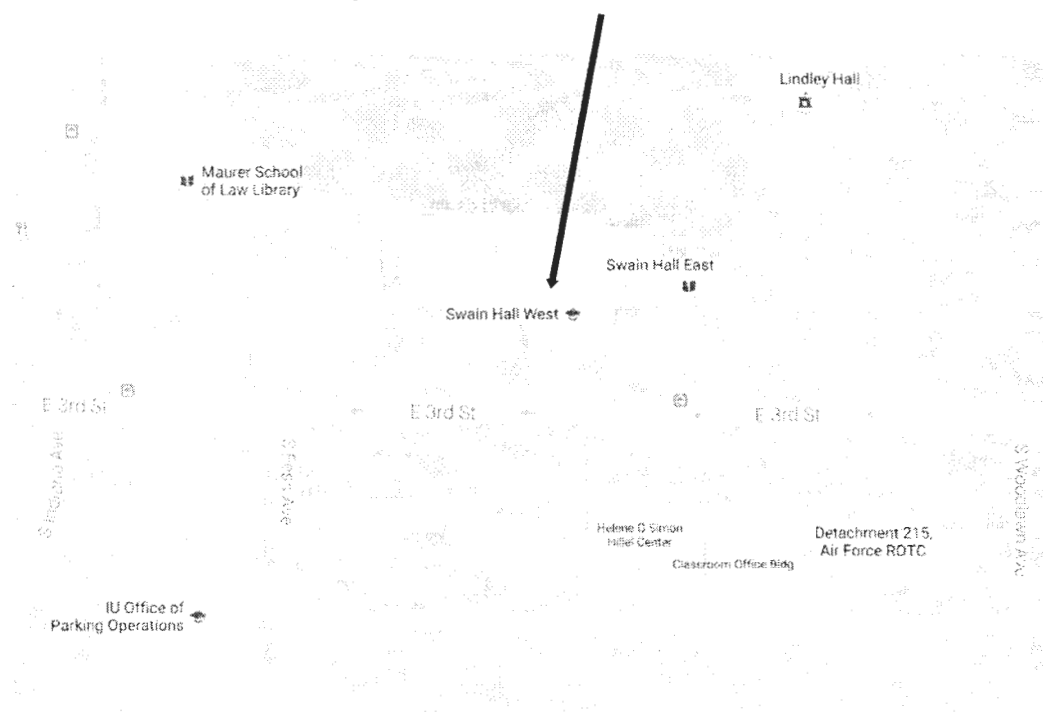
Originally built in 1940, Swain Hall West at the IU Bloomington Campus houses the university's physics department. With its last major renovations occurring in 1973, the building is currently in the process of a new renovation. Construction is currently in progress within adjacent areas of the building to those described in this plan. Upon approval of the final status survey report the

rooms and areas included in this plan will be renovated as well. Maps of the 5 floors of Swain Hall West are included as Attachment 1 to this plan.

3.1. Site Location and Description

Swain Hall is located at 727 E. 3rd Street, in Bloomington, IN. Figure 3-1 provides a detailed street view with Swain Hall indicated. The Map was obtained online from Google.

Figure 3-1 – Location of Swain Hall



4. PROJECT APPROACH

The basic project approach is outlined in the following sections. Detailed instructions for completing technical aspects of the project are provided in Section 7, Final Status Survey Design.

4.1. Characterization Surveys

After mobilization, a brief characterization survey will be performed to verify the boundaries and initial conditions in the various work rooms within Swain Hall. The characterization will include obtaining a sample(s) of the contamination within the various rooms for alpha spectroscopy. The characterization survey is performed on the building surfaces and fixed equipment within the rooms. The characterization survey is designed to identify residual contamination exceeding

release criteria, verify assumptions used to design surveys, and complement the final status survey to the extent practical.

Surface scanning, surface activity (static) measurements, and sample collection (smears) are performed to characterize building structural surfaces. The scan survey is designed using the same data quality objectives (DQOs) and minimum coverage as the final status survey so that it can be used as the scan survey portion of the final status survey, as practical and as allowed by MARSSIM. The purpose of scanning is to identify locations of elevated activity. Where elevated activity is identified, a static measurement and smear are taken at the location of highest activity identified during the scan. Where elevated activity is identified that exceeds the release criteria, the boundary of the elevated area is marked to aid in locating the area for remedial actions.

4.2. Remediation

Table 4-1 below provides the description of the systems and areas requiring remediation within Swain Hall West.

Table 4-1 – List of Remediation for Impacted Areas and Systems

| Room | Impacted Area Type of Contamination (System/Room) | Description of Remediation |
|-------|---|---|
| S-12 | System | Removal and survey of the S12 Supply Duct. This duct is a galvanized duct extending 30 feet from S12 through S17. |
| S-12 | System | Removal of the incinerator exhaust flue. This 60-foot long (4-6 inch diameter) insulated stainless steel pipe will be removed. |
| S-18 | System | Removal of sub slab piping as needed for the renovation contractor. Piping will be disposed of and area will be surveyed after removal. |
| S-18 | System | Contamination is known to exist in the remaining Fume hood exhaust duct in S18. The galvanized duct extends 65 feet from the overhead in S18 through S17 through a vertical chase to the second-floor rooftop fan. Remediation will begin with removal of the fume hood exhaust in room S-18 and continue. If any part of this system (fan or ductwork) is acceptable for unconditional release it will remain in place and be surveyed as a system during the final status survey. |
| Attic | Penetration | This remaining short duct from the attic through the roof will be removed and disposed of as radioactive waste. All the lower portions of this |

| | | |
|----------|----------------------------|---|
| | | duct originating from a Room 330 hood were removed previously. |
| Room 243 | Room surface contamination | Decontamination is required for surface contamination. Drain, pipe, and trap will be removed. |
| Room 244 | Room surface contamination | Decontamination is required for surface contamination. |
| Room 301 | Room surface contamination | Decontamination is required for surface contamination. Drain, pipe, and trap will be removed. |
| Room 302 | Room surface contamination | Decontamination is required for surface contamination. Drain, pipe, and trap will be removed. |
| Room 330 | Room surface contamination | Decontamination is required for known surface contamination on floor and walls. |
| Room 331 | Room surface contamination | Decontamination is required for known surface contamination on floor and walls |

Contamination above the release criteria is known to be present in some rooms of Swain Hall West. Ameripysics will use simple decontamination methods such as simple hand wiping where practical. If these methods are not effective in reducing the levels below the release criteria, more aggressive methods of removing the contamination will be required including removal of the contaminated surface. Remedial action control surveys will be performed during and after remediation. These surveys are performed using the same DQOs as the final status surveys so the data can be used to supplement the final status survey as practical.

4.3. Air Sampling and Concrete Dust Control

Air sampling will be performed during potential airborne radioactivity producing activities (i.e., aggressive concrete demolition). The sampling will include breathing zone, general area, and effluent sampling, as appropriate.

If air samples indicate the presence of airborne radioactivity above 1 Derived Air Concentration (DAC) within the work area, work will be stopped and additional radiological controls will be implemented (e.g., additional misting, slower demolition, additional HEPA ventilation). These samples will be evaluated against the most restrictive radionuclide of concern.

4.4. Health and Safety Program

Ameripysics maintains a comprehensive health and safety program, and specific individual procedures, which have been developed to assure compliance with federal, state, and local regulations. Ameripysics' Health and Safety Manual will be followed by personnel who are working under Ameripysics' license.

In addition to the Ameripysics Health and Safety Program, the Indiana University staff and other contractors hired by Indiana University and performing non-radiological abatement will follow their respective Health and Safety Program and associated procedures.

4.5. Final Status Survey

Final status surveys collect the statistical information needed to demonstrate that residual radioactivity satisfies the predetermined criteria for unrestricted release. Surveys are designed using MARSSIM and the DQO process it describes. Survey design is presented in greater detail in Section 7.

5. PROJECT RELEASE CRITERIA

The criteria for releasing equipment and materials that interfere with performance of the MARSSIM-based decommissioning survey are those specified in Nuclear Regulatory Commission (NRC) Regulatory Guide 1.86, *Termination of Operating Licenses for Nuclear Reactors*. Acceptable Surface Contamination Levels are provided in Table 1 of this guide.

Based on the radionuclides identified, the alpha total activity release limit is 100 dpm/100 cm² and the beta-gamma total activity release limits is 5,000 dpm/100 cm². Removable activity limits for alpha and beta-gamma emitters are 20 dpm/100 cm² and 1,000 dpm/100 cm², respectively.¹

Radiological requirements for license termination are described Title 10 of the Code of Federal Regulations, Part 20, Subpart E, Radiological Criteria for License Termination, which states that a site will be considered acceptable for unrestricted release if the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 25 millirem per year (mrem/y), and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).

The NRC has published default screening values in units of dpm/100 cm² corresponding to this limit in NUREG 1757, Volume 2, Appendix H. Table H.1 of NUREG provides acceptable surface contamination screening values for commonly used radionuclides. Where possible, these default screening values are used to provide the basis for developing the derived concentration guideline levels (DCGLs) corresponding to the release criteria for the project. The DCGL is the term MARSSIM uses to describe a radionuclide specific surface area concentration limit that could result in a dose equal to the release criterion. The DCGL is the concentration limit if the residual activity is essentially evenly distributed over a large area. For the purposes of this plan, where NUREG-1757 list a default screening value, the value is used as the project DCGL for the

¹ It should be noted that beta/gamma release limits are based on the standard beta/gamma emitter limits from Table 1. In order for the lower limits of Sr-90 to apply, Sr-90 is in its pure form where the Y-90 daughter has been chemically stripped away. Even if Sr-90 was once possessed in this form, in the time that has elapsed, the Y-90 would have grown back in.

corresponding radionuclide. Note that although MARSSIM provides a means for allowing small areas of elevated activity that exceed the DCGL to remain (not be remediated), this process is not applied to this project. Rather, any contamination exceeding the DCGL will be remediated.

The values in NUREG-1757 were derived using the DandD Modeling Code. The table in NUREG 1757 only lists common radionuclides, and Indiana University possessed several radionuclides not listed. In these instances, the RESRAD-BUILD code, Ver. 3.5, is used to determine DCGLs corresponding to the twenty-five (25) millirem per year limit. The RESRAD-BUILD Version 3.5 was used using the default parameters. The RESRAD-BUILD summary reports for the radionuclides of concern not listed in Table H.1 are provided in Attachment 2 of this plan.

These DCGLs correspond to total contamination (fixed and removable) and published default screening values are based on the assumption that no more than 10% of the contamination is removable. Consequently, a removal activity limit equal to 10% of the total activity DCGL is implemented to confirm this important assumption.

Table 5-1 shows the radionuclide specific DCGLs for this project. DCGL screening values listed are based on the equivalent screening values from NUREG-1757, or for unlisted radionuclides, the RESRAD-BUILD summary reports. This is reflected by the note following the table.

Table 5-1 – DCGLs for Nuclides of Concern at 25 mrem/yr

| Radionuclide | Half Life | Primary Radiation Type | DCGL - Total Activity Limit (dpm/100cm ²) | Removable Activity Limit (dpm/100cm ²) |
|------------------------|------------|------------------------|---|--|
| Bi-207 ² | 32.9 y | EC/Beta+ | 34,000 | 3,400 |
| C-14 ¹ | 57E3 y | Beta | 3,700,000 | 370,000 |
| Cl-36 ¹ | 3.01E5 y | Beta | 500,000 | 50,000 |
| Co-60 ¹ | 5.2713 y | Beta | 7,100 | 710 |
| Cs-137 ¹ | 30.1671 y | Beta | 28,000 | 2,800 |
| Eu-152 ² | 13.537 y | Beta | 40,000 | 4,000 |
| Eu-154 ² | 8.593 y | Beta | 37,500 | 3,750 |
| H-3 ¹ | 12.32 y | Beta | 120,000,000 | 12,000,000 |
| Ni-63 ^{1, 3} | 100.1 y | Beta | 1,800,000 | 180,000 |
| Pb-210 ^{2, 3} | 22.2 y | Beta | 2,200 | 220 |
| Ra-226 ² | 1600 y | Alpha | 4,110 | 411 |
| Sr-90 ¹ | 28.79 y | Beta | 8,700 | 870 |
| Th-232 ⁴ | 1.41E+10 y | Alpha | 73 | 7.3 |
| Tl-204 ² | 3.78 y | Beta | 5,800,000 | 580,000 |
| U-235 ² | 7.04E+08 y | Alpha | 480 | 48 |
| U-238 ² | 4.468E9 y | Alpha | 508 | 51 |

¹ DCGL Listed in NUREG-1757 Vol. 1, Rev. 2

² DCGL determined using the RESRAD-BUILD Ver.3.5 code

³ Ni-63 and Pb-210 are not detected by standard field instruments with any reasonable efficiency. These radionuclides will be evaluated by liquid scintillation counting only.

⁴ The Th-232 DCGL was determined from the USNRC memorandum SECY-98-242. The value of 7.3 dpm/100cm² assumes a removable fraction of 10%. In order to determine a value that can be realistically surveyed for, the assumption will be that no more than 1% is actually removable. This will be verified by comparisons of actual total activity and removable activity measurements performed at the beginning of the project.

The field instruments used to collect survey data are not equipped to distinguish between radionuclides. The measurements analyze for gross alpha and gross beta/gamma only. Therefore, the gross activity DCGLs are based on the most limiting release criteria for both alpha and beta/gamma. The alpha gross activity DCGL is most limited by Th-232 at 72 dpm/100cm² and the beta/gamma gross activity DCGL is most limited by Co-60 at 7,100 dpm/100cm².

6. SURVEY INSTRUMENTATION

Based on potential contaminants, their associated radiations, and the types of residual contamination categories to be evaluated, the detection sensitivities of various instruments and techniques were evaluated for use. Instruments were evaluated for use during surface scans, direct measurements, and analysis of removable contamination wipes.

6.1. Instrument Calibration

Laboratory and portable field instruments are calibrated at least annually with National Institute of Standards and Technology (NIST) traceable sources and to radiation emission types and energies that provide detection capabilities similar to the nuclides of concern.

6.2. Daily Response Checks

For radiological instruments operated by Ameriphysics, a reference source is measured prior to use each day. The result is accurate if it falls within $\pm 20\%$ of originally determined values. This is consistent with the guidance in Section 6.5.4 of MARSSIM, Instrument Calibration. Background readings are taken as part of the daily response checks and compared with the acceptance range for instrument and site conditions. If an instrument fails a response check, all data obtained with the instrument since the last satisfactory check is invalidated.

6.3. Determination of Counting Times and Minimum Detectable Concentrations

Minimum counting times for background determinations and counting times for measurement of total and removable contamination are chosen to provide minimum detectable concentrations (MDCs) that meet the DQOs specified in this plan. MARSSIM equations relative to building surfaces are modified to convert to units of dpm/100cm². Count times and scanning rates are determined using the equations in the following sections.

6.3.1. Static Counting

Static counting MDC at a 95% confidence level is calculated using the following equation, which is an expansion of NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{static} = \frac{3 + 3.29 \sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

- MDC_{static} = minimum detectable concentration level in dpm/100cm²
- B_r = background count rate in counts per minute
- t_b = background count time in minutes
- t_s = sample count time in minutes
- E_{tot} = total detector efficiency for radionuclide emission of interest
(includes combination of instrument efficiency and surface efficiency)¹
- A = detector probe area in cm²

¹. Surface efficiency applied will be in accordance with the recommended values of 0.25 for alpha and beta emitters <400keV max and 0.5 for all others.

6.3.2. Ratemeter Scanning

Scanning MDC at a 95% confidence level is calculated using the following equation which is a combination of MARSSIM equations 6-8, 6-9, and 6-10:

$$MDC_{scan} = \frac{d' \sqrt{b_i} \left(\frac{60}{i} \right)}{\sqrt{p} \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

- MDC_{scan} = minimum detectable concentration level in dpm/100 cm²
- d' = desired performance variable (1.38)
- b_i = background counts during the residence interval
- i = residence interval
- p = surveyor efficiency (0.5)
- E_{tot} = total detector efficiency for radionuclide emission of interest
(includes combination of instrument efficiency and surface efficiency)¹
- A = detector probe area in cm²

¹. Surface efficiency applied will be in accordance with the recommended values of 0.25 for alpha and beta emitters <400 keV max and 0.5 for all others.

From MARSSIM, Section 6.7.7.2, Scanning for Alpha Emitters:

"Scanning for alpha emitters differs significantly from scanning for beta and gamma emitters in that the expected background response of most alpha detectors is very close to zero. Since the time a contaminated area is under the probe varies and the background count rate of some alpha instruments is less than 1 cpm, it is not practical to determine a fixed MDC for alpha scanning. Instead, it is more useful to determine the probability of detecting an area of contamination at a predetermined DCGL for given scan rates."

For alpha survey instrumentation with backgrounds of no more than three counts per minute, a single count provides a surveyor sufficient cause to stop and investigate further. Given a known scan rate and a surface contamination DCGL, the probability of detecting a single count while passing over a contaminated area from MARSSIM Equation 6-12 is:

$$P(n \geq 1) = 1 - e^{-\frac{GE d}{60v}}$$

Where:

| | | |
|---------------|---|---|
| $P(n \geq 1)$ | = | probability of observing a single count |
| G | = | contamination activity (dpm) |
| E | = | detector efficiency (total efficiency) |
| d | = | width of detector in direction of scan (cm) |
| v | = | scan speed (cm/s) |

Once a count is recorded and the guideline level of contamination is suspected the surveyor stops and waits (dwell time) until the probability of getting another count is at least 90%. This time interval is calculated using Equation 6.13 from MARSSIM:

$$t = \frac{13,800}{CAE}$$

Where:

| | | |
|-----|---|--|
| t | = | time period for static count or dwell time |
| C | = | contamination guideline (dpm/100 cm ²) |
| A | = | physical detector area (cm ²) |
| E | = | detector efficiency (4π) |

The instruments used for alpha scans include the Ludlum 43-37 detectors paired with the Ludlum 2360 meters. Table 6-1 provides examples of scan rates, probability rates, and dwell times. Note that for higher alpha release criteria, faster scan rates can be used and still meet the desired probability rates.

Table 6-1 – Estimated Alpha Instrument Scan Probabilities and Dwell Times

| Detector Model | Scan Rate | Typical Background (cpm) | Physical Detector Area | Width of detector | Typical 4π Efficiency | Example Release Criterion | Probability of Detection | Dwell Time |
|----------------|-----------|--------------------------|------------------------|-------------------|-----------------------|-----------------------------|--------------------------|------------|
| Ludlum 43-37 | 1 cm/sec. | <1 to 3 | 584 cm ² | 13.4 cm | 15% | 36 dpm/100 cm ² | 70.06% | 1.65 sec. |
| Ludlum 43-37 | 5 cm/sec. | <1 to 3 | 584 cm ² | 13.4 cm | 15% | 480 dpm/100 cm ² | 95.99% | 0.17 sec. |

6.3.3. Removable Contamination Measurement Counting

Removable contamination measurement (smear) counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{static} = \frac{3 + 3.29 \sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E \cdot \frac{A}{100cm^2}}$$

Where:

- MDC_{smear} = minimum detectable concentration level in dpm/smear
- B_r = background count rate in counts per minute
- t_b = background count time in minutes
- t_s = sample count time in minutes
- E = instrument efficiency for radionuclide emission of interest
- A = physical area of the smear in cm²

6.4. Counting Uncertainty

The counting uncertainty for both total and removable measurements is calculated using equation 6-15 from MARSSIM:

$$\sigma_R = \sqrt{\frac{C_{s+b}}{T_{s+b}^2} + \frac{C_b}{T_b^2}}$$

Where:

- σ_R = uncertainty
- 1.96 = multiplier to achieve 95% confidence level

| | | |
|-----------|---|---------------------------------|
| C_{s+b} | = | gross counts of the sample |
| T_{s+b} | = | Sample time (minutes) |
| C_b | = | Gross background counts |
| T_b | = | Background count time (minutes) |

6.5. Uncertainty Propagation and Confidence Interval

Because calculations to determine the final static measurement results are based on dividing the net count rate by total efficiency, the uncertainty propagation formula is as follows (MARSSIM Section 6.8.3):

$$\sigma_A = u \sqrt{\left(\frac{\sigma_{R_b}}{R_b}\right)^2 + \left(\frac{\sigma_E}{E}\right)^2}$$

Where:

| | | |
|----------------|---|--|
| σ_A | = | Measurement propagated error or total uncertainty |
| u | = | Final result in dpm/100 cm ² |
| σ_{R_b} | = | Standard deviation or statistical counting uncertainty of the net count rate |
| R_b | = | Net count rate |
| σ_E | = | Standard deviation of the instrument efficiency |
| E | = | Total efficiency |

Referring to MARSSIM Table 6.9, a k value of ± 1.96 represents a confidence interval equal to 95 percent about the mean of a normal distribution. All total activity measurements will be presented as the final result in dpm/100 cm² \pm total uncertainty (σ_A).

6.6. Instrumentation Specifications

The instrumentation used for facility decommissioning surveys is summarized in the following tables.

Table 6-2 lists the standard features of each instrument such as probe size and efficiency. Table 6-3 lists the typical operational parameters such as scan rate, count time, and the associated MDCs. Alternate or additional instrumentation with similar detection capabilities may be utilized as needed for survey requirements with Ameripysics Corporate Radiation Safety Officer approval.

Table 6-2 – Instrumentation Specifications

| Detector Model | Detector Type | Detector Area | Meter Model | Window Thickness | Typical Total Efficiency |
|----------------|-----------------------------|---------------------|-------------|------------------------|---|
| Ludlum 43-68 | Alpha/Beta Gas Proportional | 126 cm ² | Ludlum 2360 | 0.8 mg/cm ² | 8% (C-14) - Beta 8% (Th-230) - Alpha |
| Ludlum 43-37 | Alpha/Beta Gas Proportional | 584 cm ² | Ludlum 2360 | 0.8 mg/cm ² | 8% (C-14) - Beta 8% (Th-230) - Alpha |
| Ludlum 43-10-1 | Alpha/Beta Scintillation | 100 cm ² | Ludlum 3030 | 0.4 mg/cm ² | 14% – Beta (C-14) 30% – Alpha (Th-230) |

Table 6-3 – Typical Instrument Operating Parameters and Sensitivities

| Measurement Type | Detector Model | Meter Model | Scan Rate | Count Time | Background (cpm) | MDC (dpm/100cm ²) |
|-------------------------|----------------|-------------|-----------|-----------------------|-------------------------|-------------------------------|
| Surface Scans | 43-68 | Ludlum 2360 | 5 cm/sec. | N/A | 350 – Beta 1 – Alpha | 2,115 – Beta N/A – Alpha |
| Total Surface Activity | 43-68 | Ludlum 2360 | N/A | 120 sec. | 350 – Beta 1 – Alpha | 626 – Beta 48 – Alpha |
| Surface Scans | 43-37 | Ludlum 2360 | 3 cm/sec. | N/A | 700 – Beta 2 – Alpha | 729 – Beta N/A – Alpha |
| Removable Beta Activity | Ludlum 43-10-1 | Ludlum 3030 | N/A | 300 sec. ¹ | 70 – Beta 1 – Alpha | 99 – Beta 4 – Alpha |

1. Background count time for the 43-10-1 is 30 minutes or 1800 seconds.

6.7. Background Determination

The use of reference background areas or paired background comparisons is not necessary for the purposes of this plan since the radionuclides of concern do not exist in background or they exist at very small fractions of the DCGLs. An ambient background measurement taken at waist level in the center of each survey unit will be used. The ambient background value will be subtracted from the applicable gross measurement count rates (in cpm) to determine the net measurement count rate. In some cases, it may be necessary to perform material specific background measurements.

7. FINAL STATUS SURVEY DESIGN

Final status surveys are performed to demonstrate that residual radioactivity in each survey unit satisfies the predetermined criteria for release for unrestricted use. The final status survey is conducted using the DQO process. Characterization and remedial action survey data is used as final status survey data to the maximum extent possible in order to minimize overall project costs.

Final status surveys are conducted by performing required scan surveys, total direct surveys, and removable contamination measurements as discussed further in this section. All survey data is documented on survey maps and associated data information sheets.

7.1. Data Quality Objectives

The process of designing a final status survey begins with development of DQOs. On the basis of these objectives and the known or anticipated radiological conditions at the site, the numbers and locations of measurement and sampling points used to demonstrate compliance with the release criterion are then determined. Finally, survey techniques appropriate to develop adequate data are selected and implemented.

Survey results obtained in accordance with the MARSSIM guidelines are used to select between one condition of the environment (the null hypothesis, H_0) and an alternative condition (the alternative hypothesis, H_a). The null hypothesis is treated like a baseline condition that is assumed to be true in the absence of strong evidence to the contrary. Acceptance or rejection of the null hypothesis depends upon whether or not the particular survey results are consistent with the hypothesis.

A decision error occurs when the decision maker rejects the null hypothesis when it is true, or accepts the null hypothesis when it is false. These two types of decision errors are classified as Type I and Type II decision errors.

A Type I decision error occurs when the null hypothesis is rejected when it is true, and is sometimes referred to as a false positive error. The probability of making a Type I decision error, or the level of significance, is denoted by alpha (α). Alpha reflects the amount of evidence the decision maker would like to see before abandoning the null hypothesis, and is also referred to as the size of the test.

A Type II decision error occurs when the null hypothesis is accepted when it is false. This is sometimes referred to as a false negative error. The probability of making a Type II decision error is denoted by beta (β). The term $(1 - \beta)$ is the probability of rejecting the null hypothesis when it is false, and is also referred to as the power of the test.

The null hypothesis for this decommissioning project will be that the residual radioactivity concentrations exceed the release criterion. Acceptable decision error probabilities for testing the hypothesis are set at $\alpha = 0.05$ and $\beta = 0.05$.

7.2. Area Classification

Classification is a critical step in the survey design process. The working hypothesis of MARSSIM is that all impacted areas being evaluated for release have a potential for radioactive contamination above the DCGL. This initial assumption means that all areas are initially considered Class 1 areas unless some basis for reclassification as Class 2, Class 3 or non-impacted is provided. Consistent with this approach, Class 1 areas have the greatest potential for contamination and, therefore, receive the highest degree of survey effort, followed by Class 2 and then Class 3 areas.

Areas that have no reasonable potential for residual contamination do not need any level of survey coverage and are designated as non-impacted areas. These areas have no radiological impact from site operations and are typically identified during the Historical Site Assessment (HSA).

As discussed previously, impacted areas are areas that have some potential for containing contaminated material. They can be subdivided into three classes:

- Class 1 areas: Areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination. Examples of Class 1 areas include site areas previously subjected to remedial actions, locations where leaks or spills are known to have occurred, former burial or disposal sites, waste storage sites, and areas with contaminants in discrete solid pieces of material high specific activity.
- Class 2 areas: These areas have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are not expected to exceed the DCGL. To justify changing an area's classification from Class 1 to Class 2, the existing data (from the HSA, scoping surveys, or characterization surveys) should provide a high degree of confidence that no individual measurement would exceed the DCGL. Examples of areas that might be classified as Class 2 include locations where radioactive materials were present in an unsealed form, potentially contaminated transport routes, upper walls and ceilings of rooms subjected to airborne radioactivity, areas where low concentrations of radioactive materials were handled, and areas on the perimeter of former contamination control areas.
- Class 3 areas: Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the DCGL, based on site operating history and previous radiological surveys. Examples of areas that might be classified as Class 3 include buffer zones around Class 1 or Class 2 areas, and areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification.

The working hypothesis of MARSSIM is that all impacted areas being evaluated for release have a potential for radioactive contamination above the DCGL. This initial assumption means that all areas are initially considered Class 1 areas unless some basis for reclassification as Class 2, Class 3 or non-impacted is provided. Consistent with this approach, Class 1 areas have the greatest potential for contamination and, therefore, receive the highest degree of survey effort, followed by Class 2 and then Class 3 areas.

Based on the current process knowledge and prior survey data, all rooms where remediation is planned will be classified as Impacted Class 1. Areas that have been potentially impacted by equipment removal will be initially classified as impacted Class 2 as long as proper controls were in place during the removal process.

7.3. Survey Unit Identification

A survey unit is a physical area consisting of structures or land areas of specified size and shape for which a separate decision is made as to whether or not that area exceeds the release criterion.

As this decision is made as a result of the final status survey, the survey unit is the primary entity for demonstrating compliance with the release criterion. To facilitate survey design and ensure that the number of survey data points for a specific site is relatively uniformly distributed among areas of similar contamination potential, the site is divided into survey units that share a common history or other characteristics, or are naturally distinguishable from other portions of the site.

A survey unit should not include areas that have different classifications. The survey unit's characteristics should be generally consistent with exposure pathway modeling that is used to convert dose or risk into radionuclide concentrations. For indoor areas each room may be designated as a survey unit. Indoor areas may also be subdivided into several survey units of different classification, such as separating floors and lower walls from upper walls and ceilings (and other upper horizontal surfaces) or subdividing a large warehouse based on floor area.

MARSSIM states that survey units should be limited in size based on classification, exposure pathway modeling assumptions, and site-specific conditions. MARSSIM also suggests size limitations, which for Class 1 structural surfaces is 100 m² or less and Class 2 structural surfaces 100 to 1000 m². Survey units will be established so the recommended size limits are not exceeded.

7.4. Surface Scans

Scanning is used to identify locations within the survey unit that exceed the investigation level, which for this survey is the DCGL. These locations are marked and receive additional investigations to determine the concentration, area, and extent of the contamination. Scanning surveys are designed to detect small areas of elevated activity that are not detected by the measurements using the systematic pattern. For this reason, the measurement locations and the number of total surface activity measurements may need to be adjusted based on the sensitivity of the scanning technique.

Scan surveys are performed for gross alpha and for gross beta/gamma. For the purposes of the final status survey, Class 1 survey units will receive a 100% scan survey of all accessible surfaces. Class 2 survey units will receive a minimum of 25% scan survey of all accessible surfaces. Class 3 survey units will receive a minimum of 25% scan survey of all accessible surfaces.

If elevated activity is detected during the scan surveys, then the location is marked and total and removable surface activity measurements are taken to quantify the activity. Note that these measurements are evaluated on an individual basis and are in addition to the static measurements required by MARSSIM.

7.5. Determining the Number of Sample Locations

For situations where the contaminant is not present in background, or is present at such a small fraction of the DCGL as to be considered insignificant, a background reference area is not

necessary. Instead, the contaminant levels are compared directly with the DCGL value. A one-sample Sign test is used to statistically demonstrate compliance with the release criterion.

The lower bound of the gray region (LBGR) is selected to be one-half the DCGL and is used as an arbitrary starting point for developing an acceptable survey design along with target values of 0.05 for α and β . The width of the gray region, equal to DCGL minus the LBGR, is a parameter that is central to the Sign test. This parameter is also referred to as the shift, Δ .

The absolute size of the shift is actually of less importance than the relative shift, Δ/σ , where σ is an estimate of the standard deviation of the measured values in the survey unit. Values estimated for σ include both the real spatial variability in the quantity being measured and the precision of the chosen measurement system. The relative shift, Δ/σ , is an expression of the resolution of the measurements in units of measurement uncertainty.

The importance of choosing appropriate values for σ must be emphasized. If the value is grossly underestimated, the number of data points will be too few to obtain the desired power level for the test and a resurvey may be recommended. Therefore, in the interest of conservatism a larger value is selected even though the number of data points determined is increased.

The shift (Δ) is equal to the width of the gray region (DCGL - LBGR), and the relative shift is defined as Δ/σ , where σ is an estimate of the standard deviation in the survey unit. Since an actual value for σ is not known, it is preliminarily assumed to be no more than thirty percent of the DCGL. This important assumption is confirmed during characterization. Using this estimate of σ , the relative shift is calculated using a LBGR of fifty percent of the DCGL ($\Delta = 1 \times \text{DCGL} - 0.5 \times \text{DCGL}$). This calculation is shown below.

$$\text{Relative shift} = \frac{\Delta}{\sigma} = \frac{1 - 0.5}{0.3} = 1.6$$

Table 5.5 of MARSSIM provides a list of the number of data points used to demonstrate compliance using the Sign test for selected values of α , β , and Δ/σ .

The value extracted from the table using the expected site-specific parameters is seventeen (17) and represents the minimum number of measurements performed in each survey unit. The values were calculated using the methodology presented in MARSSIM and increased by 20% to account for missing or unusable data.

7.6. Determination of Sampling Locations

In Class 1 survey units, the sampling locations are established in a unique pattern beginning with the random start location and the determined sample spacing. After determining the number of samples needed in the survey unit, sample spacing is determined from MARSSIM equation 5-8:

$$L = \sqrt{\frac{A}{n}} \text{ for a square grid}$$

Where:

- L = sample spacing interval
- A = the survey unit area
- n = number of samples needed in the survey unit

Maps are generated of the survey unit's permanent surfaces included in the statistical tests (floors, walls, ceilings, fixed cabinetry, etc.) and folded out in a 2-dimensional view. A random starting point is determined using computer-generated random numbers coinciding with the x and y coordinates of the total survey unit. A grid is plotted across the survey unit surfaces based on the random start point and the determined sample spacing. A measurement location is plotted at each intersection of the grid plot.

For Class 3 survey units, sample locations are determined by randomly selecting x and y coordinates for each location.

In addition to the survey locations identified for statistical evaluations and elevated measurement comparisons, data may be obtained from judgment locations that are selected due to unusual appearance, location relative to contamination areas, high potential for residual activity, general supplemental information, etc. Data points selected based on professional judgment are not included with the data points from the systematic grid for statistical evaluations; instead they are compared individually with the established DCGLs and conditions. Measurement locations selected based on professional judgment violate the assumption of unbiased measurements used to develop the statistical tests described by MARSSIM.

Much of these processes can be automated using the Visual Sample Plan software developed by the Department of Energy.

7.7. Total Surface Activity Measurements

Direct surveys (static measurements) are performed on building surfaces to the extent practical in impacted areas utilizing instrumentation of the best geometry based on the surface at the survey location. Additionally, locations of elevated activity identified and marked during the scan survey require total activity measurements.

Total surface contamination measurements for gross beta are taken at statistically determined sample locations. Scaler count times are based on achieving detection sensitivity below the DCGL.

7.8. Removable Contamination Measurements

Removable contamination measurements (smears) are collected on building surfaces and structures at each total activity sample location to determine the potential removable contamination. Additionally, removable contamination measurements are collected for building system internals. An area of approximately 100 cm² is wiped if possible. If an area of less than 100cm² is wiped, a comment is added to the survey data sheet estimating the surface area wiped to allow for area correction of the results. Swabs may be used when system or component access points are not large enough to allow for a wipe of a 100 cm² surface area.

7.9. Survey Investigation Levels

Investigation levels are used to flag locations that require special attention and further investigation to ensure areas are properly classified and adequate surveys are performed. These locations are marked and receive additional investigations to determine the concentration, area, and extent of the contamination. The survey investigation levels for each type of measurement are listed by classification in Table 7.1.

Table 7-1 – Survey Investigation Levels

| Survey Unit Classification | Flag Direct Measurement Result When: | Flag Scanning Measurement Result When: | Flag Removable Measurement Result When: |
|----------------------------|--------------------------------------|--|--|
| Class 1 | >75% of DCGL | >75% of DCGL | >200 dpm/100cm ² Beta >15 dpm/100cm ² Alpha |
| Class 2 | >50% of DCGL | >50% of DCGL | >200 dpm/100cm ² Beta >15 dpm/100cm ² Alpha |
| Class 3 | >10% of DCGL | >10% of DCGL | >200 dpm/100cm ² Beta >15 dpm/100cm ² Alpha |

7.10. Survey Documentation

A survey package is developed for each survey unit containing the following:

- Survey Instruction Sheets
- General survey requirements
- Instrument requirements with associated MDCs, count times and scan rates
- Survey Maps
- Overview maps detailing survey locations and placement methodology
- Survey sub-unit maps with additional sample location information, as needed
- Survey Data Sheets
- Signature of Data Collector and Reviewer

7.11. Data Validation

Field data is reviewed and validated to ensure:

- Completeness of forms and that the type of survey was correctly assigned to the survey unit.
- The MDCs for measurements meet the established data quality objectives; independent calculations are performed for a representative sample of data sheets and survey areas.
- Instrument calibrations and daily functional checks were performed accurately and at the required frequency.

7.12. Evaluating Survey Results

In addition to simply comparing the data against the release criteria, basic statistical quantities are calculated for the data obtained from the survey units. First, the average of the data set and the standard deviation are calculated. The average of the data is compared to the DCGL to get a preliminary indication of the survey unit status. Where remediation is inadequate, this comparison may readily reveal that a survey unit contains excess residual radioactivity - even before applying statistical tests. For example, if every measurement in the survey unit is below the DCGL, the survey unit clearly meets the release criterion.

The value of the sample standard deviation is especially important. If the value is too large compared to that assumed during the survey design, this may indicate an insufficient number of samples were collected to achieve the desired power of the statistical test.

The median is the middle value of the data set when the number of data points is odd, and is the average of the two middle values when the number of data points is even. Thus 50% of the data points are above the median, and 50% are below the median. Large differences between the average and the median are an early indication of skewness in the data. Ideally, the difference between the average and the mean should be a small fraction of the sample standard deviation.

Examining the minimum, maximum, and range of the data may provide additional useful information. The range should not be unusually large. When there are 30 or fewer data points, values of the range much larger than about 4 to 5 standard deviations are considered unusual. For larger data sets the range might be wider.

8. FINAL REPORT

A Final Report summarizing decommissioning activities performed at the facility will be prepared and submitted to Indiana University for their review and submittal to the NRC. The Final Report will include:

- Introduction
- Radionuclides of Concern

- Facility Description
- FSS Objectives
- FSS Procedures
- Data Interpretation
- Findings and Results
- Comparison of Results with Guidelines
- Conclusions

Supporting appendices/attachments will also be provided, as required. Discussions therein may include the number of samples and measurements collected, maps and drawings illustrating findings and the locations of samples/measurements, statistical evaluations and other comparisons to guidelines, descriptions of field changes and anomalous results, conclusions based on specific and overall finding of the investigation, and other relevant information as required to demonstrate compliance with this plan and overall project objectives.

9. RADIOACTIVE WASTE MANAGEMENT PROGRAM

Radioactive wastes generated as a result of decontamination will be transported to either a licensed radioactive materials processor or for direct disposal at a licensed radioactive materials disposal facility.

9.1. Waste Characterization

Previous and in process sample results will be used to develop the mix of nuclides in the waste. Activities of the concrete wastes may be estimated using the sample results collected during the characterization multiplied by the weight of the wastes.

9.2. Waste Shipment

Waste containers will be prepared, loaded, and manifested by personnel who have satisfied the training requirements of Title 49 of the Code of Federal Regulations (CFR) Part 172, Subpart H. Shipping papers will reflect Indian University as the generator.

10. REFERENCES

1. NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM)
2. NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of Final Decommissioning Surveys"
3. NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions"
4. NUREG 1757, Volume 1 "Consolidated NMSS Decommissioning Guidance," Appendix B
5. NUREG 1757, Volume 2 "Consolidated NMSS Decommissioning Guidance,"

6. 10 CFR 20 Subpart E, "Radiological Criteria for License Termination"
7. Ameripysics Radiological Control Procedure Manual and associated Procedures.
8. Handbook of Health Physics and Radiological Health, Third Edition.