May 27, 1998 SECY-98-117

FOR: The Commissioners

FROM: L. Joseph Callan /s/
Executive Director for Operations

SUBJECT: SHELWELL SERVICES, INC., RISK ASSESSMENT

PURPOSE:

To request Commission guidance on two matters related to the Shelwell site: (1) the staff's proposal to apply a risk-informed method for assessing the residual contamination at the Shelwell site; and (2) coordination with the State of Ohio in light of its intent to become an Agreement State.

BACKGROUND:

Shelwell Services, Inc., located outside of Columbus, Ohio, is licensed to use sealed sources and unsealed radioactive material in well logging and tracer studies of oil and gas wells. In September 1983, the licensee accidentally drilled into a 2-curie (Ci) cesium (Cs) -137 sealed source. Release of Cs-137 resulted in widespread contamination of the licensee's employees, facilities, and grounds, as well as homes and non-licensee businesses.

Shelwell performed extensive remediation of the contaminated areas, with the exception of an onsite sewer line and sewer lift station. In a May 22, 1984, letter, the Nuclear Regulatory Commission (NRC) staff released the Shelwell facilities for "licensee use." However, conditions were placed on Shelwell's license that restricted the use of the property. According to Mr. Keith Moon, a Shelwell consultant, the cost of the 1983 cleanup was about $800,000, and NRC's May 22, 1984, letter, was used by the licensee's insurance company to relieve the insurance company from further liability.

From 1984 to 1995, routine inspections were conducted at the Shelwell site. On July 20, 1995, the licensee requested that "NRC release Shelwell's sewer line and remove all license conditions restricting the facility." To determine if the facility was suitable for unrestricted use, thereby allowing the license conditions to be removed, the staff conducted limited confirmatory surveys at the site.

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Elevated contamination levels were identified in the sewer line and sewer lift station, on the grounds around Building 2, and on the interior surface of Building 2. These contamination levels exceeded the unrestricted use criteria in the Site Decommissioning Management Plan (SDMP) Action Plan (57 FR 13389). Since 1995, the staff has corresponded with Shelwell, or visited the site, on several occasions, and has made a number of radiological surveys and evaluations to determine if the license conditions restricting the facility could be removed.

In a January 13, 1998, letter, the licensee requested that its license be terminated, as opposed to amended. The licensee stated that it is "not filing bankruptcy at this time, but of course, it is always a consideration." Therefore, the financial condition of the licensee is a concern.

DISCUSSION:

1. Recent NRC Surveys

The staff inspected the Shelwell site on April 29 through May 1, 1997. NRC's measurements during the inspection identified elevated levels of radiation in over 200 separate locations in the outdoor areas surrounding Building 2. The elevated radiation was caused by very small, discrete particles containing Cs-137. The particles appear to be insoluble, with minimal leaching to surrounding soil. Contamination was also identified on surfaces inside Building 2. Over 70 areas with elevated radiation levels were identified in the building, mostly in the northwestern parts of the building where the source was breached. The building contamination was also in the form of very small particles. The initial analysis of the soil samples collected from the elevated areas, and the review of the building surface contamination measurements, indicated that the contamination levels significantly exceeded NRC criteria for unrestricted use. The licensee is remediating the particles identified by NRC. However, since NRC did not perform a definitive survey, the staff believes that additional, unidentified, particles remain in the soil, and to a lessor extent the building. Detection and remediation of the remaining particles would be technically and financially challenging for the licensee and would potentially generate large volumes of waste. In addition, the success of the effort would be difficult to evaluate, and particles would likely remain after a comprehensive survey and remediation effort is completed. Therefore, the staff evaluated the risk from releasing the site for unrestricted use with particles remaining.

The fact that the contamination identified was in the form of discrete, very small, particles made comparison with existing guidelines difficult. The existing unrestricted-use guidelines for both building surfaces and soil, as listed in the SDMP Action Plan, apply to average contamination levels and assume that the contamination is uniformly distributed and relatively widespread. However, calculating average levels to determine compliance for the Shelwell site has limited usefulness. For example, using conservative assumptions, one could demonstrate that the average Cs-137 concentration in the soil at the Shelwell site is less than the applicable guideline. However, individual soil samples were identified that contained over 70 times the guideline level. The high activity levels were caused by the presence of one, or perhaps a few, discrete particles in the soil samples. Therefore, to determine the risk to the public at the Shelwell site, the individual particles must be evaluated, in addition to the average contamination level.

2. Shelwell Risk Assessment

The staff performed a risk assessment to determine if the site would be suitable for unrestricted use with particles remaining in the soil. A detailed report on the risk assessment, including all assumptions and calculations, is included in the attachment. The first step was to estimate the dose from the inhalation and ingestion of a single particle. The single-particle doses are listed below. The doses from particles in the soil were estimated using a probabilistic analysis because there is a wide range of particle sizes and activities, resulting in a correspondingly wide range of potential doses. For the building, the maximum doses were less than 25 mrem because the maximum particle activity was much lower than that found in the soil. Therefore, only the maximum building doses were calculated, as opposed to ranges for soil.

- Soil

  Inhaling single particle (Dose Range): 0.02 mrem - 500 mrem
  Ingesting single particle (Dose Range): 0.02 mrem - 31 mrem

- Building

  Inhaling single particle (Maximum Dose): 24 mrem
  Ingesting single particle (Maximum Dose): 1 mrem

The doses listed above assume that a particle is inhaled or ingested. However, the probability of inhaling or ingesting a particle in a given year is clearly not 100 percent; in fact, it is considerably lower. Since the probability of inhaling or ingesting a particle is very low, the staff does not believe that it is appropriate to use the single-particle doses, alone, as the indicators of risk at the Shelwell site. Risk was calculated by estimating the annual probability of inhaling and ingesting a particle and multiplying that probability by the resulting dose. This expression of risk is called the "expectation dose." It should be noted that this is the first time that the staff has proposed to account for the probability of exposure to discrete particles of residual contamination in considering license termination and release of a site for unrestricted use. Although this approach is not explicitly addressed in the recently promulgated Final Rule on "Radiological Criteria for License Termination" (LTR) (62 FR 39058), it is not inconsistent with, and appears to be within the intent of, the LTR. This is also consistent with risk-informed approaches used for calculating dose from low-level and high-level waste disposal. The probabilities were calculated using conservative, bounding assumptions, and the expectation doses were calculated using the maximum single-particle doses. The probabilities and expectation doses are listed below.

	Soil	Building
Inhalation:		
Probability of inhalation:	1 particle in 75,000 years	1 particle in 5 years
Maximum expectation dose:	7E-3 mrem/yr	5 mrem/yr
Ingestion:		
Probability of ingestion:	1 particle in 7,000 years	1 particle in 5 years
Maximum expectation dose:	4E-3 mrem/yr	0.2 mrem/yr

The annual risk from the building and soil contamination at the Shelwell site is low, notwithstanding the fact that the maximum dose from an individual particle in the soil could be as high as 500 mrem. The maximum lifetime risk of fatal cancer from the particles in soil, assuming a 30-year exposure period, is estimated to be less than 1.1E-07. Because the 1.1E-07 risk estimate is well below the risk level associated with the 25 mrem annual dose limit in the LTR (3.8E-04), the staff believes that the probabilistic approach is appropriate for determining whether the Shelwell site is suitable for unrestricted use. Prior to making a final assessment, the staff would require the licensee to remediate identified "hot spots" where direct radiation levels exceed guideline levels.

3. Consultation With the State of Ohio

NRC provided the Ohio State Department of Health (ODH) with a draft copy of the attached risk assessment for review and comment. The ODH staff expressed concerns about the probabilistic approach, and indicated that it would prefer some type of restrictions on site use after license termination because of the potentially high maximum dose from the inhalation of a single particle. After careful consideration of the State's comments, the NRC staff still believes that the probabilistic approach provides an appropriate consideration of risk and should be used to determine whether the site is suitable for unrestricted use. Note that Ohio has filed a letter of intent to become an Agreement State and is expecting approval of its application in fiscal year 1999, which would place the Shelwell site under Ohio jurisdiction.

The staff seeks Commission guidance regarding three possible options for moving forward in light of the concerns expressed by the State of Ohio on use of the probabilistic approach: 1) continue the review of Shelwell's license termination request, using the probabilistic approach, and provide the State an opportunity to provide input during the process, including public meetings; 2) attempt to gain Ohio's agreement on the appropriate approach prior to proceeding with the review of the license termination request; or 3) defer further review for license termination pending transfer of the site to Ohio when it becomes an Agreement State. If either Option 1 or 2 is followed, the staff would seek Commission approval before an action is initiated to terminate the Shelwell license if Ohio does not support the action. Under Option 2, if Ohio has not agreed to support the risk assessment approach by the time Ohio's Agreement State application is approved, and the case is not resolved, the site will be transferred to Ohio. Note that the licensee's consultant has contacted Congressional representatives in the past to complain about delays, which has prompted Congressional staff inquiries as to the status of the case.

4. NRC Actions For License Termination

If the Commission directs the staff to move forward with license termination under Option 1, the staff would provide for input from State and local officials and the public prior to making a final decision. An Environmental Assessment (EA) would be performed using the risk assessment method discussed in this paper. The results of the EA would be published in the Federal Register and sent to local and State government officials. In addition, a public meeting would be held, in the vicinity of the Shelwell site, to discuss the pending license termination. At this time, it is not certain whether the license termination process could be completed before Ohio becomes an Agreement State in the 1999 time frame. If the Commission directs the staff to proceed with Option 2, the staff would pursue agreement with the State of Ohio prior to proceeding with the above activities.

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objection.

RECOMMENDATION:

The staff recommends that the Commission: 1) approve the staff's proposed use of a probabilistic approach in determining whether the Shelwell site may be released for unrestricted use; 2) approve Option 2 above, which would direct the staff to attempt to gain agreement with the State of Ohio regarding the application of the probabilistic approach before proceeding with the actions required to terminate the license.

L. Joseph Callan
Executive Director
for Operations

Attachment: As stated

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objection.

RECOMMENDATION:

The staff recommends that the Commission: 1) approve the staff's proposed use of a probabilistic approach in determining whether the Shelwell site may be released for unrestricted use; 2) approve Option 2 above, which would direct the staff to attempt to gain agreement with the State of Ohio regarding the application of the probabilistic approach before proceeding with the actions required to terminate the license.

L. Joseph Callan
Executive Director
for Operations

Attachment: As stated

FILE NAME: A:\SHELX2.COM ***See previous concurrence**

OFC	LLDP	TechEd	LLDP	LLDP E	OGC	RIII
NAME	DFauver/bg/cv	EKraus*	LBell*	JHickey*	STreby*	RCaniano*
DATE	1/23 /98	1/26/98	1/29/98	4/02/98	2/9/98	2/11/98

OFC	DWM*	OSP*	NMSS*	DEDR	EDO	
NAME	MVFederline	DBangart	CPaperiello	HThompson	LJCallan	
DATE	4/02/98	4/ 08 /98	5/ 01 /98	5/ /98	5/ /98	

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Risk Assessment for Cs-137 Particles Identified During 4/29/97 Inspection of the Shelwell Services, Inc. Site

1. **Background**

The Nuclear Regulatory Commission (NRC) inspected the Shelwell Services, Inc. (Shelwell) site in Hebron, Ohio, on April 29 through May 1, 1997. The purpose of the inspection was to conduct confirmatory surveys of the Shelwell site to determine if the site was suitable for unrestricted use. The inspection was conducted by the NRC Region III office with assistance from the Oak Ridge Institute for Science and Education (ORISE) and NRC Division of Waste Management staff. The inspection was documented in NRC Inspection Report # 030-05798, and in an ORISE report "Final Letter Report - Radiological Survey of Building 2, Exterior Grounds, and Wastewater Pipe, Shelwell Services, Inc. (Docket No. 30-05798, RFTA No. 97-16)," June 17, 1997.

The confirmatory survey identified over 200 separate locations of elevated activity in the outdoor areas surrounding Building #2 (Attachment 1). The radiation levels ranged from twice background to over 1000 times background at ground level. The elevated radiation was caused by very small, discrete particles containing Cs-137. This was not unexpected since an evaluation by Argonne National Laboratory (February 7, 1984, letter from L.A Neimark, Argonne National Laboratory, to Mr. P. Loysen, NRC)(Attachment 2) indicated that particles remaining in the breached source contained Cs-137 particles ranging in size from 5 um to 100 um. Eighteen of the elevated soil areas were sampled by NRC staff and analyzed using gamma spectroscopy. The total activity in these samples ranged from about 0.008 uCi to 6.4 uCi Cs-137. Note that the exempt quantity for Cs-137 in Schedule B of 10 CFR 20 is 10 uCi. The total activity was assumed to be contained in a single particle within each sample. The particles appear to be insoluble, with minimal leaching to surrounding soil.

Contamination was also identified in Building 2. Over 70 elevated areas were identified in the building, mostly in the northwestern parts of the building where the source was breached (Attachment 3). The building contamination was also in the form of small particles. The survey results ranged from 200 cpm/100 cm^2 to over 100,000 cpm/100 cm^2.

The fact that the contamination at the Shelwell site is in the form of discrete, very small, particles makes comparison to existing guidelines difficult. The unrestricted use guidelines for both building surface contamination and soil contamination apply to average contamination levels and assume that the contamination is uniformly distributed and relatively widespread. However, calculating average contamination levels to determine compliance for the contamination at the Shelwell site has limited usefulness. For example, assuming that 1000 particles remain in the soil at the site and that all of the particles contain the maximum activity level of 6 uCi Cs-137, the average Cs-137 concentration in the soil could be calculated to be 2.5 pCi/g Cs-137 (assuming the volume of concern is 100m X 100m X .15m). This compares favorably with the unrestricted use criteria of 15 pCi/g Cs-137 in place prior to the issuance of the new decommissioning rule. However, individual soil samples were identified to contain over 1000 pCi/g. Therefore, to determine the risk to the public at the Shelwell site, the individual particles must be evaluated, in addition to the overall average contamination level. This report evaluates the risk from the particulate contamination at the Shelwell site and provides recommendations for future action at the site.

2. **Committed effective dose equivalent Draft Report on "Hot Particles in the Eye, Ear, or Lung"**

A draft report on hot particle risk and dose assessment was developed by the National Council on Radiation Protection and Measurements under NRC contract. The report is entitled "Hot-Particles in the Eye, Ear, and Lung," SC 86, May 2, 1997. Although the draft was intended for comment only, and not for reference, it was considered the most up to date information available to NRC and was used as general guidance in this report. The National Council on Radiation Protection and Measurements recommends the following exposure criteria for hot particles:

Skin - 50 rad/particle

Respiratory System (inhalation) - Currently applicable effective dose limits using general respiratory system models for insoluble material.

Gastrointestinal (GI) System (ingestion) - Currently applicable effective dose limits using general GI models for insoluble materials.

3. **Inhalation and Ingestion Dose Coefficients**

Before the inhalation and ingestion doses could be estimated, dose coefficients for insoluble Cs-137 needed to be calculated. New dose coefficients were needed since the primary NRC sources for this information, Federal Guidance Report No. 11 and 10 CFR 20, do not contain coefficients for insoluble Cs-137. The insoluble dose coefficients were obtained from Dr. Keith Eckerman, Oak Ridge National Laboratory. The coefficients were calculated using the same methodology as in Federal Guidance Report No. 11 except that the ICRP 66 lung model was used. The ICRP 66 lung model is an update of the model used in Federal Guidance Report No. 11 and is better suited for handling particulates. Dose coefficients were calculated for two particle sizes, 5 um and 100 um per the 1984 Argonne National Laboratory report.

Attachment 4 contains the summary reports received from Oak Ridge National Laboratory. The coefficients are listed below. The inhalation dose coefficient is a function of particle size; the ingestion coefficient is independent of particle size.

Inhalation Dose Coefficients:

5 um diameter particle = 2.15E-08 Sv/Bq (committed effective dose equivalent)
100 um diameter particle = 5.5E-10 Sv/Bq (committed effective dose equivalent)

Ingestion Dose Coefficient:

All Particle Sizes = 1.3E-9 Sv/Bq (committed effective dose equivalent)

4.0 **Risk Assessment for Particles in Soil**

The risk from particles in the soil was estimated by determining the annual "expectation" dose. The expectation dose is calculated by multiplying the probability of inhaling or ingesting a particle in a given year by the dose from the particle. The maximum dose from inhaling and ingesting a single particle was estimated to be about 530 mrem, with 500 mrem attributable to particle inhalation and 30 mrem attributable to particle ingestion. The 530 mrem maximum

dose significantly exceeds the 25 mrem decommissioning limit in 10 CFR 20, as well as the public dose limit of 100 mrem/year. However, the probability of incurring the dose was believed to be very small. The magnitude of the maximum single particle dose prompted the staff to evaluate the distribution of potential doses to get a better understanding of the dose range and the probability of exceeding 25 mrem. To determine the distribution of potential doses, a probabalistic analysis was performed using the "Crystal Ball" (Version 3.0.3) software package.

To use the Crystal Ball software, it was necessary to estimate the distributions of the variables that serve as inputs to the dose calculation. A description of the input distributions to the inhalation dose calculation, and the bases for the distributions, is provided below. Subsequent sections provide the output of the Crystal Ball Monte-Carlo simulations, the probability of inhaling and ingesting a single particle in a given year, and the annual "expectation" dose, i.e., risk, for the inhalation and ingestion of particles in the soil.

4.1 **Risk From Particle Inhalation (Soil)**

4.1.1 **Inhalation Dose Calculation Input Distributions (Soil)**

Source Term - 17 of the elevated areas identified during the confirmatory survey were sampled by NRC and analyzed in the NRC mobile laboratory. The selection of sample locations was, in general, biased toward the elevated areas with the highest survey instrument readings. However, some of the samples were collected from elevated areas that exhibited readings that could be characterized as closer to the average of the elevated areas identified. Overall, the 17 samples analyzed represent a distribution of particle activities that does not appear to underestimate the activity distribution of the particles remaining in the soil.

The 17 sample results were used to estimate the source term input distribution. The results ranged from 0.008 uCi to 6.4 uCi. The distribution is based directly on a histogram of the sample results. Page 7 of the Crystal Ball report in Attachment 5 contains a tabular and graphical display of the source term distribution.

Particle Size - The particle size distribution is taken directly from the 1984 Argonne National Laboratory report. This report states that the particles range in size from 5 um to 100 um. There is no information as to the distribution of the particle sizes. Therefore a uniform distribution is assumed for the dose assessment. See page 7 of Attachment 5 for a description of the particle size distribution.

Dose Coefficients - As discussed above, inhalation dose coefficients were calculated for particle sizes of 5 um and 100 um. It is assumed that the dose coefficient is a linear function of particle size between 5 um and 100 um.

4.1.2 **Inhalation Dose Calculation - Single Particle (Soil)**

The Crystal Ball software was used to generate a distribution of estimated doses by making 1000 inhalation simulations using the Monte Carlo technique. Attachment 5, Page 1, contains a

summary table of the results. Page 9 of Attachment 5 shows a probability plot of the projected inhalation dose from a single particle. The dose percentiles are reproduced in Table 1.

Probability	mrem
1.0	0.02
0.9	1
0.8	3
0.7	6
0.6	20
0.5	40
0.4	70
0.3	100
0.2	140
0.1	210
0.0	500

Table 1 - Probability that the dose from the inhalation of a single particle that is resuspended with soil exceeds the listed value.

4.1.3 **Probability of Particle Inhalation (Soil)**

4.1.3.1 Assumptions

Number of Particles in Soil (Bounding Estimate) - There is considerable uncertainty regarding the number of particles remaining in the soil at the Shelwell site. However, there appears to be enough information to justify a bounding estimation. The bounding calculation starts with a limiting condition that the average concentration in the soil should not exceed 15 pCi/g, which was the decommissioning criteria in place prior to the issuance of the Final Rule on Radiological Criteria for License Termination (62 FR 39058). The precise reference for the 15 pCi/g limit for Cs-137 is the "Order Establishing Criteria and Schedule for Decommissioning the Bloomsburg Site," (57 FR 6136). The license termination rule allows licensees to defer the use of the new rule until August 20, 1998. Therefore 15 pCi/g is considered appropriate.

The 15 pCi/g limiting condition was cross-checked by estimating the exposure rate that would occur if 15 pCi/g Cs-137 were uniformly distributed in the first 15 cm of soil. Exposure rate measurements at the site, collected at 1 m above the ground surface, have not indicated any extended areas above background levels. However, the measurements made to date have been limited in scope. If the soil were contaminated at an average level of 15 pCi/g, the general area exposure rate would be about 8 uR/hr, above background at 1 meter. This value was

estimated using the Microshield software package (Version 4.2.1). Attachment 6 contains the Microshield report. Since the projected exposure rate appears to be above the general area levels measured at the Shelwell site, the assumption that the average concentration level is 15 pCi/g or less is qualitatively supported.

As shown below, the bounding number of particles is estimated to be 18,000 particles. For the bounding estimate of 18,000 particles to be exceeded, the number of particles present would be over 90 times greater than the 200 particles identified by NRC during the confirmatory survey. It is difficult to quantify the particle detection efficiency of the scan instrumentation used by NRC. However, the fact that particles were identified with activities ranging from 0.01 uCi to 6.4 uCi, at depths ranging from the surface to 12 inches, supports a qualitative argument that it is unlikely that the number of particles was underestimated by a factor of 90. This further supports the assertion that 18,000 particles is bounding.

Additional assumptions:

- contaminated volume of land 100m x 100m x 0.15m.

- soil density 1.6 g/cm^3

- each particle contains the average Cs-137 activity level of 2.0 uCi

Calculation of Bounding Estimate:

- Bounding Number of Particles =

  [100m x 100m x 0.15m)(1E+6 cm^3/m^3)(1.6 g/cm^3)(15 pCi/g) x (1E-6 uCi/pCi)] ÷ 2 uCi/particle

  = 18,000 particles in soil

Breathing Rate - 8400 m^3/yr (RESRAD default value)

Dust Mass Loading Factor in Air - 200 ug/m^3 (RESRAD default value)

Particles per gram of soil

- Particles/g =

  18,000 particles ÷ 2.4E+9 g

  = 7.5E-06 particles/g

4.1.3.2 Calculation

- Annual Inhalation Probability =

(7.5E-06 particle/g)(200E-06 g/m^3)(8400 m^3/yr)

= 1.3E-05 particles inhaled/yr

4.1.4 **Annual Risk From Particle Inhalation (Soil)**

The risk is expressed as the annual expectation dose. A bounding risk estimate was made using the maximum estimated dose of 500 mrem per particle. A list of the probability percentiles from the Monte-Carlo Simulations of the expectation dose is on Page 2 Of Attachment 5. The calculation of the maximum expectation dose is provided below.

- Maximum Annual Expectation Dose =

  (500 mrem/particle)(1.3E-05 particles inhaled per year)

  = 7E-03 mrem/yr expectation dose

4.2 **Risk From Particle Ingestion (Soil)**

The risk from ingesting a particle in the soil is estimated using the same method that was used for particle inhalation. The risk is estimated by multiplying the probability of ingesting a single particle by the resulting dose.

4.2.1 **Ingestion Dose Calculation - Single Particle (Soil)**

The maximum dose from ingesting a single particle is about 30 mrem, as discussed below. Although the maximum dose is relatively low, it does exceed 25 mrem. Therefore, the dose distribution was determined using the Crystal Ball software. Another reason for using Crystal Ball was to determine the total risk and total dose from inhalation and ingestion of particles in the soil.

4.2.1.1 Assumptions

Ingestion Dose Coefficient - 1.3E-9 Sv/Bq

Single Particle Activity - The activity distribution developed for the inhalation calculation was also used for ingestion. See page 7 of Attachment 5.

4.2.1.2 Calculation

The distribution of ingestion doses is in the “percentile” table on page 3 of Attachment 5. The dose ranges from a maximum of 31 mrem to a minimum of 0.04 mrem. The maximum dose calculation is provided below.

- Maximum Ingestion Dose =

  (6.4 uCi)(3.7E+4 Bq/uCi)(1E+5 mrem/Sv)(1.3E-09 Sv/Bq)

= 31 mrem

4.2.2 **Probability of Particle Ingestion (Soil)**

4.2.2.1 Assumptions

Adult soil ingestion rate - 50 mg/d (RESRAD default)

Days per year - 365 days per year (RESRAD default)

Particles per gram of soil - 7.5E-6 particles/g

4.2.2.2 Calculation

- Particles Ingested per Year =

  (7.5E-06 particles/g)(1 g/1000 mg)(50 mg/d)(365 d/yr)

  = 1.4E-4 particles/yr

4.2.3 **Annual Risk From Particle Ingestion (Soil)**

The calculation of maximum annual risk is provided below. Page 4 of Attachment 5 provides the "percentile" table which shows the distribution of ingestion risk.

- Maximum Annual Expectation Dose =

  (1.4E-4 particles ingested/yr)(31 mrem/particle)

  = 4.3E-3 mrem/yr expectation dose

4.3 **Total Dose and Risk from Inhalation and Ingestion of Particles in Soil**

Page 5 and 6 of Attachment 5 provide the distributions of total dose and risk, respectively, from the particles in the soil The maximum total dose is 535 mrem/yr. The maximum total risk is 1E-2 mrem (expectation dose)/yr.

5. **Risk Assessment for Particles on Building Surfaces**

The exposure pathways considered in the risk assessment for the particles on the building surfaces are the same as for soil, i.e., inhalation, ingestion, and particle deposition on the skin. The maximum activity of the particles remaining in the building is expected to be below 0.3 uCi.

As shown below, if a single 0.3 uCi particle is inhaled and a single 0.3 uCi particle is ingested in a given year the dose would be 25 mrem (committed effective dose equivalent). This assumes that the particle size is 5 um, which results in the highest dose.

Because the dose is expected to be at or below 25 mrem, a simple bounding risk estimate was performed as opposed to a probabilistic assessment as was done for the particles in the soil. However, the approach to estimating risk was the same. The risk was calculated by multiplying the probability of inhaling and ingesting a particle by the resulting doses. This product is referred to as the annual expectation dose.

5.1 **Risk Assessment for Particle Inhalation (Building)**

5.1.1 **Probability of Particle Inhalation (Building)**

5.1.1.1 Assumptions

Resuspension Factor - There have been numerous studies to estimate the amount of resuspension from building surfaces. The studies typically estimate the ratio of activity per air volume to activity per surface area (pCi/m^3 per pCi/m^2). Resuspension factors have been measured to range from 1E-08 to 1E-02 under a variety of conditions such as sweeping, walking, and extreme mechanical and wind disturbance. A conservative value of 1E-04 was selected. The primary reason that this value is considered conservative is that all of the studies to determine resuspension factor assume that the contamination is readily removable. The particles in the building are predominantly fixed, particularly on the floor, where the greatest chance of disturbance and resuspension exists.

Number of Particles Remaining in Building - Over 70 particles were identified in the building during the confirmatory survey. However, this survey was not comprehensive. Many potentially contaminated areas were inaccessible or were not surveyed due to time constraints. Notwithstanding the qualitative nature of the survey results, a bounding estimate of 1000 particles is considered justified for use in this risk assessment.

The 1000 particle estimate is considered conservative and bounding for two reasons. First, the particles are readily detectable. The good detection efficiency supports the conclusion that the 1000 particle estimate is conservative according to the following argument. Assume that NRC surveyed 25% of the potentially contaminated areas, and that these areas are representative of the areas not surveyed. For 1000 particles to remain in the building, a minimum of 250 particles would need to be present on the 25% of the building surveyed. The NRC survey would have had to miss over 75% of the particles in the surveyed areas, if the assumption of 250 particles is correct. This is very unlikely given the good detection efficiency. Second, the building was remediated in the early 1980's after the Cs-137 source was breached. It is reasonable to assume that extensively contaminated areas, such as would be required to have 1000 particles remaining in the building, would have been identified and remediated at that time.

However, there is considerable uncertainty as to the extent of contamination underneath and behind equipment that was present in the building. A significant fraction of the floor area with the highest contamination potential was covered by this equipment. It is not clear whether this equipment was present at the time of the incident, and if so, whether the equipment was moved for remediation or surveys. Therefore, the conservative estimate is justified.

Contaminated Surface Area - The floor and lower 2 meters of the walls in the northwestern portion of the building wall were considered the potentially contaminated areas. This is essentially half of the building. The building floor area is 70m by 40m.

- Potentially Contaminated Surface Area =

  [(70m X 40m) + 2(70m X 2m) + 2(40 m X 2m)]÷ 2

  = 1510 m^2

Uniform Mixing - The particles are assumed to be uniformly mixed in the air available for inhalation.

Inhalation Rate - The inhalation rate is assumed to be 1.2 m3/h. This is the breathing rate for light activity referenced in ICRP 23.

Occupancy Time - 3000 hr/y

5.1.1.2 Calculation of Particle Inhalation Probability

- Particles per Surface Area =

  (1000 particles) ÷ (1510 m^2)

  = 0.67 particles/m^2

- Particles Resuspended per Volume =

  (1E-04/m)(0.67 particles/m^2)

  = 6.7 E-05 particles/m^3

- Annual Probability of Inhaling Particle =

  (6.7E-05 particles per m^3)(1.2 m^3/hr)(3000 hr/yr)

  = 0.24 particle/yr

5.1.2 **Particle Activity (Building)**

The activity of the 70 spots identified in the building were qualitatively evaluated during the survey. The quantitative conversion from counts per minute (cpm) to disintegrations per minute was not considered warranted since the existing surface contamination criteria were clearly exceeded. The activity of the particles identified ranged from about 200 cpm to over 100,000 cpm in one case. The majority of the spots appeared to be below 50,000 cpm. Assuming an efficiency of 15%, 100,000 cpm is equal to 0.3 uCi. There is a low probability that a significant number of particles exceeded this activity. In addition, since a 100,000 cpm particle is easy to identify using standard survey instrumentation it is reasonable to assume that prior remediation efforts have identified and removed the vast majority of the high activity particles. For the reasons stated above, 0.3 uCi is considered the highest activity particle available for inhalation during the risk assessment.

5.1.3 **Inhalation Dose (Building)**

The inhalation dose was calculated assuming that the particle has a 5 um diameter. This assumption results in the highest inhalation dose. The maximum activity was assumed to be 0.3 uCi. The resulting dose, as calculated below, was 24 mrem.

- Maximum Single Particle Dose =

  (0.3 uCi)(3.7E+4 Bq/uCi)(1E+5 mrem/Sv)(2.15E-8 Sv/Bq)

  = 24 mrem

5.1.4 **Annual Risk from Particle Inhalation (Building)**

- Annual Expectation Dose =

  (0.24 particles inhaled per year)(24 mrem per particle)

  = 5 mrem/yr expectation dose

5.2 **Risk from Particle Ingestion (Building)**

5.2.1 **Probability of Particle Ingestion (Building)**

5.2.1.1 Assumptions

<u>Particles per Surface Area</u>

- (1000 particles) ÷ (1510 m^2) = 0.67 particles/m^2

<u>Effective Transfer Factor</u> - The effective transfer rate is the surface area contacted per unit time, the contents of which are ultimately transferred to the mouth by inadvertent fingering of the

mouth or placing contaminated objects, such as food, cigarettes, pencils, etc. There have been a number of studies to estimate this factor. For adults, the transfer factor ranges from 4E-05 m^2/hr to 1E-04 m^2/hr. The most conservative transfer factor, 1E-04 m^2/hr, was used for this risk assessment.

5.2.1.2 Calculation

- Annual Probability of Particle Ingestion =

  (0.67 particles/m^2)(1E-4 m^2/hr)(3000 h/yr)

  = 0.20 particles Ingested/yr

5.2.2 **Dose From Particle Ingestion (Building)**

The dose is calculated using the maximum estimated particle activity, i.e., 0.3 uCi, and the Dose Coefficient for ingestion as discussed in Section 3.

- Maximum Single Particle Ingestion Dose =

  (0.3 uCi)(1.3E-09 Sv/Bq)(3.7E4 Bq/uCi)(1E+5 mrem/Sv)

  = 1 mrem

5.2.3 **Annual Risk From Particle Ingestion (Building)**

- Annual Expectation Dose =

  (1E-04 m2/hr)(3000 h/y)(0.67 particle/m^2)(1 mrem/particle)

  = 0.2 mrem/yr expectation dose

5.3 **Total Dose and Risk from Inhalation and Ingestion of Particles on Building Surfaces**

The maximum dose from the ingestion and inhalation of a particle on the building surface is 25 mrem. The maximum total annual risk, expressed as expectation dose, is 5.2 mrem/yr.

6.0 **Risk Assessment for Skin Deposition of Particles in Soil and on Building Surfaces**

There was no direct reference available to estimate the probability of a particle being transferred from the building surface to the skin. However, the low estimated particle density on building surfaces leads to a general conclusion that the probability is low. In addition, the particles in the building appeared to be concentrated on the horizontal surfaces of wall structures, such as the upper surfaces of I-beams, in crevices between the I-beams and the walls, and, in some cases, lodged into holes in the wall insulation material. The general inaccessibility of the particles further decreases the probability of skin deposition.

Assuming the low-probability event of a particle being deposited on the skin, the resulting skin dose was estimated using the VARSKIN-MOD2 computer code. The exposure was assumed to occur at a depth of 70 mg/cm^2 and was averaged over a 10 cm^2 area per the draft National

Council on Radiation Protection and Measurements report. It was also assumed that the particle remains on the skin for 24 hours. The maximum skin dose, assuming a 0.3 uCi particle, was 0.6 rem. This is well below the 50 rem threshold criteria recommended in the draft ICRP report. The VARSKIN-MOD2 computer code printout is in Attachment 7.

As for the building, the probability that a particle in the soil will be deposited on the skin is difficult to bound, but considered to be a low-probability event. The estimated skin dose from the maximum activity particle identified in the soil during the confirmatory survey, i.e. 6.4 uCi, was 11 rem (Attachment 7). This dose is also below the ICRP threshold of 50 rem.

It is important to recognize that the 50 rem protection criteria recommended by the National Council on Radiation Protection and Measurements is the threshold for the induction of a blister, and possible infection. The cancer risk from exposure to particles on the skin is insignificant at the 50 rem dose level and below.

7.0 **Summary**

The maximum total dose from the inhalation of a single particle and the ingestion of a single particle from the soil at the Shelwell site is 535 mrem. The majority of the dose is from inhalation, i.e., 504 mrem. The distribution of potential particle doses ranges from 7E-2 mrem to 535 mrem, with a 60% probability of exceeding 25 mrem. However, the probability of particle intake is very low; 1E-5/yr for inhalation and 1E-4/yr for ingestion. Because of the very low probability of intake, the risk from the particle contamination in the soil is low. The maximum total risk, expressed as the “expectation” dose, is 1E-2 mrem/yr.

The maximum total dose from inhaling and ingesting a single particle that is removed or resuspended from the building surface is 25 mrem. The range and distribution of doses from the building surface were not determined since the maximum dose was 25 mrem. The probabilities of inhaling or ingesting a particle in a given year are 0.24/yr and 0.20/yr, respectively. The maximum total risk, expressed as “expectation” dose, is 5 mrem/yr.

The maximum doses from the deposition of a particle on the skin are 11 rem from the soil and 0.6 rem from the building. This is well below the 50 rem action threshold recommended by the ICRP.

8. **Recommendations**

8.1 **Particles in Soil**

The risk from the particles in the soil appears to be low at 1E-2 mrem/yr expectation dose. However, there are areas of the site that were not surveyed due to the presence of old equipment. In addition, one area was identified that contained a significant concentration of particles due to being in a surface water runoff path. The old equipment should be removed, and the potentially contaminated soil areas, including the areas under the removed equipment, should be surveyed. Any areas with significant particle contamination, such as the runoff area, should be remediated. “Significant particle contamination” should be defined as any area that exceeds 10 uR/hr, above background, at 1 meter from the ground surface.

8.2 **Particles on Building Surfaces**

The risk from the particles on the building surface appears to be low at 5 mrem/yr expectation dose. However, several of the building surfaces with high contamination potential were not surveyed due to the presence of equipment. The equipment should be removed and a survey performed over the northwestern half of the building. All contaminated areas should be wiped down to ensure easily removable contamination is removed. Any particles above 0.3 uCi should be remediated. Also, any areas with significant particle contamination should be remediated. "Significant particle contamination" should be defined as any area exceeding 5 uR/h, above background, at 1 meter from the building surface.

8.3. **Particles in Sewer Line**

The sewer line is assumed to have the same distribution of particle sizes and activities as was found in the soil. The risk from individual particles is therefore assumed to be acceptably low. Therefore, since the sewer line meets the criteria previously defined by NRC, the line should be released for unrestricted use with no further action.

ATTACHMENTS