DRAFT

Zion*Solutions*, LLC

ZS-2022-0001
Enclosure

Zion Nuclear Power Station, Units 1 and 2

License Amendment Request:
License Termination Plan

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1. SUMMARY DESCRIPTION

In February 1998, in accordance with 10 CFR 50.82(a)(1)(i) and (ii) (Reference 1), Exelon Generating Company LLC (Exelon) notified the Nuclear Regulatory Commission (NRC) of the permanent cessation of operations at the Zion Nuclear Power Station (ZNPS). The NRC transferred Facility Operating License Numbers DPR-39 and DPR-48 on September 1, 2010, from Exelon to Zion*Solutions,* LLC (Zion*Solutions*) (Reference 2) so Zion*Solutions* could begin active decommissioning of the site.

10 CFR Section 50.82(a)(9) requires that a licensee submit an application for the termination of the site's Part 50 license. The application for termination of the license must be accompanied or preceded by a license termination plan (LTP) to be submitted for NRC approval. The LTP describes the process used to meet the requirements for terminating the 10 CFR Part 50 license and releasing the site for unrestricted use. The LTP is a supplement to the plant's UFSAR or an equivalent document (Defueled Safety Analysis Report (DSAR)).

The NRC issued Amendment Nos. 191 and 178 to the ZNPS licenses on September 28, 2018 (Reference 3). The amendments revised the ZNPS, Units 1 and 2, licenses to add License Condition 2.C.(17). The license condition incorporated the LTP into the ZNPS license and specified limits on changes Zion*Solutions* could make to the LTP without prior NRC review and approval.

Currently, Chapter 5 of the ZNPS LTP provides the Final Status Survey (FSS) Plan for the Zion Station Restoration Project (ZSRP). Chapter 6 of the ZNPS LTP provides the methods used by the ZSRP to demonstrate compliance with the dose criterion in 10 CFR 20.1402. The proposed amendment would add Subsection 5.4.7, *Survey Considerations for Suspected Discrete Radioactive Particle Areas,* to define discrete radioactive particles (DRPs) and incorporate the DRP Survey Plan, for the detection and remediation of DRPs, into the LTP by reference. In addition, the proposed amendment would revise LTP Subsection 6.4.6, *Alternate Scenarios*, to add a fourth scenario which would consider the less likely but plausible (LLBP) scenario where a hypothetical DRP is ingested, inhaled, or deposited on the skin. LTP Subsection 6.4.6 would refer to a new attachment within Chapter 6, Attachment 5, titled *Less Likely but Plausible Scenario for Exposure to Hypothetical Discrete Radioactive Particles.* The proposed attachment would provide an estimate of the number of DRPs that may hypothetically remain on site following survey completion and the methods for calculating dose and risk from the hypothetical DRPs.

2. DETAILED DESCRIPTION

As presented in Subsection 6.1 of the LTP, the site release criteria for the ZSRP are the two radiological criteria for unrestricted use specified in 10 CFR 20.1402:

- Dose Criterion: 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 (AMCG) that does not exceed 25 millirem/year (mrem/yr), including that from groundwater sources of drinking water; and

- As Low As Reasonable Achievable (ALARA) Criterion: the residual radioactivity has been reduced to levels that are ALARA.

The Final Status Survey (FSS) Plan for the ZSRP is presented in Chapter 5 of the LTP. The purpose of the FSS plan is to describe the methods used in planning, designing, conducting, and evaluating the FSS. The FSS Plan describes the final survey process used to demonstrate that the ZNPS facility and site comply with the radiological criteria for unrestricted use specified in 10 CFR 20.1402 (i.e., the Dose Criterion and the ALARA Criterion). Zion*Solutions* has concluded that because the survey methodology to detect DRPs is different from the survey techniques described in Chapter 5 of the LTP, a revision to the LTP is necessary.

Zion*Solutions* proposes to amend Chapter 5 of the LTP by incorporating a new section, Subsection 5.4.7, titled *Survey Considerations for Suspected Discrete Radioactive Particle Areas*. This section would define DRPs as specks of radioactive material identified usually as either activated corrosion product such as cobalt-60, or an irradiated fuel fragment exhibiting greater than 10,000 corrected counts per minute using a beta-sensitive GM pancake detector (100,000 dpm). In addition, the *Survey Plan for Discrete Radioactive Particle Identification and Remediation, ZS-LT-07* (the "DRP Survey Plan"), is proposed to be incorporated by reference into the LTP. The survey plan describes the special survey techniques used for the detection of DRPs in open land survey units where DRPs are suspected.

Chapter 6 provides the methods used by the ZSRP to demonstrate compliance with the Dose Criterion. LTP Subsection 6.4 provides a general overview of the dose Modeling approach. Dose Modeling is performed to demonstrate that remaining residual radioactivity does not result in a dose exceeding 25 mrem/yr as required by the Dose Criterion. The four potential sources of residual radioactivity discussed in Subsection 6.4 are backfilled basements, buried pipe, soil, and groundwater. Alternate scenarios, which were qualitatively considered, are provided in Subsection 6.4.6, *Alternate Scenarios*. The alternate scenarios studied involved changes to the "as left" geometry of the backfilled basements.

Zion*Solutions* proposes to amend Chapter 6 of the LTP by revising Subsection 6.4.6 to add a fourth alternate scenario which considers the LLBP scenario where a hypothetical DRP is ingested, inhaled, or deposited on the skin. Additionally, Subsection 6.4.6 would refer to a new attachment, Attachment 5, *Less Likely but Plausible Scenario for Exposure to Hypothetical Discrete Radioactive Particles.* LTP Chapter 6, Attachment 5, is proposed to provide an estimate of the number of DRPs that may hypothetically remain on site and the methods for calculating dose and risk from those hypothetical DRPs. The proposed amendment states the results of the DRP Survey Plan will be provided in Technical Support Document 22-001, *Discrete Radioactive Particle Survey Report* (the "DRP Survey Report").

In summary, the proposed changes add Subsection 5.4.7 to define DRPs and to incorporate the DRP Survey Plan into the LTP by reference. In addition, the proposed amendment would revise LTP Subsection 6.4.6 to add a fourth alternate scenario which would consider the LLBP scenario where a hypothetical DRP is ingested, inhaled, or deposited on the skin. LTP Chapter 6 would contain a new attachment that would provide an estimate of the number of DRPs that may hypothetically remain on site following survey completion and the methods for calculating dose and risk from those hypothetical DRPs.

The proposed changes to the LTP are shown on the marked-up pages included in Attachment 1. The clean retyped pages are provided in Attachment 2.

3. TECHNICAL EVALUATION

DRPs were periodically identified on the Zion site during decommissioning operations as well as during Final Status Survey. Zion*Solutions* concluded that the survey techniques and dose calculations for DRPs were sufficiently different from those described in the LTP. Therefore, a change to the LTP is proposed to incorporate a DRP Survey Plan, and to add the LLBP scenario for exposure to hypothetical DRPs.

DRP Survey Plan

As there is a lack of specific NRC guidance on planning and conducting surveys for DRPs, Zion*Solutions* devised a DRP Survey Plan. The objective of the DRP Survey Plan is to identify and remediate all the DRPs identified. This approach provides reasonable assurance that there will be no known DRPs remaining on the Zion site that could pose an unacceptably high risk to a member of the public.

The survey approach relies on proven technology and incorporates available industry experience in conducting field surveys. The Data Quality Objective Process and the equipment used to implement the plan are described in detail in the DRP Survey Plan. A discussion on survey techniques and the areas surveyed is presented below.

Survey Techniques and Detailed Investigations

The survey approach uses a towed array of six detectors mounted on a utility terrain vehicle and attached to a counter data logger (the “towed array”). The unit is equipped with a single GPS receiver and antenna combined with a high-accuracy inertial measurement unit (IMU). The data logger, GPS receiver, and the IMU are integrated using an on-board tablet or laptop computer running the scanning software. Any time the investigation level is exceeded during a towed array survey, a detailed investigation is performed. The investigation is designed to identify and remove DRPs that potentially were the source of the elevated reading by the towed array.

The towed array has significant advantages over hand scanning. It provides the ability to cover a large area far more efficiently than hand scanning. This method is consistent with the proposed guidance contained in the draft revision to NUREG-1575 (MARSSIM) (Reference 4), where NRC staff was involved. The draft revision is informative as it recognizes advances in technology. These advances have encouraged the use of automated scanning as a viable option for large survey areas.

Areas inaccessible to the towed array are surveyed using hand-scanning methods. The protocols for gamma scanning with hand-held detectors are delineated in the DRP Survey Plan. Any elevated activity detected by hand scanning would result in a detailed investigation.

Survey Areas

Thirty-six survey units were selected for surveying using the DRP Survey Plan. These areas were selected because they were considered at higher risk for the presence of DRPs based on decommissioning project experience (e.g., a location where clean concrete demolition debris was temporarily stored or transported through), or where previous surveys identified particles or areas of elevated activity. The DRP Survey Plan specifies that areas within the scope of the survey will be expanded, as necessary, as a result of investigations performed, to bound areas of elevated radioactivity or as a result of remediation.

The rationale for not including certain areas in the DRP Survey Plan is that there is a low potential for the presence of DRPs in those areas. This assumption is based on process knowledge and the results of previous radiological surveys, including FSS and ORISE surveys.

LLBP Scenario for Exposure to Hypothetical DRPs

The proposed revision to the LTP provides an estimate of the number of DRPs that may hypothetically remain on site and the methods for calculating dose and risk from those hypothetical DRPs. The DRP activity assumed, and the results of the dose and risk calculations will be provided in a DRP Survey Report.

Justification for Designation as a LLBP Scenario

In the proposed markup to Chapter 6, the DRP exposure scenario is evaluated as an LLBP scenario due to the low probability of DRP exposure occurring. Treating the low-probability DRP exposure as an LLBP scenario is consistent with the approach approved in the Zion LTP for assessing the low-probability scenario of the well driller contacting the Auxiliary Building drains, which was also designated as an LLBP scenario. To justify the designation as an LLBP scenario, the probabilities of DRP ingestion and inhalation are compared to the probability of drilling into the Auxiliary Building drains, which was accepted by the NRC as not likely. The probability of a drill contacting the Auxiliary Building drains is 1.5×10^{-3}. The lifetime probability of a future site resident ingesting or inhaling a DRP, assuming one DRP remains on site, is 1.6×10^{-8} and 1.7×10^{-10}, respectively. These values, which assume a lifetime exposure period of 30 years, are much lower than that of the probability of drilling into the Auxiliary Building drains.

The final lifetime probability of ingesting or inhaling a DRP accounts for the projection of all DRPs hypothetically remaining on site. The estimate of the number of DRPs that could hypothetically remain was calculated by multiplying the number of DRPs identified during execution of the DRP Survey Plan (i.e., one DRP, assumed to be contained in 1.0 cm of soil) by 30.5 (i.e., assumption that DRPs are limited to first 30.5 cm of soil). Therefore, the estimate of the number of unidentified DRPs that hypothetically remain is 31. The lifetime probabilities of a future resident on the Zion site

ingesting or inhaling a hypothetical DRP, assuming 31 DRPs hypothetically remain, is projected to be $4.8x10^{-7}$ and $5.2x10^{-9}$, respectively.

The probability of a DRP being deposited on the skin during the lifetime of a future site resident is $1.2x10^{-7}$. The dermal deposition parameters, used in the equation to derive the probability, are from the Environmental Protection Agency's Risk Assessment Guidance for Superfund (Reference 5). The single DRP lifetime probability is multiplied by the 31 DRP projected to hypothetically remain on the site to derive a final lifetime probability of $3.7x10^{-6}$.

In accordance with Section 5.5.2 of NUREG-1757 (Reference 6), an LLBP scenario is used to "…better risk-inform the decision" and to ensure that "…unacceptably high risks would not result," but are not considered compliance scenarios. Zion*Solutions*' approach is to demonstrate that the risk from the hypothetically remaining DRPs is not unacceptably high. Consistent with the designation as an LLBP exposure scenario, the dose from the hypothetical DRPs will not be added to the compliance dose.

Acceptance Criteria

As no NRC guidance currently exists concerning the dose and/or risk assessment of DRPs, Zion*Solutions* proposes to perform five separate assessments to demonstrate that unacceptably high risks would not result from hypothetical exposure to a DRP. The dose and risk assessments include calculating the following:

- Expectation dose (mrem/yr) from ingestion and inhalation
- TEDE (mrem/yr) from DRP Activity Distributed in Soil
- Lifetime fatal cancer risk from ingestion and inhalation
- EDE (mrem) from skin exposure
- Lifetime fatal cancer risk from SDE due to skin exposure

The final dose and risk assessments from DRP ingestion, inhalation, and skin exposure will be calculated, using the equations in the proposed amendment, and provided in the DRP Survey Report. The proposed amendment to LTP Chapter 6 includes the addition of Table A5-4, *Acceptance Criteria for Demonstrating that "unacceptably high risks would not result" from the LLBP DRP Exposure Scenario.* Table A5-4 is shown below. The acceptance criteria proposed in the table are not intended to be the absolute limits at which the LLBP DRP scenario is assessed. Meeting the acceptance criteria demonstrates that unacceptably high risks do not result; however, higher values may be acceptable on a case-by-case basis. Higher values which are determined to be acceptable will be justified in the DRP Survey Report.

Table A5-4 Acceptance Criteria for Demonstrating that "unacceptably high risks would not result" from the LLBP DRP Exposure Scenario

DRP Exposure Pathway	Lifetime Probability of DRP Exposure Occurring	Assessment Criteria	Acceptance Criteria
Ingestion and Inhalation	NA[1]	Expectation Dose	<25 mrem/yr
Ingestion and Inhalation	Ingestion: 4.8×10^{-7} Inhalation: 5.2×10^{-9}	Fatal Cancer Risk from DRP inhalation and Ingestion[2]	$<4 \times 10^{-4}$
Ingestion and Inhalation	NA[3]	TEDE from DRP Activity Distributed in Soil	<25 mrem/yr
Skin	3.7×10^{-6}	Skin Dose (EDE)	<25 mrem
Skin	3.7×10^{-6}	Fatal Cancer Risk from SDE	$<4 \times 10^{-4}$

1) The expectation dose calculation includes annual probability of exposure occurring

2) The 4×10^{-4} fatal cancer risk is the risk corresponding to the 25 mrem/yr unrestricted use criterion as stated in SECY-97-046A

3) The exposure to a small soil area of distributed activity is assumed to occur annually in the same manner as other small soil elevated areas

Summary

The DRP Survey Plan provides confidence that any remaining DRPs that might pose an unacceptably high risk to an AMCG have been identified and remediated. The DRP Survey Plan supplements the FSS Plan. In accordance with NUREG-1757, the evaluation of the LLBP scenario for exposure to hypothetical DRPs ensures that "unacceptably high risks would not result," but are not considered compliance scenarios. Accordingly, the dose from the hypothetical DRPs will not be added to the ZSRP compliance dose. Rather, the hypothetical DRP dose will be used to better risk inform the decision to terminate the license.

Since the LTP continues to be based on NRC guidance and establishes the methodology Zion*Solutions* will use to meet license termination criteria, this proposed license amendment is appropriate to allow completion of the ZNPS decommissioning project and license termination.

4. REGULATORY EVALUATION

The proposed amendment has been evaluated to determine whether applicable regulations and requirements continue to be met. Zion*Solutions* has determined that the proposed changes do not require any exemptions or relief from regulatory requirements.

4.1 Applicable Regulatory Requirements/Criteria

4.1.1 10 CFR 50.82, *Termination of License*

10 CFR 50.82(a)(6)

Licensees shall not perform any decommissioning activities, as defined in 10 CFR 50.2, that -

(i) Foreclose release of the site for possible unrestricted use;

(ii) Result in significant environmental impacts not previously reviewed; or

(iii) Result in there no longer being reasonable assurance that adequate funds will be available for decommissioning.

The proposed changes add a new section in Chapter 5 to define DRPs and to incorporate the DRP Survey Plan into the LTP by reference. In addition, the proposed amendment would revise LTP Subsection 6.4.6 to add a fourth scenario which would consider the LLBP scenario where a hypothetical DRP is ingested, inhaled, or deposited on the skin. LTP Chapter 6 would contain a new attachment that would provide an estimate of the number of DRPs that may hypothetically remain on site following survey completion and the methods for calculating dose and risk from the hypothetical DRPs.

Therefore, the proposed changes do not impact the criteria listed above in 10 CFR 50.82(a)(6).

10 CFR 50.82(a)(9)

All power reactor licensees must submit an application for termination of license. The application for termination of license must be accompanied or preceded by a license termination plan to be submitted for NRC approval.

(i) The license termination plan must be a supplement to the FSAR or equivalent and must be submitted at least 2 years before termination of the license date.

(ii) The license termination plan must include -

(A) A site characterization;

(B) Identification of remaining dismantlement activities;

(C) Plans for site remediation;

(D) Detailed plans for the final radiation survey;

(E) A description of the end use of the site, if restricted;

(F) An updated site-specific estimate of remaining decommissioning costs;

(G) A supplement to the environmental report, pursuant to 10 CFR 51.53, describing any new information or significant environmental change associated with the licensee's proposed termination activities; and

(H) Identification of parts, if any, of the facility or site that were released for use before approval of the license termination plan.

The initial LTP was submitted to the NRC and incorporated into the ZNPS DSAR as required by 10 CFR 50.82(a)(9)(i). With the proposed changes, the LTP continues to include the information required by 10 CFR 50.82(a)(9)(ii).

4.1.2 10 CFR 50.59, Changes, Tests and Experiments

A 10 CFR 50.59 screening was performed to determine if the proposed changes to the LTP should be evaluated against the criteria of 10 CFR 50.59(c)(2). The proposed changes to the LTP screened out; the proposed changes do not meet the requirements for an evaluation in accordance with 10 CFR 50.59(c)(2).

4.1.3 ZNPS, Units 1 and 2, License Numbers DPR-39 and DPR-48, License Condition 2.C.(17), License Termination Plan (LTP)

Zion*Solutions* shall implement and maintain in effect all provisions of the approved License Termination Plan as approved in License Amendment Nos. 191 and 178 subject to and as amended by the following stipulations:

Zion*Solutions* may make changes to the LTP without prior approval provided the proposed changes do not meet any of the following criteria:

(A) Require Commission approval pursuant to 10 CFR 50.59.

(B) Result in significant environmental impacts not previously reviewed.

(C) Detract or negate the reasonable assurance that adequate funds will be available for decommissioning.

(D) Decrease a survey unit area classification (i.e., impacted to not impacted; Class 1 to Class 2; Class 2 to Class 3; or Class 1 to Class 3) without providing the NRC a minimum 14 day notification prior to implementing the change in classification.

(E) Increase the derived concentration guideline levels (DCGL) and related minimum detectable concentrations (for both scan and fixed measurement methods).

(F) Increase the radioactivity level, relative to the applicable DCGL, at which an investigation occurs.

(G) Change the statistical test applied other than the Sign test.

(H) Increase the approved Type I decision error above the level stated in the LTP.

(I) Change the approach used to demonstrate compliance with the dose criteria (e.g., change from demonstrating compliance using derived concentration levels to demonstrating compliance using a dose assessment that is based on final concentration data).

(J) Change parameter values or pathway dose conversion used to calculate the dose such that the resultant dose is lower than in the approved LTP and if a dose assessment is being used to demonstrate compliance with the dose criteria.

(K) Reuse concrete from demolished structures, other than from the list of areas specified in Section 2.1.1 of TSD 17-010, "Final Report - Unconditional Release Surveys at the Zion Station Restoration Project, Revision 1", as backfill.

(L) Assign a dose for reuse concrete other than the dose values provided along with the LTP (as shown in Table 6-53 (Revision 2) of the LTP) and documented in Section 8 and Table 33 of TSD 14-010, "RESRAD Dose Modeling for Basement Fill Model and Soil DCGL and Calculation of Basement Fill Model Dose Factors and DCGLs, Revision 6."

(M) Use area-specific surrogate ratios that are less than the maximum surrogate ratios (H-3/Cs-137, Ni-63/Co-60, Sr-90/Cs-137) presented in Table 5-15 (Revision 2) of the LTP.

The proposed changes to the LTP meet License Condition 2.C.(17), Criterion I; therefore, the proposed changes to the LTP require prior NRC approval.

4.2 Precedent

None.

4.3 Significant Hazards Consideration

Zion*Solutions* is requesting an amendment to the ZNPS LTP. An evaluation to determine whether or not a significant hazards consideration is involved with the proposed amendment was completed by focusing on the standards set forth in 10 CFR 50.92, *Issuance of amendment*. As discussed below.

4.3.1 Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No

The proposed changes incorporate, into the LTP, a survey plan for discrete radioactive particles. In addition, the proposed changes provide an estimate of the number of DRPs that may hypothetically remain on site following survey completion and the methods for calculating dose and risk from the hypothetical DRPs. There are no physical changes proposed at ZNPS. Therefore, the proposed changes do not involve a significant increase in the probability or consequences of any accident previously evaluated.

4.3.2 Does the proposed amendment create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No

The proposed changes incorporate, into the LTP, a survey plan for discrete radioactive particles. In addition, the proposed changes provide an estimate of the number of DRPs that may hypothetically remain on site following survey completion and the methods for calculating dose and risk from the hypothetical DRPs. There are no physical changes proposed at ZNPS. Therefore, the proposed changes do not involve a significant increase in the probability or consequences of any accident previously evaluated.

4.3.3 Does the proposed amendment involve a significant reduction in a margin of safety?

Response: No

The proposed changes incorporate, into the LTP, a survey plan for discrete radioactive particles. In addition, the proposed changes provide an estimate of the number of DRPs that may hypothetically remain on site following survey completion and the methods for calculating dose and risk from the hypothetical DRPs. There are no physical changes proposed at ZNPS. Therefore, the proposed changes do not involve a significant reduction in a margin of safety.

4.4 Conclusions

In conclusion, based on the considerations above: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public. Therefore, it is concluded that the requested amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of "no significant hazards consideration" is justified.

5 ENVIRONMENTAL CONSIDERATION

The details of the proposed changes are provided in Section 2 of this License Amendment Request. A review has determined the proposed changes require an amendment to the licensing basis. However, Zion*Solutions* has determined the requested amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9), in that:

(i) The proposed changes involve no significant hazards consideration.

(ii) There is no significant change in the types or significant increase in the amounts of any effluents that may be released off site.

(iii) There is no significant increase in individual or cumulative occupational radiation exposure.

Accordingly, the proposed changes meet the criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 50.92(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

6 REFERENCES

1) 10 CFR 50.82, "Termination of License"

2) John B. Hickman (U.S. NRC) letter to John A. Christian, (Zion*Solutions*), "Issuance of Conforming Amendments Relating to the Transfer of Licenses for Zion Nuclear Power Station, Units 1 and 2", dated September 1, 2010

3) John B. Hickman (U.S. NRC) letter to John Sauger, (Energy*Solutions*), "Zion Nuclear Power Station, Units 1 and 2 – Issuance of Amendments 191 and 178 for the Licenses to Approve the License Termination Plan", dated September 28, 2018

4) NUREG-1575, Rev. 2 Draft Report, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," Revision 1, U.S. Nuclear Regulatory Commission, August 2000.

5) "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment," U.S. Environmental Protection Agency, EPA/540/R/99/005, Exhibit 3-5, July 2004.

6) NUREG-1757, Vol. 2, Rev. 2, Draft Report, "Consolidated Decommissioning Guidance – Characterization, Survey, and Determination of Radiological Criteria," September 2020.

Zion*Solutions*, LLC

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Attachment 1
Zion Nuclear Power Station, Units 1 and 2
License Termination Plan Markup

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LIST OF ACRONYMS AND ABBREVIATIONS

AF	Area Factor
ALARA	As Low As Reasonably Achievable
AMCG	Average Member of the Critical Group
BFM	Basement Fill Model
CAQ	Conditions Adverse to Quality
CCDD	Clean Concrete Demolition Debris
C/LT	Characterization/License Termination
CsI	Cesium Iodide
CoC	Chain of Custody
CVS	Contamination Verification Survey
DCGL	Derived Concentration Guideline Levels
DQA	Data Quality Assessment
DQO	Data Quality Objectives
DRP	Discrete Radioactive Particle
EMC	Elevated Measurement Comparison
ETD	Easy to Detect
FOV	Field of View
FSS	Final Status Survey
GPS	Global Positioning System
HPGe	High-Purity Germanium
HSA	Historical Site Assessment
HTD	Hard to Detect
IC	Insignificant Contributor
ISFSI	Independent Spent Fuel Storage Installation
ISOCS	*In Situ* Object Counting System
LBGR	Lower Bound of the Gray Region
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
NAD	North American Datum
NaI	Sodium Iodide
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ODCM	Off Site Dose Calculation Manual
QA	Quality Assurance

The CVS will include extensive scan surveys on the structural surfaces (walls, floors and miscellaneous equipment) that will be subject to open air demolition, regardless of elevation. The scan coverage is dependent on the contamination potential of the structural surface being surveyed. Class 1 survey units will require 100% scan coverage of all exposed concrete surface areas. Any areas identified in excess of the open air demolition limits will be earmarked for remediation.

For structural surfaces below the 588 foot elevation that will remain and be subject to a FSS (primarily any basement floor and outer walls), additional remediation will be performed to ensure that any individual ISOCS measurement will not exceed the Operational $DCGL_B$ from Table 5-4 during FSS. Any areas identified that have the potential to exceed the Operational $DCGL_B$ by ISOCS measurement during the performance of CVS in these areas will be remediated. Any areas of elevated activity that could potentially approach the Operational $DCGL_B$ will be identified as a location for a judgmental ISOCS measurement during FSS.

5.4.6. Post-Demolition Survey

Following demolition, after all debris is removed and the floors cleaned, an additional scan survey will be performed to ensure that any individual ISOCS measurement will not exceed the Operational $DCGL_B$ from Table 5-4 during FSS. The survey will be performed using hand-held beta-gamma instrumentation as presented in Table 5-27 in typical scanning and measurement modes.

5.4.7. Survey Considerations for Suspected Discrete Radioactive Particle Areas

Discrete radioactive particles (DRP) are defined as specks of radioactive material identified usually as either activated corrosion products such as cobalt-60, or an irradiated fuel fragment exhibiting greater than 10,000 corrected counts per minute (100,000 dpm). In open land (soil) survey units where the presence of DRPs is suspected, special survey techniques and actions must be considered. The survey techniques for the detection of DRPs are described in the Survey Plan for Discrete Radioactive Particle Identification and Remediation, ZS-LT-07 (the "DRP Survey Plan") (Reference 5-26), which is incorporated into this LTP by reference.

5.5. Final Status Survey of Basement Structures

Basement structures are defined as basement surfaces (concrete and steel liner), embedded pipe, and penetrations. As described in section 5.4.5, all remaining floor and wall concrete surfaces will be remediated to levels below the Operational $DCGL_B$ as measured by ISOCS. After remediation, a FSS will be conducted to demonstrate that the residual radioactivity in building basements corresponds to a dose below the 25 mrem/yr criteria.

5.5.1. Instruments Selected for Performing FSS of Basement Surfaces

The Canberra ISOCS has been selected as the primary instrument that will be used to perform FSS of basement surfaces. Direct beta measurements taken on the concrete surface will not provide the data necessary to determine the residual radioactivity at depth in concrete and therefore, would have to be augmented with core sampling. The ISOCS was selected as the instrument of choice to perform FSS of basement surfaces for the following reasons:

- The surface area covered by a single ISOCS measurement is large (a nominal range of 10-30 m^2) which essentially eliminates the need for scan surveys.

Development"

5-20 Zion*Solutions* TSD 14-022, Revision 1, "Use of In-Situ Gamma Spectroscopy for Source Term Survey of End State Structures"

5-21 Zion*Solutions* Technical Support Document 10-002, Revision 1, "Technical Basis for Radiological Limits for Structure/Building Open Air Demolition"

5-22 Zion*Solutions* ZS-QA-10, Revision 9, "Quality Assurance Project Plan - Zion Station Restoration Project"

5-23 International Standard ISO 7503-1, Part 1, "Evaluation of Surface Contamination, Beta-Emitters (maximum beta energy greater than 0.15 MeV) and Alpha-Emitters" – August 1998

5-24 U.S. Nuclear Regulatory Commission Inspection Procedure No. 84750 "Radioactive Waste Treatment, and Effluent and Environmental Monitoring" – March 1994

5-25 ZionSolutions ZS-AD-08, "Corrective Action Program"

5-26 ZionSolutions ZS-LT-07, "Survey Plan for Discrete Radioactive Particle Identification and Remediation"

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LIST OF ACRONYMS AND ABBREVIATIONS

AF	Area Factor
ALARA	As Low As (is) Reasonably Achievable
AMSL	Above Mean Sea Level
ANL	Argonne National Laboratory
BFM	Basement Fill Model
CRA	Conestoga Rovers & Associates
DCGL	Derived Concentration Guideline Level
DCF	Dose Conversion Factor
DRP	Discrete Radioactive Particle
DUST-MS	Disposal Unit Source Term - Multiple Species
EPA	Environmental Protection Agency
FGR	Federal Guidance Report
FOV	Field of View
FSS	Final Status Survey
GW	Groundwater
HSA	Historical Site Assessment
HTD	Hard-to-Detect
IC	Insignificant Contributor
ISFSI	Independent Spent Fuel Storage Installation
ISOCS	In-Situ Object Counting System
LLBP	Less Likely but Plausible
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimal Detectable Concentration
NRC	The U.S. Nuclear Regulatory Commission
ODCM	Off-site Dose Calculation Manual
PRCC	Partial Rank Correlation Coefficient
RASS	Remedial Action Support Surveys
REMP	Radiological Environmental Monitoring Program
RESRAD	RESidual RADioactive materials
ROC	Radionuclides of Concern
SFP	Spent Fuel Pool
TEDE	Total Effective Dose Equivalent
WWTF	Waste Water Treatment Facility
ZNPS	Zion Nuclear Power Station
ZSRP	Zion Station Restoration Project

A fourth alternate scenario considers the less likely but plausible (LLBP) scenario where a hypothetical discrete radioactive particle (DRP) is ingested, inhaled, or deposited on the skin. Note that all DRPs identified to date have been remediated and no known DRPs remain. The DRP LLBP scenario assessment is contained in Attachment 5

6.5. Basement Fill Conceptual Model

This section describes in detail the BFM conceptual model, including the source term, ROC, future land use and exposure scenario, AMCG, and exposure pathways. The BFM is used to calculate dose to the AMCG from residual radioactivity in the backfilled, below ground Basements to remain at the time of license termination. The list of Basements to remain is provided in Table 6-1. The computational model used to implement the conceptual model is described in section 6.6.

6.5.1. Source Term

The source term for the BFM is the residual radioactivity, surface plus volumetric, remaining in each of the Basements at the time of license termination. The source term includes residual radioactivity in wall and floor concrete, or steel liner in the case of the Containment Basements, as well as in embedded piping and penetrations that are contained in or interface with a given basement. Embedded pipe and penetrations are treated as separate survey units within the applicable basement that release activity into the basement fill in the same manner as activity from walls and floors (see sections 6-13 and 6-14). The embedded pipe and penetration source terms are accounted for by adding the dose from the embedded pipe and penetration survey units to the dose from the applicable basement wall and floor survey unit. The total dose from all three sources within a given basement must be less than 25 mrem/yr. See section 6.17.1 for discussion of the process for summing the dose from walls/floors, embedded pipe, and penetrations.

LTP Chapter 2 provides detailed characterization data regarding current contamination levels in the Basements. The data is based on concrete core samples obtained at biased locations with high contact dose rates and/or evidence of leaks/spills. The expected source term configuration and radionuclide distribution expected to remain in each Basement, after remediation is completed, is summarized below.

6.5.1.1. Unit 1 and Unit 2 Containment Building Basements

Both Unit 1 and Unit 2 Containment Buildings are comprised of concrete walls and floors with all interior surfaces of the containment 'shell' covered by a 0.25 inch steel liner. The liner on the 565 foot elevation floor is covered by a 30 inch thick layer of concrete. The floor of the Under-Vessel area is located at the 541 foot elevation. A 30 inch layer of concrete is present above the liner in the Under-Vessel area and a 15 inch layer of concrete is on the walls in the Under-Vessel area. The steel liner on walls above the 568 foot elevation and below the 588 foot elevation has surficial contamination with removable contamination levels ranging from less than 1,000 dpm/100cm^2 to approximately 10,000 dpm/100cm^2 as indicated by operational and routine radiological surveys.

ATTACHMENT 5

Less Likely But Plausible Scenario for Exposure to Hypothetical Discrete Radioactive Particles

Less Likely But Plausible Scenario for Exposure to Hypothetical Discrete Radioactive Particles

A.5.1 Introduction

Discrete radioactive particles (DRP) were identified on the Zion site during decommissioning operations as well as during FSS. As discussed in Chapter 5 of this LTP, after the completion of FSS Zion*Solutions* prepared the *Survey Plan for Discrete Radioactive Particle Identification and Remediation*, ZS-LT-07, Revision 1 (DRP Survey Plan). The objective of the DRP Survey Plan is to identify and remediate all of the DRPs identified. Although there is no known DRP source term remaining on the site it cannot be said with absolute certainty that no DRP remain. This attachment provides an estimate of the number of DRPs that may hypothetically remain and the methods for calculating dose and risk from the hypothetical DRPs.

The results of the DRP survey are provided in Technical Support Document 22-001, *Discrete Radioactive Particle Survey Report* (DRP Survey Report). The dose and risk calculations will be performed using the methods described in this attachment. The activity assumed to be present in hypothetical DRPs and the results of the corresponding dose and risk calculations are provided in the DRP Survey Report. The projection of the number of DRP that could hypothetically remain is made in this attachment based on the number of DRP identified during the DRP survey (i.e., one).

A5.2 DRP Exposure Probability and Designation as Less Likely but Plausible Scenario

DRP dose and risk is assessed as a LLBP scenario due to the low probability of hypothetical DRP exposure occurring. Treating the low-probability DRP exposure as an LLBP scenario is consistent with the approach used for assessing the low-probability scenario of the well driller contacting the Auxiliary Building drains, which was also designated as an LLBP scenario. In accordance with NUREG-1757, the evaluation of LLBP exposure scenarios ensures that "unacceptably high risks would not result", however, the evaluation of LLBP scenarios is not conducted to demonstrate compliance. Accordingly, the dose from the hypothetical DRP will not be added to the Zion compliance dose.

To justify the designation of the hypothetical DRP exposure pathways as an LLBP scenario, the probabilities of DRP ingestion and inhalation are compared to the probability of drilling into the Auxiliary Building drains, which was accepted by NRC as not likely. The probability of a drill contacting the Auxiliary Building drains is 1.5×10^{-3}/y as calculated by Equation A5-1. The lifetime probability of a future site resident ingesting or inhaling a DRP, assuming that one DRP remains, is much lower at 1.6×10^{-8} and 1.7×10^{-10}, respectively, as calculated using Equation A5-2.

Equation A5.1

$$P_{drain} = \frac{SA_{drain}}{A_{cz}}$$

where:
P_{drain} = probability of drill contacting Auxiliary Building drain
SA_{drain} = projected surface area of Auxiliary Building drains (96.2 m^2)[1]
A_{cz} = area of contaminated zone (64,500 m^2)[2]

Equation A5-2

$$P_{DRP} = \frac{IR_s Te}{\left(A_{cz} t_{cz} CF_{cm^3/m^3} d_s\right)}$$

where:
P_{DRP} = lifetime probability of ingesting or inhaling a DRP if one DRP hypothetically remains
IR_s = soil mass ingestion rate (18.3 g/y) or inhalation rate 0.2 (g/y)
A_{cz} = area of Zion contaminated zone for soil DCGL calculations (64,500 m^2)
t_{cz} = thickness of soil layer affected by DRP (0.3048 m)
$CF_{cm3/m3}$ = conversion factor (1x10^{-6} cm^3/m^3)
d_s = density of soil (1.8 g/cm^3)
Te = lifetime exposure period of site resident (30 y)

Note: The mass inhalation rate of 0.2 g/y is derived by multiplying the RESRAD mass loading for inhalation value (2.35x10^{-5} g/m^3) by the breathing rate (8400 m^3/y). The assumed 30-year lifetime occupancy period for the site resident is from SECY-97-046A, "Final Rule on Radiological Criteria for License Termination," March 31, 1997 (SECY-97-046A).

The number of unidentified DRPs that could hypothetically remain was calculated by conservatively assuming that all of the DRPs identified during the DRP scan survey were contained in a 1.0 cm layer of soil, regardless of the actual depth at which they were found. Assuming the DRP are contained in a shallow soil layer provides a qualitative correlation to the depth assumptions in the *a posteriori* MDC values used in the dose calculations. The first 1 cm layer of soil throughout the entire site is then assumed to contain the number of DRP identified during the scan survey. The DRP(s) are assumed to be randomly distributed in the 1 cm soil layer. In addition, the hypothetical DRPs were assumed to be limited to the first 30.5 cm (1 foot) layer of soil. Each successive 1 cm thick soil layer, below the first 1 cm layer, is assumed to have the same DRP density as the first 1 cm layer with the DRP being randomly distributed within each layer. Given these assumptions, the estimate of the number of DRPs that could hypothetically remain was calculated by multiplying the number of DRPs identified during the DRP scan survey by 30.5. One DRP was identified during the DRP scan survey (see DRP Survey

[1] Zion*Solutions*, Zion Station Restoration Project, Final Status Survey Release Record, Revision 1, Auxiliary Building 542 ft Embedded Floor Drain Pipe Survey Unit 05119A, 09/01/2019
[2] Zion site conceptual model contaminated area

Report). Therefore, the estimate of the number of unidentified DRP that hypothetically remain is 31 (30.5 x 1).

The final lifetime probability of ingesting or inhaling a DRP must account for the projection of 31 DRPs hypothetically remaining. The adjustment is made by multiplying the single DRP probability discussed above, i.e., 1.6 $x10^{-8}$ and 1.7 $x10^{-10}$ for ingestion and inhalation, respectively, by 31. The lifetime probabilities of a future resident on the Zion site ingesting or inhaling a hypothetical DRP is therefore projected to be $4.8x10^{-7}$ and $5.2x10^{-9}$, respectively.

The probability of a DRP being deposited on the skin during the lifetime of a future site resident is $1.2x10^{-7}$. The lifetime probability is calculated using Equation A5-3 assuming one DRP remains on the site. The single DRP lifetime probability is multiplied by the 31 DRP projected to hypothetically remain on the site to derive a final lifetime probability of $4x10^{-6}$. The dermal deposition parameters used to calculate "M_{skin}" in Equation A5-3 are from the U.S. Environmental Protection Agency, "Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment" (Exhibit 3-5)

Equation A5-3

$$P_{DRP} = \frac{M_{skin} T_e}{\left(A_{cz} t_{cz} CF_{cm^3/m^3} d_s\right)}$$

where:

P_{DRP} = lifetime probability of skin exposure to assuming one DRP present on site
A_{cz} = area of Zion contaminated zone (64,500 m^2)
t_{cz} = thickness of soil layer affected by DRP (0.3048m)
$CF_{cm3/m3}$ = conversion factor (1E+06 cm^3/m^3)
d_s = density of soil (1.8 g/cm^3)
T_e = time that resident occupies the site (30 y)
M_{skin} = mass loading of soil on skin (g)

where: $M_{skin} = f_{skin\ mass\ loading\ event} Ef_{event\ frequency} Af_{soil} CF_{g/mg} A_{skin}$

$f_{skin\ mass\ loading\ event}$ = mass loading frequency (1 event/d)
$Ef_{event\ frequency}$ = frequency of event per year (350 d/y)
Af_{soil} = soil adherence factor for resident gardener (0.07 mg/cm^2)
$CF_{g/mg}$ = conversion factor (1E-03 g/mg)
A_{skin} = skin surface area (5,700 cm^2)

A.5.3 DRP Ingestion, Inhalation, and Skin Dose Calculations

The methods and assumptions to be used in the dose analyses for DRPs are detailed below. Dose analysis methods are detailed for both activated metal and irradiated fuel DRPs. The derivations of the parameters and basis for the assumptions used are documented in TSD 22-001 "Discrete Radioactive Particle Survey Report".

Exposure Pathways to be Evaluated

The exposure pathways to be evaluated include:

1. Potential doses from the ingestion of large non-respirable particles.
2. Potential inhalation doses from the fractionation of large particles into 1 µm AMAD respirable particles.
3. Complete dissolution of the particles and the resulting localized distributed soil concentrations. Area factors and $DCGL_{EMC}$s for the DRP radionuclides of concern have been calculated. From these calculated concentrations, the potential ingestion and inhalation doses have been calculated.
4. Potential shallow dose and effective dose equivalents (EDE) for the exposure from particles deposited on the skin for a 24-hour exposure period.

Particle Activity Calculations

As a part of the DRP survey, gamma scanning was performed using a towed array system. From these measurements a probabilistic model was developed to calculate an *a posteriori* Minimum Detectable Activity (MDA) for a particle on the ground surface. MDAs were calculated for both Co-60 and Cs-137. These calculations are also contained in TSD 22-01.

The DRP dose analyses have used the activity of a hypothetical particle at an activity equal to the 50th percentile a *posteriori* MDA of the towed array. The 50th percentile MDA was chosen because it represents the median and most likely detectable particle activities that would be encountered and thus the most likely doses that would result from exposure to DRPs. This is consistent with the guidance in NUREG-1757 Appendix I, Section I.3.3.3.7 which states that: "Analyses of less likely but plausible scenarios are not meant to be 'worst-case' analyses and should not utilize a set of 'worst-case' parameters."

The Co-60 MDA is used to represent activated metal particle activities and the Cs-137 MDA is used to represent irradiated fuel particle activities.

The calculated 50th percentile a *posteriori* MDAs are:

- 0.20 µCi Co-60 and
- 0.70 µCi Cs-137.

Activated Metal Radionuclide Fractions

Characterization of activated metal particle S0124 was performed by ORISE and is documented in ORISE report 5271-SR-09-0. The nuclide activities reported in the characterization of particle S0124 have been scaled to the Co-60 activity. Scaling factors to Co-60 for the remainder of the activation radionuclides were derived from the activation activity calculations of the reactor internal components. These scaling factors have been applied to the Co-60 activities at the 50th percentile of the DRP scan MDA distribution.

The radionuclide scaling factors (i.e., activity ratios) and particle activities are included in Table A5-1.

Table A5-1 Activated Metal DRP 50th Percentile Scan MDA Activity

Nuclide	Activation Activity Calculation for U1 (Ci)	Activity Ratio to Co-60	Particle Activity Scaled to 50th Percentile MDA (pCi)
H-3	2.53E+02	2.53E-03	5.06E+02
C-14	3.59E+02	3.59E-03	7.17E+02
Mn-54	2.85E+01	2.85E-04	5.70E+01
Fe-55	7.15E+03	7.14E-02	1.43E+04
Co-60	1.00E+05	1.00E+00	2.00E+05
Ni-59	1.66E+03	1.66E-02	3.32E+03
Ni-63	2.27E+05	2.27E+00	4.54E+05
Nb-94	5.54E+00	5.53E-05	1.11E+01
Tc-99	1.18E+00	1.17E-05	2.35E+00

Irradiated Fuel Particle Radionuclide Fractions

Characterization of irradiated fuel particle S0126 was performed by ORISE and is documented in ORISE report 5271-SR-09-0. The nuclide activities analyzed in the characterization of particle S0126 have been scaled to its Cs-137 activity. These scaling factors have then been applied to the Cs-137 activity at the 50th percentile of the DRP scan MDA distribution.

The radionuclide scaling factors and particle activities are included in Table A5-2.

Table A5-2 Irradiated Fuel Particle at DRP 50th Percentile Scan MDA Activity

Radionuclide	Activity Ratio to Cs-137	Particle Activity Scaled to 50th Percentile MDA (pCi)
Eu-155	8.47E-03	5.93E+03
Am-241	8.08E-01	5.66E+05
Cm-244	1.50E-01	1.05E+05
Cs-137	1.00E+00	7.00E+05
Np-237	3.94E-05	2.76E+01
Pu-238	2.65E-01	1.85E+05
Pu-239	7.62E-02	5.34E+04
Sr-90	8.47E-03	1.11E+06

Particle Size Estimates

Particle sizes have been estimated for both activated steel and irradiated fuel. The particle sizes estimated for both types of particles at the 50th percentile MDAs are substantially larger than the respirable size limit of 10 µm.

The minimum activated metal DRP diameter has been calculated by using the highest activated Co-60 specific activity from decommissioning activities, which is represented by the activation calculations of the reactor vessel internals. The Unit 1 baffle plates were used to estimate a

minimum DRP volume for activities corresponding to the 50th percentile of the *a posteriori* Co-60 MDA. Using the Unit 1 baffle concentration of 4.06×10^{-2} Ci/cm^3, the volume for 50th percentile scan MDA activity (0.2 µCi Co-60) DRP is 4.92×10^{-6} cm^3. This volume corresponds to a particle diameter of 211 µm.

The equation to calculate aerodynamic equivalent diameter (d_{ae}) equivalent to AMAD for a distribution of particle sizes weighted by activity, from the physical equivalent volume diameter, is taken from Equation 2-1 on page 2-2 in a report prepared for the NRC.[3]

Therefore, the intact particle aerodynamic equivalent diameters (AED) for 8 g/cm^3 density steel sphere with a 1.5 shape factor for the 50th percentile is 487 µm, respectively. Thus, activated metal DRPs detected at the Co-60 MDA far exceed the 10 µm respirable particle threshold. Also, since the particle would not likely be truly spherical the median aerodynamic diameter could be substantially larger.

The irradiated fuel particle mass was estimated using the activity and the specific activity (Bq/kg) of Pu-239 in sample S0126. Therefore, the mass of Pu-239 in particle S0126 (1.22×10^{-7} g) is equivalent to 2.43×10^{-5} g of spent fuel as follows. Spent fuel contains 941 kg/tonne of U-238 or 0.941 grams of U-238 per gram of spent fuel. Based on this, the U-238 or uranium oxide mass is 2.29×10^{-5} gram.

Converting the U-238 mass to volume using a Uranium Dioxide density of 10.97 g/cm^3 results in a particle volume of 2.09×10^{-6} cm^3. This fuel mass corresponds to a physical spherical diameter of 155 µm and an aerodynamic equivalent diameter, d_{ae}, of 420 µm AMAD using a density of 10.97 g/cm^3 and a shape factor of 1.5, well above the size considered respirable.

When the S0126 radionuclide mix is scaled to the Cs-137 Scan *a posteriori* MDAs, the Pu-239 activity is 5.34×10^4 pCi. The corresponding physical parameters are: 8.61×10^{-7} grams of Pu-239, 1.53×10^{-4} grams of U-238, a U-238 volume of 1.39×10^{-5} cm^3 and a physical diameter of 2.98×10^2 µm.

Particle Solubility

For each particle type, it has been assumed that each is best represented by the most insoluble form since these have been exposed to weathering and have likely become stable since the particle's creation.

There appears to be no available data within the literature for absorption of radionuclides within the GI tract for activated steel particles, but it is reasonable to expect that this absorption will be very low. There is some data available for irradiated fuel fragments. Therefore, to represent these insoluble states, we have selected forms with the lowest value of the parameter that represents absorption from the GI tract (alimentary tract) to the blood stream following a hypothetical ingestion event. In each case, the calculated internal dose follows the methodology from ICRP-30, the basis of the methods represented in 10 CFR 20, including the tissue weighting factors. The ingestion internal doses are calculated using IMBA Professional Plus Version 4.1.11 using

[3] *Airborne Particle Resuspension and Inhalation Radiological Dose Estimation Following Volcanic Events*, prepared for U.S. Nuclear Regulatory Commission, Contract NRC–02–07–006, September 2011.

parameters from ICRP-26/30 or directly from Federal Guidance Report No. 11 (FGR11) as noted below.

Ingestion Dose Calculations from Activated Metal Particles

The ingestion dose from an activated metal DRP has been based on the activity of a hypothetical particle at an activity equal to the towed array *a posteriori* 50th percentile Co-60 MDA.

The lowest f_1 value and its corresponding dose conversion factor from FGR11 have been used.

Irradiated Fuel Particle Ingestion Dose

The ingestion dose from this particle has been calculated using IMBA. ICRP-137 provides a source of estimating absorption from the GI (i.e., alimentary) tract for this type of particle (irradiated fuel). It adopts a f_A value of $5x10^{-4}$ for all chemical forms. However, ICRP-137 does not provide direct guidance for ingestion exposure to irradiated fuel particles for the actinides. It does provide an in-depth discussion on Cs-137 in irradiated fuel particles. This states that for ingestion, of all forms of Cs, except irradiated fuel, the f_A value (same as f_1 for ICRP-30) is 1.0 but for irradiated fuel, the value is 0.1 or a factor of 10 reduction.

ICRP-137 does not include f_A values for actinides in irradiated fuel particles. However, it does include a value for Cs-137, a very soluble element. Using this factor of 10 reduction is applicable to the f_A value of $5x10^{-4}$ for a final value of $5x10^{-5}$. Therefore, the value for f_1 for the actinides used in this internal dose analysis is $5x10^{-5}$. For Sr-90 and Eu-155 the lowest f_1 value from FGR11 is used. A factor of 10 reduction in the lowest f_1 values from FGR11 is used for the other radionuclides identified in this particle.

This approach is considered appropriate and conservative for the hypothetical doses from this type of particle since an f_1 value of zero may actually apply to such an exposure. This value is consistent with the work reported in *Environment Health Perspectives*[4] with a value of $3x10^{-5}$ for the fractional absorption by ingestion of radionuclides within irradiated fuel fragments. Additionally, this reference states, in regard to ingestion absorption of elements within a fuel fragment: "…fission products in the fused particulate form renders them virtually inert in metabolic terms and the radionuclides are not metabolized along biological pathways characteristic for the elementary form."

The f_1 values are shown in Table A5-3 along with the source of the f_1 values used.

[4] *Environmental Health Perspectives*, Review, Volume 103, No. 10, October 1995, p. 920 - 934: "Biokinetics of Nuclear Fuel Compounds and Biological Effects of Nonuniform Radiation," Sakari Lang (Department of Environmental Sciences, University of Kuopio, Kuopio, Finland), Kristina Servomaa (Department of Research, Finnish Centre for Radiation and Nuclear Safety, Helsinki, Finland), Veli-Matte Kosma (Department of Pathology, University of Kuopio, Kuopio, Finland), and Tapio Rytomaa (Finnish Centre for Radiation and Nuclear Safety).

Table A5-3 Irradiated Fuel Particle at Scan MDA Ingestion Dose

Radionuclide	f_1	Source of f_1
Eu-155	1.00×10^{-3}	FGR11
Am-241	5.00×10^{-5}	ICRP 137 modified
Cm-244	5.00×10^{-5}	ICRP 137 modified
Cs-137	1.00×10^{-1}	ICRP 137
Np-237	5.00×10^{-5}	ICRP 137 modified
Pu-238	5.00×10^{-5}	ICRP 137 modified
Pu-239	5.00×10^{-5}	ICRP 137 modified
Sr-90	1.00×10^{-2}	FGR11

Inhalation Doses from 1 µm AMAD DRPs

The potential for a particle to be reduced in size over time has also been considered. The anticipated particles sizes accounting for changes in size over the 1,000-year compliance period have also been evaluated. Calculations have been performed to assess the inhalation dose from respirable 1 um AMAD activated metal and irradiated fuel particles.

The doses from inhalation of these particles created by fractionation of larger particles would be reduced in proportion to this decrease in activity. Thus, even if over time the size of activated metal particles is reduced to a respirable particle size, the dose from inhalation would be insignificant.

The inhalation dose from DRPs that have been reduced in size to 1 µm AMAD over time has been calculated. The ICRP-30 lung model is based upon 1 µm AMAD particles.

The spherical volume of a 1 µm AMAD activated steel particle is 4.25×10^{-14} cm^3. Thus, the activity of a 1 µm AMAD particle derived from a particle at the 50th percentile Co-60 MDA would be reduced by a factor of 8.63×10^{-9}. This would result in a Co-60 particle activity of 1.727×10^{-3} pCi for an equivalent volume diameter of 1 µm AMAD.

The spherical physical volume of the 1 µm AMAD irradiated fuel particle is 2.65×10^{-14} cm^3. Thus, the activity of a 1 µm AMAD particle derived from a particle at the 50th percentile Cs-137 MDA would be reduced by a factor of 1.90×10^{-9}. This reduction in size would result in a Cs-137 activity of 1.33×10^{-3} pCi for a 1 µm particle.

These calculations for the activity of 1 µm AMAD irradiated fuel particle and activated steel particles have then been used to calculate inhalation doses using the FGR11 dose conversion factors.

Doses from Complete Dissolution of Particles

Ingestion and inhalation doses have also been evaluated resulting from the complete dissolution of particles over time into distributed residual radioactivity. Both activated metal and irradiated fuel particles have been considered in this evaluation.

The particle activities in pCi were divided by the soil masses associated with areas of 0.01, 0.1, and 1 m^2 and at soil depths of 15 cm to calculate the distributed contamination soil concentration in pCi/g.

Surface Area Factors for all the activated metal and irradiated fuel nuclides were then used to calculate the dilution mass of the soil within these areas. A soil density of 1.8 g/ cm^3 was used. The Surface Area Factors and $DCGL_{EMCS}$ calculations from the LTP Chapter 6.11 were used if available. Area Factors for nuclides not listed in the LTP were calculated using the RESRAD computer model.

The analysis does not account for radioactive decay and is thus very conservative since complete dissolution would likely occur over many years, if at all.

Skin Doses from DRPs

External skin doses have been calculated for exposure to both activated metal and irradiated fuel particles. The doses were evaluated using the 50th percentile scan *a posteriori* MDAs.

The Varskin Version 6.2.1 computer model has been used to calculate Shallow Dose Equivalent (SDE) from DRPs. For each of the type of particle, the equivalent volume diameter, d_e, was calculated. This diameter for a spherical particle was used in Varskin as the variable that accounts for the self-attenuation of beta particles within each DRP.

For activated metal DRPs, only the Co-60 skin dose was analyzed since this nuclide clearly dominates the activity profile. For irradiated fuel DRPs, only Sr-90 and Cs-137 have been included in the calculations since the alpha emitters would make an insignificant contribution to SDE. Varskin includes the doses from daughter nuclides. Therefore, the calculated dose includes the contribution from Y-90.

To allow comparison of SDE to the 25 mrem/year dose limit, the SDE is multiplied by a risk factor to calculate fatal cancer risk and compared to the risk corresponding to the 25 mrem/year TEDE criterion as provided in SECY-97-046A, which is $4x10^{-4}$/y.

The fatal cancer risk factor applied to the SDE dose is from the 2002 Final Rule for Revision of the Skin Dose Limit[5]. The risk factor from DRP SDE exposure is given as $6.6x10^{-10}$/rem.

The calculated dose rates are converted to a total dose for a 24-hour exposure period.

To better evaluate the dose relative to the 25 mrem/year site release criteria for DRPs on the skin, the EPRI guidance for calculating a DRP skin dose has been used.[6] This approach, authorized by the NRC in RIS-2003-04,[7] has been used to calculate the Effective Dose Equivalents for Co-60 and Cs-137 at the 50th percentile MDAs.

Using the Cs-137 and Co-60 EDE dose conversion factors, the EDE for a 24-hour exposure period from particles at the 50th percentile MDAs have been calculated.

[5] Final Rule, *Revision of the Skin Dose Limit*, 67 FR 16298, April 5, 2002.
[6] *Implementing the EPRI Effective Dose Equivalent (EDE) Methodology for Discrete Radioactive Particles on the Skin, Electric Power Research Institute*, EPRI 1002823, October 2004.
[7] *Use Of the Effective Dose Equivalent in Place of The Deep Dose Equivalent in Dose Assessments*, U.S. Nuclear Regulatory Commission, Regulatory Issue Summary (RIS) 2003-04, February 13, 2003.

A5.4 Risk and Dose from Hypothetical DRP Ingestion, Inhalation, and Skin Exposure

As stated above, in accordance with NUREG-1757, the evaluation of LLBP scenarios such as the hypothetical DRP exposure ensures that "unacceptably high risks would not result". The LLBP scenarios are not considered compliance scenarios. SECY-97-046A addresses the dose and risk from widespread residual radioactivity but does not contemplate the dose or risk from DRPs. However, there are two sites where NRC has approved DRP exposure assessments in support of unrestricted use license termination, i.e., the Shelwell Site in Hebron Ohio and the Sacramento Municipal Utility District (SMUD) Ranch Seco Nuclear Generating Station (Rancho Seco). The methods approved by the NRC at these two sites will be applied to the Zion DRP assessment of ingestion and inhalation exposures.

In addition to the two NRC approved assessment approaches, Zion*Solutions* has calculated the lifetime fatal cancer risk from ingestion and inhalation of the hypothetical DRPs that are projected to remain in order to demonstrate that the fatal cancer risk from DRP exposure is less than the fatal cancer risk corresponding to the 25 mrem/y criterion as provided in SECY-97-04A. The fatal cancer risk from the shallow dose equivalent (SDE) due to DRP skin exposure is also calculated as well as the effective dose equivalent (EDE) from skin exposure.

In summary, because there is no NRC guidance on the dose and/or risk assessment of DRPs, five separate assessments are performed to demonstrate that "unacceptably high risks would not result" from hypothetical exposure to DRP. The dose and risk assessments include the following:

1. expectation dose (mrem/yr) from ingestion and inhalation using the Shelwell method
2. dose (mrem/yr) from ingestion and inhalation using the Rancho Seco method
3. lifetime fatal cancer risk from ingestion and inhalation
4. EDE (mrem) from skin exposure.
5. lifetime fatal cancer risk from SDE due to skin exposure.

The criteria to be used to demonstrate that "unacceptably high risks would not result" are listed in Table A5-4.

Expectation Dose

The DRP assessment method for the Shelwell site is described in SECY-98-117, "Shelwell Services, Inc., Risk Assessment", May 27, 1998. The method applied a risk informed approach that entailed calculating an "expectation dose" by multiplying the CEDE from DRP exposure by the annual probability of DRP exposure occurring. In a Staff Requirements Memorandum dated June 30, 1998, the NRC staff was directed by the Commission to apply the SECY-98-117 DRP assessment method to the review of Shelwell license termination request. The NRC terminated the license on July 14, 1999, using the SECY-98-117 risk informed approach as justification. The expectation dose is calculated using Equation A5-4.

Equation A5-4

$$ED = \frac{p_l}{t_o} D_{drp}$$

where:

ED = expectation dose (mrem/yr)

p_l = lifetime probability of DRP ingestion or inhalation (4.8×10^{-7} and 5.2×10^{-9} for ingestion and inhalation, respectively, as calculated in section A5.2)

t_0 = resident lifetime site occupancy time (30 y)

D_{drp} = dose from ingestion or inhalation of DRP (mrem)

TEDE from DRP Activity Distributed in Soil

The DRP assessment method at Rancho Seco was described in Attachment 2 of a June 8, 2009 letter from Einar Ronnington, SMUD, to John Hickman, USNRC, "Phased Release of the Ranch Seco Site". The method was approved in a September 25, 2009, letter from Keith McConnell, USNRC, to Einar Ronnington, SMUD, which states that "the NRC staff has reviewed your proposed partial site release, as described in your June 8, 2009, letter, and finds the proposed release to be acceptable". The Rancho Seco DRP assessment method assumed that the activity in the DRP is uniformly distributed within a volume of soil that is 1 m^2 in area and 0.15 m deep. The dose from the radionuclide concentrations uniformly distributed in the soil volume is then calculated using soil DCGLs and the unity rule. The result represents a DRP dose that can be compared to the TEDE dose units that are used to express the unrestricted use criteria in 10 CFR 20 Subpart E. The Rancho Seco approach was applied but modified to be more comprehensive by also assessing soil areas less than 1 m^2 and more realistic by using soil area factors in conjunction with soil DCGLs to properly account for the dose from small areas. See section A5.3 for details on the dose calculation using the Rancho Seco method.

Fatal Cancer Risk from DRP Ingestion and Inhalation

The third method that will be used to assess the risk from DRP, in a manner that can be compared to a dose expressed in units of TEDE, is to convert DRP ingestion and inhalation dose to a corresponding fatal cancer risk. In support of the promulgation of the LTR, SECY-97-046A states that the lifetime fatal cancer risk corresponding to the 25 mrem/yr unrestricted use criterion is 4×10^{-4} and that this risk is estimated assuming a risk coefficient of 5×10^{-4} rem^{-1} and a 30-year lifetime exposure. As shown in Section A5.1, exposure to a DRP is a low probability, once in a lifetime event, as compared to the assumed continuous exposure over a 30-year lifetime from uniformly distributed source terms such as soil. Therefore, the ingestion and inhalation doses (CEDE) from the hypothetical DRP will be multiplied by the risk coefficient applied in SECY-97-046A, i.e., 5×10^{-4} rem^{-1}, and compared to the risk of 4×10^{-4} that corresponds to the 25 mrem/year unrestricted use criterion. If the lifetime fatal cancer risk from the LLBP DRP ingestion and inhalation exposure scenarios is less than 4×10^{-4}, then the risk is not considered unacceptably high.

Fatal Cancer Risk from SDE Due to Skin Exposure

As described in section A.5.3, Varskin Version 6.2.1 will be used to calculate shallow dose equivalent (SDE) to the skin. However, the dose criterion in 10 CFR 20 Subpart E applies to

TEDE, not SDE to the skin, and therefore direct comparison of SDE to the TEDE criterion is not appropriate. To allow comparison of SDE to a dose in units of TEDE, the SDE was multiplied by a risk factor to calculate fatal cancer risk and compared to the fatal cancer risk corresponding to the 25 mrem/yr TEDE criterion as provided in SECY-97-046A, i.e., $4x10^{-4}$ yr^{-1}. The fatal cancer risk factor applied to the SDE dose is from the Final Rule, "Revision of the Skin Dose Limit", 67 FR 16298, April 5, 2002, which recommends a value of $6.6x10^{-10}$ rem^{-1}.

EDE from Skin Exposure

In addition to fatal cancer risk from SDE, the EDE from DRP will be calculated using the method authorized in NRC Regulatory Issue Summary (RIS) 2003-04, "Use of the Effective Dose Equivalent in Place of The Deep Dose Equivalent in Dose Assessments", February 13, 2003 (see section A5.3 for details).

Demonstration That "Unacceptably High Risks Would Not Result" from DRP Exposure

The final dose and risk from DRP ingestion, inhalation, and skin exposure will be calculated and provided in the DRP Survey Report. The acceptance criteria provided in Table A5-4, column 4, will be used to demonstrate that "unacceptably high risks would not result" from the LLBP exposure to hypothetical DRPs. Note that the ingestion and inhalation fatal cancer risks, and the skin doses in Table A5-4 assume that the exposure occurs notwithstanding the very low lifetime probability of such an exposure actually occurring. See column 2 of Table A5-4 for the lifetime probabilities of DRP exposure. The acceptance criteria in Table A5-4 are not intended to be the absolute limits at which the LLBP DRP scenario is assessed but are intended as criteria that if met, do demonstrate that unacceptably high risks do not result. Higher values may also be acceptable on a case-by-case basis if justified in the DRP Survey Report.

Table A5-4 Acceptance Criteria for Demonstrating that "unacceptably high risks would not result" from the LLBP DRP Exposure Scenario

DRP Exposure Pathway	Lifetime Probability of DRP Exposure Occurring	Assessment Criteria	Acceptance Criteria
Ingestion and Inhalation	NA[1]	Expectation Dose	<25 mrem/yr
Ingestion and Inhalation	Ingestion: $4.8x10^{-7}$ Inhalation: $5.2x10^{-9}$	Fatal Cancer Risk[2]	$<4x10^{-4}$
Ingestion and Inhalation	NA[3]	TEDE from DRP Activity Distributed in Soil	<25 mrem/yr
Skin	$3.7x10^{-6}$	Skin Dose (EDE)	<25 mrem
Skin	$3.7x10^{-6}$	Fatal Cancer Risk from SDE	$<4x10^{-4}$

1) The expectation dose calculation includes annual probability of exposure occurring
2) The $4x10^{-4}$ fatal cancer risk is the risk corresponding to the 25 mrem/yr unrestricted use criterion as stated in SECY-97-046A
3) The exposure to a small soil area of distributed activity is assumed to occur annually in the same manner as other small soil elevated areas

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ZS-2022-0001
Enclosure

Attachment 2
Zion Nuclear Power Station, Units 1 and 2
License Termination Plan Clean Pages

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LIST OF ACRONYMS AND ABBREVIATIONS

AF	Area Factor
ALARA	As Low As Reasonably Achievable
AMCG	Average Member of the Critical Group
BFM	Basement Fill Model
CAQ	Conditions Adverse to Quality
CCDD	Clean Concrete Demolition Debris
C/LT	Characterization/License Termination
CsI	Cesium Iodide
CoC	Chain of Custody
CVS	Contamination Verification Survey
DCGL	Derived Concentration Guideline Levels
DQA	Data Quality Assessment
DQO	Data Quality Objectives
DRP	Discrete Radioactive Particle
EMC	Elevated Measurement Comparison
ETD	Easy to Detect
FOV	Field of View
FSS	Final Status Survey
GPS	Global Positioning System
HPGe	High-Purity Germanium
HSA	Historical Site Assessment
HTD	Hard to Detect
IC	Insignificant Contributor
ISFSI	Independent Spent Fuel Storage Installation
ISOCS	*In Situ* Object Counting System
LBGR	Lower Bound of the Gray Region
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
NAD	North American Datum
NaI	Sodium Iodide
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ODCM	Off Site Dose Calculation Manual
QA	Quality Assurance

The CVS will include extensive scan surveys on the structural surfaces (walls, floors and miscellaneous equipment) that will be subject to open air demolition, regardless of elevation. The scan coverage is dependent on the contamination potential of the structural surface being surveyed. Class 1 survey units will require 100% scan coverage of all exposed concrete surface areas. Any areas identified in excess of the open air demolition limits will be earmarked for remediation.

For structural surfaces below the 588 foot elevation that will remain and be subject to a FSS (primarily any basement floor and outer walls), additional remediation will be performed to ensure that any individual ISOCS measurement will not exceed the Operational $DCGL_B$ from Table 5-4 during FSS. Any areas identified that have the potential to exceed the Operational $DCGL_B$ by ISOCS measurement during the performance of CVS in these areas will be remediated. Any areas of elevated activity that could potentially approach the Operational $DCGL_B$ will be identified as a location for a judgmental ISOCS measurement during FSS.

5.4.6. Post-Demolition Survey

Following demolition, after all debris is removed and the floors cleaned, an additional scan survey will be performed to ensure that any individual ISOCS measurement will not exceed the Operational $DCGL_B$ from Table 5-4 during FSS. The survey will be performed using hand-held beta-gamma instrumentation as presented in Table 5-27 in typical scanning and measurement modes.

5.4.7. Survey Considerations for Suspected Discrete Radioactive Particle Areas

Discrete radioactive particles (DRP) are defined as specks of radioactive material identified usually as either activated corrosion products such as cobalt-60, or an irradiated fuel fragment exhibiting greater than 10,000 corrected counts per minute (100,000 dpm). In open land (soil) survey units where the presence of DRPs is suspected, special survey techniques and actions must be considered. The survey techniques for the detection of DRPs are described in the Survey Plan for Discrete Radioactive Particle Identification and Remediation, ZS-LT-07 (the "DRP Survey Plan") (Reference 5-26), which is incorporated into this LTP by reference.

5.5. Final Status Survey of Basement Structures

Basement structures are defined as basement surfaces (concrete and steel liner), embedded pipe, and penetrations. As described in section 5.4.5, all remaining floor and wall concrete surfaces will be remediated to levels below the Operational $DCGL_B$ as measured by ISOCS. After remediation, a FSS will be conducted to demonstrate that the residual radioactivity in building basements corresponds to a dose below the 25 mrem/yr criteria.

5.5.1. Instruments Selected for Performing FSS of Basement Surfaces

The Canberra ISOCS has been selected as the primary instrument that will be used to perform FSS of basement surfaces. Direct beta measurements taken on the concrete surface will not provide the data necessary to determine the residual radioactivity at depth in concrete and therefore, would have to be augmented with core sampling. The ISOCS was selected as the instrument of choice to perform FSS of basement surfaces for the following reasons:

- The surface area covered by a single ISOCS measurement is large (a nominal range of 10-30 m^2) which essentially eliminates the need for scan surveys.

Development"

5-20 Zion*Solutions* TSD 14-022, Revision 1, "Use of In-Situ Gamma Spectroscopy for Source Term Survey of End State Structures"

5-21 Zion*Solutions* Technical Support Document 10-002, Revision 1, "Technical Basis for Radiological Limits for Structure/Building Open Air Demolition"

5-22 Zion*Solutions* ZS-QA-10, Revision 9, "Quality Assurance Project Plan - Zion Station Restoration Project"

5-23 International Standard ISO 7503-1, Part 1, "Evaluation of Surface Contamination, Beta-Emitters (maximum beta energy greater than 0.15 MeV) and Alpha-Emitters" – August 1998

5-24 U.S. Nuclear Regulatory Commission Inspection Procedure No. 84750 *"*Radioactive Waste Treatment, and Effluent and Environmental Monitoring*"* – March 1994

5-25 ZionSolutions ZS-AD-08, "Corrective Action Program"

5-26 ZionSolutions ZS-LT-07, "Survey Plan for Discrete Radioactive Particle Identification and Remediation"

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AF	Area Factor
ALARA	As Low As (is) Reasonably Achievable
AMSL	Above Mean Sea Level
ANL	Argonne National Laboratory
BFM	Basement Fill Model
CRA	Conestoga Rovers & Associates
DCGL	Derived Concentration Guideline Level
DCF	Dose Conversion Factor
DRP	Discrete Radioactive Particle
DUST-MS	Disposal Unit Source Term - Multiple Species
EPA	Environmental Protection Agency
FGR	Federal Guidance Report
FOV	Field of View
FSS	Final Status Survey
GW	Groundwater
HSA	Historical Site Assessment
HTD	Hard-to-Detect
IC	Insignificant Contributor
ISFSI	Independent Spent Fuel Storage Installation
ISOCS	In-Situ Object Counting System
LLBP	Less Likely but Plausible
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimal Detectable Concentration
NRC	The U.S. Nuclear Regulatory Commission
ODCM	Off-site Dose Calculation Manual
PRCC	Partial Rank Correlation Coefficient
RASS	Remedial Action Support Surveys
REMP	Radiological Environmental Monitoring Program
RESRAD	RESidual RADioactive materials
ROC	Radionuclides of Concern
SFP	Spent Fuel Pool
TEDE	Total Effective Dose Equivalent
WWTF	Waste Water Treatment Facility
ZNPS	Zion Nuclear Power Station
ZSRP	Zion Station Restoration Project

A fourth alternate scenario considers the less likely but plausible (LLBP) scenario where a hypothetical discrete radioactive particle (DRP) is ingested, inhaled, or deposited on the skin. Note that all DRPs identified to date have been remediated and no known DRPs remain. The DRP LLBP scenario assessment is contained in Attachment 5

6.5. Basement Fill Conceptual Model

This section describes in detail the BFM conceptual model, including the source term, ROC, future land use and exposure scenario, AMCG, and exposure pathways. The BFM is used to calculate dose to the AMCG from residual radioactivity in the backfilled, below ground Basements to remain at the time of license termination. The list of Basements to remain is provided in Table 6-1. The computational model used to implement the conceptual model is described in section 6.6.

6.5.1. Source Term

The source term for the BFM is the residual radioactivity, surface plus volumetric, remaining in each of the Basements at the time of license termination. The source term includes residual radioactivity in wall and floor concrete, or steel liner in the case of the Containment Basements, as well as in embedded piping and penetrations that are contained in or interface with a given basement. Embedded pipe and penetrations are treated as separate survey units within the applicable basement that release activity into the basement fill in the same manner as activity from walls and floors (see sections 6-13 and 6-14). The embedded pipe and penetration source terms are accounted for by adding the dose from the embedded pipe and penetration survey units to the dose from the applicable basement wall and floor survey unit. The total dose from all three sources within a given basement must be less than 25 mrem/yr. See section 6.17.1 for discussion of the process for summing the dose from walls/floors, embedded pipe, and penetrations.

LTP Chapter 2 provides detailed characterization data regarding current contamination levels in the Basements. The data is based on concrete core samples obtained at biased locations with high contact dose rates and/or evidence of leaks/spills. The expected source term configuration and radionuclide distribution expected to remain in each Basement, after remediation is completed, is summarized below.

6.5.1.1. Unit 1 and Unit 2 Containment Building Basements

Both Unit 1 and Unit 2 Containment Buildings are comprised of concrete walls and floors with all interior surfaces of the containment 'shell' covered by a 0.25 inch steel liner. The liner on the 565 foot elevation floor is covered by a 30 inch thick layer of concrete. The floor of the Under-Vessel area is located at the 541 foot elevation. A 30 inch layer of concrete is present above the liner in the Under-Vessel area and a 15 inch layer of concrete is on the walls in the Under-Vessel area. The steel liner on walls above the 568 foot elevation and below the 588 foot elevation has surficial contamination with removable contamination levels ranging from less than 1,000 dpm/100cm^2 to approximately 10,000 dpm/100cm^2 as indicated by operational and routine radiological surveys.

ATTACHMENT 5

Less Likely But Plausible Scenario for Exposure to Hypothetical Discrete Radioactive Particles

Less Likely But Plausible Scenario for Exposure to Hypothetical Discrete Radioactive Particles

A.5.1 Introduction

Discrete radioactive particles (DRP) were identified on the Zion site during decommissioning operations as well as during FSS. As discussed in Chapter 5 of this LTP, after the completion of FSS Zion*Solutions* prepared the *Survey Plan for Discrete Radioactive Particle Identification and Remediation*, ZS-LT-07, Revision 1 (DRP Survey Plan). The objective of the DRP Survey Plan is to identify and remediate all of the DRPs identified. Although there is no known DRP source term remaining on the site it cannot be said with absolute certainty that no DRP remain. This attachment provides an estimate of the number of DRPs that may hypothetically remain and the methods for calculating dose and risk from the hypothetical DRPs.

The results of the DRP survey are provided in Technical Support Document 22-001, *Discrete Radioactive Particle Survey Report* (DRP Survey Report). The dose and risk calculations will be performed using the methods described in this attachment. The activity assumed to be present in hypothetical DRPs and the results of the corresponding dose and risk calculations are provided in the DRP Survey Report. The projection of the number of DRP that could hypothetically remain is made in this attachment based on the number of DRP identified during the DRP survey (i.e., one).

A5.2 DRP Exposure Probability and Designation as Less Likely but Plausible Scenario

DRP dose and risk is assessed as a LLBP scenario due to the low probability of hypothetical DRP exposure occurring. Treating the low-probability DRP exposure as an LLBP scenario is consistent with the approach used for assessing the low-probability scenario of the well driller contacting the Auxiliary Building drains, which was also designated as an LLBP scenario. In accordance with NUREG-1757, the evaluation of LLBP exposure scenarios ensures that "unacceptably high risks would not result", however, the evaluation of LLBP scenarios is not conducted to demonstrate compliance. Accordingly, the dose from the hypothetical DRP will not be added to the Zion compliance dose.

To justify the designation of the hypothetical DRP exposure pathways as an LLBP scenario, the probabilities of DRP ingestion and inhalation are compared to the probability of drilling into the Auxiliary Building drains, which was accepted by NRC as not likely. The probability of a drill contacting the Auxiliary Building drains is 1.5×10^{-3}/y as calculated by Equation A5-1. The lifetime probability of a future site resident ingesting or inhaling a DRP, assuming that one DRP remains, is much lower at 1.6×10^{-8} and 1.7×10^{-10}, respectively, as calculated using Equation A5-2.

Equation A5.1

$$P_{drain} = \frac{SA_{drain}}{A_{cz}}$$

where:
P_{drain} = probability of drill contacting Auxiliary Building drain
SA_{drain} = projected surface area of Auxiliary Building drains (96.2 m^2)[1]
A_{cz} = area of contaminated zone (64,500 m^2)[2]

Equation A5-2

$$P_{DRP} = \frac{IR_s Te}{\left(A_{cz} t_{cz} CF_{cm^3/m^3} d_s\right)}$$

where:
P_{DRP} = lifetime probability of ingesting or inhaling a DRP if one DRP hypothetically remains
IR_s = soil mass ingestion rate (18.3 g/y) or inhalation rate 0.2 (g/y)
A_{cz} = area of Zion contaminated zone for soil DCGL calculations (64,500 m^2)
t_{cz} = thickness of soil layer affected by DRP (0.3048 m)
$CF_{cm3/m3}$ = conversion factor ($1x10^{-6}$ cm^3/m^3)
d_s = density of soil (1.8 g/cm^3)
Te = lifetime exposure period of site resident (30 y)

> Note: The mass inhalation rate of 0.2 g/y is derived by multiplying the RESRAD mass loading for inhalation value ($2.35x10^{-5}$ g/m^3) by the breathing rate (8400 m^3/y). The assumed 30-year lifetime occupancy period for the site resident is from SECY-97-046A, "Final Rule on Radiological Criteria for License Termination," March 31, 1997 (SECY-97-046A).

The number of unidentified DRPs that could hypothetically remain was calculated by conservatively assuming that all of the DRPs identified during the DRP scan survey were contained in a 1.0 cm layer of soil, regardless of the actual depth at which they were found. Assuming the DRP are contained in a shallow soil layer provides a qualitative correlation to the depth assumptions in the *a posteriori* MDC values used in the dose calculations. The first 1 cm layer of soil throughout the entire site is then assumed to contain the number of DRP identified during the scan survey. The DRP(s) are assumed to be randomly distributed in the 1 cm soil layer. In addition, the hypothetical DRPs were assumed to be limited to the first 30.5 cm (1 foot) layer of soil. Each successive 1 cm thick soil layer, below the first 1 cm layer, is assumed to have the same DRP density as the first 1 cm layer with the DRP being randomly distributed within each layer. Given these assumptions, the estimate of the number of DRPs that could hypothetically remain was calculated by multiplying the number of DRPs identified during the DRP scan survey by 30.5. One DRP was identified during the DRP scan survey (see DRP Survey

[1] Zion*Solutions*, Zion Station Restoration Project, Final Status Survey Release Record, Revision 1, Auxiliary Building 542 ft Embedded Floor Drain Pipe Survey Unit 05119A, 09/01/2019
[2] Zion site conceptual model contaminated area

Report). Therefore, the estimate of the number of unidentified DRP that hypothetically remain is 31 (30.5 x 1).

The final lifetime probability of ingesting or inhaling a DRP must account for the projection of 31 DRPs hypothetically remaining. The adjustment is made by multiplying the single DRP probability discussed above, i.e., 1.6 $x10^{-8}$ and 1.7 $x10^{-10}$ for ingestion and inhalation, respectively, by 31. The lifetime probabilities of a future resident on the Zion site ingesting or inhaling a hypothetical DRP is therefore projected to be $4.8x10^{-7}$ and $5.2x10^{-9}$, respectively.

The probability of a DRP being deposited on the skin during the lifetime of a future site resident is $1.2x10^{-7}$. The lifetime probability is calculated using Equation A5-3 assuming one DRP remains on the site. The single DRP lifetime probability is multiplied by the 31 DRP projected to hypothetically remain on the site to derive a final lifetime probability of $4x10^{-6}$. The dermal deposition parameters used to calculate "M_{skin}" in Equation A5-3 are from the U.S. Environmental Protection Agency, "Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment" (Exhibit 3-5)

Equation A5-3

$$P_{DRP} = \frac{M_{skin} T_e}{\left(A_{cz} t_{cz} CF_{cm^3/m^3} d_s\right)}$$

where:

P_{DRP} = lifetime probability of skin exposure to assuming one DRP present on site
A_{cz} = area of Zion contaminated zone (64,500 m^2)
t_{cz} = thickness of soil layer affected by DRP (0.3048m)
$CF_{cm3/m3}$ = conversion factor (1E+06 cm^3/m^3)
d_s = density of soil (1.8 g/cm^3)
T_e = time that resident occupies the site (30 y)
M_{skin} = mass loading of soil on skin (g)

where: $$M_{skin} = f_{skin\ mass\ loading\ event} Ef_{event\ frequency} Af_{soil} CF_{g/mg} A_{skin}$$

$f_{skin\ mass\ loading\ event}$ = mass loading frequency (1 event/d)
$Ef_{event\ frequency}$ = frequency of event per year (350 d/y)
Af_{soil} = soil adherence factor for resident gardener (0.07 mg/cm^2)
$CF_{g/mg}$ = conversion factor (1E-03 g/mg)
A_{skin} = skin surface area (5,700 cm^2)

A.5.3 DRP Ingestion, Inhalation, and Skin Dose Calculations

The methods and assumptions to be used in the dose analyses for DRPs are detailed below. Dose analysis methods are detailed for both activated metal and irradiated fuel DRPs. The derivations of the parameters and basis for the assumptions used are documented in TSD 22-001 "Discrete Radioactive Particle Survey Report".

Exposure Pathways to be Evaluated

The exposure pathways to be evaluated include:

1. Potential doses from the ingestion of large non-respirable particles.
2. Potential inhalation doses from the fractionation of large particles into 1 μm AMAD respirable particles.
3. Complete dissolution of the particles and the resulting localized distributed soil concentrations. Area factors and $DCGL_{EMC}$s for the DRP radionuclides of concern have been calculated. From these calculated concentrations, the potential ingestion and inhalation doses have been calculated.
4. Potential shallow dose and effective dose equivalents (EDE) for the exposure from particles deposited on the skin for a 24-hour exposure period.

Particle Activity Calculations

As a part of the DRP survey, gamma scanning was performed using a towed array system. From these measurements a probabilistic model was developed to calculate an *a posteriori* Minimum Detectable Activity (MDA) for a particle on the ground surface. MDAs were calculated for both Co-60 and Cs-137. These calculations are also contained in TSD 22-01.

The DRP dose analyses have used the activity of a hypothetical particle at an activity equal to the 50th percentile a *posteriori* MDA of the towed array. The 50th percentile MDA was chosen because it represents the median and most likely detectable particle activities that would be encountered and thus the most likely doses that would result from exposure to DRPs. This is consistent with the guidance in NUREG-1757 Appendix I, Section I.3.3.3.7 which states that: "Analyses of less likely but plausible scenarios are not meant to be 'worst-case' analyses and should not utilize a set of 'worst-case' parameters."

The Co-60 MDA is used to represent activated metal particle activities and the Cs-137 MDA is used to represent irradiated fuel particle activities.

The calculated 50th percentile a *posteriori* MDAs are:

- 0.20 μCi Co-60 and
- 0.70 μCi Cs-137.

Activated Metal Radionuclide Fractions

Characterization of activated metal particle S0124 was performed by ORISE and is documented in ORISE report 5271-SR-09-0. The nuclide activities reported in the characterization of particle S0124 have been scaled to the Co-60 activity. Scaling factors to Co-60 for the remainder of the activation radionuclides were derived from the activation activity calculations of the reactor internal components. These scaling factors have been applied to the Co-60 activities at the 50th percentile of the DRP scan MDA distribution.

The radionuclide scaling factors (i.e., activity ratios) and particle activities are included in Table A5-1.

Table A5-1 Activated Metal DRP 50th Percentile Scan MDA Activity

Nuclide	Activation Activity Calculation for U1 (Ci)	Activity Ratio to Co-60	Particle Activity Scaled to 50th Percentile MDA (pCi)
H-3	2.53E+02	2.53E-03	5.06E+02
C-14	3.59E+02	3.59E-03	7.17E+02
Mn-54	2.85E+01	2.85E-04	5.70E+01
Fe-55	7.15E+03	7.14E-02	1.43E+04
Co-60	1.00E+05	1.00E+00	2.00E+05
Ni-59	1.66E+03	1.66E-02	3.32E+03
Ni-63	2.27E+05	2.27E+00	4.54E+05
Nb-94	5.54E+00	5.53E-05	1.11E+01
Tc-99	1.18E+00	1.17E-05	2.35E+00

Irradiated Fuel Particle Radionuclide Fractions

Characterization of irradiated fuel particle S0126 was performed by ORISE and is documented in ORISE report 5271-SR-09-0. The nuclide activities analyzed in the characterization of particle S0126 have been scaled to its Cs-137 activity. These scaling factors have then been applied to the Cs-137 activity at the 50th percentile of the DRP scan MDA distribution.

The radionuclide scaling factors and particle activities are included in Table A5-2.

Table A5-2 Irradiated Fuel Particle at DRP 50th Percentile Scan MDA Activity

Radionuclide	Activity Ratio to Cs-137	Particle Activity Scaled to 50th Percentile MDA (pCi)
Eu-155	8.47E-03	5.93E+03
Am-241	8.08E-01	5.66E+05
Cm-244	1.50E-01	1.05E+05
Cs-137	1.00E+00	7.00E+05
Np-237	3.94E-05	2.76E+01
Pu-238	2.65E-01	1.85E+05
Pu-239	7.62E-02	5.34E+04
Sr-90	8.47E-03	1.11E+06

Particle Size Estimates

Particle sizes have been estimated for both activated steel and irradiated fuel. The particle sizes estimated for both types of particles at the 50th percentile MDAs are substantially larger than the respirable size limit of 10 µm.

The minimum activated metal DRP diameter has been calculated by using the highest activated Co-60 specific activity from decommissioning activities, which is represented by the activation calculations of the reactor vessel internals. The Unit 1 baffle plates were used to estimate a

minimum DRP volume for activities corresponding to the 50th percentile of the *a posteriori* Co-60 MDA. Using the Unit 1 baffle concentration of 4.06×10^{-2} Ci/cm^3, the volume for 50th percentile scan MDA activity (0.2 µCi Co-60) DRP is 4.92×10^{-6} cm^3. This volume corresponds to a particle diameter of 211 µm.

The equation to calculate aerodynamic equivalent diameter (d_{ae}) equivalent to AMAD for a distribution of particle sizes weighted by activity, from the physical equivalent volume diameter, is taken from Equation 2-1 on page 2-2 in a report prepared for the NRC.[3]

Therefore, the intact particle aerodynamic equivalent diameters (AED) for 8 g/cm^3 density steel sphere with a 1.5 shape factor for the 50th percentile is 487 µm, respectively. Thus, activated metal DRPs detected at the Co-60 MDA far exceed the 10 µm respirable particle threshold. Also, since the particle would not likely be truly spherical the median aerodynamic diameter could be substantially larger.

The irradiated fuel particle mass was estimated using the activity and the specific activity (Bq/kg) of Pu-239 in sample S0126. Therefore, the mass of Pu-239 in particle S0126 (1.22×10^{-7} g) is equivalent to 2.43×10^{-5} g of spent fuel as follows. Spent fuel contains 941 kg/tonne of U-238 or 0.941 grams of U-238 per gram of spent fuel. Based on this, the U-238 or uranium oxide mass is 2.29×10^{-5} gram.

Converting the U-238 mass to volume using a Uranium Dioxide density of 10.97 g/cm^3 results in a particle volume of 2.09×10^{-6} cm^3. This fuel mass corresponds to a physical spherical diameter of 155 µm and an aerodynamic equivalent diameter, d_{ae}, of 420 µm AMAD using a density of 10.97 g/cm^3 and a shape factor of 1.5, well above the size considered respirable.

When the S0126 radionuclide mix is scaled to the Cs-137 Scan *a posteriori* MDAs, the Pu-239 activity is 5.34×10^{4} pCi. The corresponding physical parameters are: 8.61×10^{-7} grams of Pu-239, 1.53×10^{-4} grams of U-238, a U-238 volume of 1.39×10^{-5} cm^3 and a physical diameter of 2.98×10^{2} µm.

Particle Solubility

For each particle type, it has been assumed that each is best represented by the most insoluble form since these have been exposed to weathering and have likely become stable since the particle's creation.

There appears to be no available data within the literature for absorption of radionuclides within the GI tract for activated steel particles, but it is reasonable to expect that this absorption will be very low. There is some data available for irradiated fuel fragments. Therefore, to represent these insoluble states, we have selected forms with the lowest value of the parameter that represents absorption from the GI tract (alimentary tract) to the blood stream following a hypothetical ingestion event. In each case, the calculated internal dose follows the methodology from ICRP-30, the basis of the methods represented in 10 CFR 20, including the tissue weighting factors. The ingestion internal doses are calculated using IMBA Professional Plus Version 4.1.11 using

[3] *Airborne Particle Resuspension and Inhalation Radiological Dose Estimation Following Volcanic Events*, prepared for U.S. Nuclear Regulatory Commission, Contract NRC–02–07–006, September 2011.

parameters from ICRP-26/30 or directly from Federal Guidance Report No. 11 (FGR11) as noted below.

Ingestion Dose Calculations from Activated Metal Particles

The ingestion dose from an activated metal DRP has been based on the activity of a hypothetical particle at an activity equal to the towed array *a posteriori* 50th percentile Co-60 MDA.

The lowest f_1 value and its corresponding dose conversion factor from FGR11 have been used.

Irradiated Fuel Particle Ingestion Dose

The ingestion dose from this particle has been calculated using IMBA. ICRP-137 provides a source of estimating absorption from the GI (i.e., alimentary) tract for this type of particle (irradiated fuel). It adopts a f_A value of $5x10^{-4}$ for all chemical forms. However, ICRP-137 does not provide direct guidance for ingestion exposure to irradiated fuel particles for the actinides. It does provide an in-depth discussion on Cs-137 in irradiated fuel particles. This states that for ingestion, of all forms of Cs, except irradiated fuel, the f_A value (same as f_1 for ICRP-30) is 1.0 but for irradiated fuel, the value is 0.1 or a factor of 10 reduction.

ICRP-137 does not include f_A values for actinides in irradiated fuel particles. However, it does include a value for Cs-137, a very soluble element. Using this factor of 10 reduction is applicable to the f_A value of $5x10^{-4}$ for a final value of $5x10^{-5}$. Therefore, the value for f_1 for the actinides used in this internal dose analysis is $5x10^{-5}$. For Sr-90 and Eu-155 the lowest f_1 value from FGR11 is used. A factor of 10 reduction in the lowest f_1 values from FGR11 is used for the other radionuclides identified in this particle.

This approach is considered appropriate and conservative for the hypothetical doses from this type of particle since an f_1 value of zero may actually apply to such an exposure. This value is consistent with the work reported in *Environment Health Perspectives*[4] with a value of $3x10^{-5}$ for the fractional absorption by ingestion of radionuclides within irradiated fuel fragments. Additionally, this reference states, in regard to ingestion absorption of elements within a fuel fragment: "…fission products in the fused particulate form renders them virtually inert in metabolic terms and the radionuclides are not metabolized along biological pathways characteristic for the elementary form."

The f_1 values are shown in Table A5-3 along with the source of the f_1 values used.

[4] *Environmental Health Perspectives*, Review, Volume 103, No. 10, October 1995, p. 920 - 934: "Biokinetics of Nuclear Fuel Compounds and Biological Effects of Nonuniform Radiation," Sakari Lang (Department of Environmental Sciences, University of Kuopio, Kuopio, Finland), Kristina Servomaa (Department of Research, Finnish Centre for Radiation and Nuclear Safety, Helsinki, Finland), Veli-Matte Kosma (Department of Pathology, University of Kuopio, Kuopio, Finland), and Tapio Rytomaa (Finnish Centre for Radiation and Nuclear Safety).

Table A5-3 Irradiated Fuel Particle at Scan MDA Ingestion Dose

Radionuclide	f_1	Source of f_1
Eu-155	1.00×10^{-3}	FGR11
Am-241	5.00×10^{-5}	ICRP 137 modified
Cm-244	5.00×10^{-5}	ICRP 137 modified
Cs-137	1.00×10^{-1}	ICRP 137
Np-237	5.00×10^{-5}	ICRP 137 modified
Pu-238	5.00×10^{-5}	ICRP 137 modified
Pu-239	5.00×10^{-5}	ICRP 137 modified
Sr-90	1.00×10^{-2}	FGR11

Inhalation Doses from 1 µm AMAD DRPs

The potential for a particle to be reduced in size over time has also been considered. The anticipated particles sizes accounting for changes in size over the 1,000-year compliance period have also been evaluated. Calculations have been performed to assess the inhalation dose from respirable 1 um AMAD activated metal and irradiated fuel particles.

The doses from inhalation of these particles created by fractionation of larger particles would be reduced in proportion to this decrease in activity. Thus, even if over time the size of activated metal particles is reduced to a respirable particle size, the dose from inhalation would be insignificant.

The inhalation dose from DRPs that have been reduced in size to 1 µm AMAD over time has been calculated. The ICRP-30 lung model is based upon 1 µm AMAD particles.

The spherical volume of a 1 µm AMAD activated steel particle is 4.25×10^{-14} cm^3. Thus, the activity of a 1 µm AMAD particle derived from a particle at the 50th percentile Co-60 MDA would be reduced by a factor of 8.63×10^{-9}. This would result in a Co-60 particle activity of 1.727×10^{-3} pCi for an equivalent volume diameter of 1 µm AMAD.

The spherical physical volume of the 1 µm AMAD irradiated fuel particle is 2.65×10^{-14} cm^3. Thus, the activity of a 1 µm AMAD particle derived from a particle at the 50th percentile Cs-137 MDA would be reduced by a factor of 1.90×10^{-9}. This reduction in size would result in a Cs-137 activity of 1.33×10^{-3} pCi for a 1 µm particle.

These calculations for the activity of 1 µm AMAD irradiated fuel particle and activated steel particles have then been used to calculate inhalation doses using the FGR11 dose conversion factors.

Doses from Complete Dissolution of Particles

Ingestion and inhalation doses have also been evaluated resulting from the complete dissolution of particles over time into distributed residual radioactivity. Both activated metal and irradiated fuel particles have been considered in this evaluation.

The particle activities in pCi were divided by the soil masses associated with areas of 0.01, 0.1, and 1 m^2 and at soil depths of 15 cm to calculate the distributed contamination soil concentration in pCi/g.

Surface Area Factors for all the activated metal and irradiated fuel nuclides were then used to calculate the dilution mass of the soil within these areas. A soil density of 1.8 g/ cm^3 was used. The Surface Area Factors and $DCGL_{EMCS}$ calculations from the LTP Chapter 6.11 were used if available. Area Factors for nuclides not listed in the LTP were calculated using the RESRAD computer model.

The analysis does not account for radioactive decay and is thus very conservative since complete dissolution would likely occur over many years, if at all.

Skin Doses from DRPs

External skin doses have been calculated for exposure to both activated metal and irradiated fuel particles. The doses were evaluated using the 50th percentile scan *a posteriori* MDAs.

The Varskin Version 6.2.1 computer model has been used to calculate Shallow Dose Equivalent (SDE) from DRPs. For each of the type of particle, the equivalent volume diameter, d_e, was calculated. This diameter for a spherical particle was used in Varskin as the variable that accounts for the self-attenuation of beta particles within each DRP.

For activated metal DRPs, only the Co-60 skin dose was analyzed since this nuclide clearly dominates the activity profile. For irradiated fuel DRPs, only Sr-90 and Cs-137 have been included in the calculations since the alpha emitters would make an insignificant contribution to SDE. Varskin includes the doses from daughter nuclides. Therefore, the calculated dose includes the contribution from Y-90.

To allow comparison of SDE to the 25 mrem/year dose limit, the SDE is multiplied by a risk factor to calculate fatal cancer risk and compared to the risk corresponding to the 25 mrem/year TEDE criterion as provided in SECY-97-046A, which is $4x10^{-4}$/y.

The fatal cancer risk factor applied to the SDE dose is from the 2002 Final Rule for Revision of the Skin Dose Limit[5]. The risk factor from DRP SDE exposure is given as $6.6x10^{-10}$/rem.

The calculated dose rates are converted to a total dose for a 24-hour exposure period.

To better evaluate the dose relative to the 25 mrem/year site release criteria for DRPs on the skin, the EPRI guidance for calculating a DRP skin dose has been used.[6] This approach, authorized by the NRC in RIS-2003-04,[7] has been used to calculate the Effective Dose Equivalents for Co-60 and Cs-137 at the 50th percentile MDAs.

Using the Cs-137 and Co-60 EDE dose conversion factors, the EDE for a 24-hour exposure period from particles at the 50th percentile MDAs have been calculated.

[5] Final Rule, *Revision of the Skin Dose Limit*, 67 FR 16298, April 5, 2002.
[6] *Implementing the EPRI Effective Dose Equivalent (EDE) Methodology for Discrete Radioactive Particles on the Skin, Electric Power Research Institute*, EPRI 1002823, October 2004.
[7] *Use Of the Effective Dose Equivalent in Place of The Deep Dose Equivalent in Dose Assessments*, U.S. Nuclear Regulatory Commission, Regulatory Issue Summary (RIS) 2003-04, February 13, 2003.

A5.4 Risk and Dose from Hypothetical DRP Ingestion, Inhalation, and Skin Exposure

As stated above, in accordance with NUREG-1757, the evaluation of LLBP scenarios such as the hypothetical DRP exposure ensures that "unacceptably high risks would not result". The LLBP scenarios are not considered compliance scenarios. SECY-97-046A addresses the dose and risk from widespread residual radioactivity but does not contemplate the dose or risk from DRPs. However, there are two sites where NRC has approved DRP exposure assessments in support of unrestricted use license termination, i.e., the Shelwell Site in Hebron Ohio and the Sacramento Municipal Utility District (SMUD) Ranch Seco Nuclear Generating Station (Rancho Seco). The methods approved by the NRC at these two sites will be applied to the Zion DRP assessment of ingestion and inhalation exposures.

In addition to the two NRC approved assessment approaches, Zion*Solutions* has calculated the lifetime fatal cancer risk from ingestion and inhalation of the hypothetical DRPs that are projected to remain in order to demonstrate that the fatal cancer risk from DRP exposure is less than the fatal cancer risk corresponding to the 25 mrem/y criterion as provided in SECY-97-04A. The fatal cancer risk from the shallow dose equivalent (SDE) due to DRP skin exposure is also calculated as well as the effective dose equivalent (EDE) from skin exposure.

In summary, because there is no NRC guidance on the dose and/or risk assessment of DRPs, five separate assessments are performed to demonstrate that "unacceptably high risks would not result" from hypothetical exposure to DRP. The dose and risk assessments include the following:

1. expectation dose (mrem/yr) from ingestion and inhalation using the Shelwell method
2. dose (mrem/yr) from ingestion and inhalation using the Rancho Seco method
3. lifetime fatal cancer risk from ingestion and inhalation
4. EDE (mrem) from skin exposure.
5. lifetime fatal cancer risk from SDE due to skin exposure.

The criteria to be used to demonstrate that "unacceptably high risks would not result" are listed in Table A5-4.

Expectation Dose

The DRP assessment method for the Shelwell site is described in SECY-98-117, "Shelwell Services, Inc., Risk Assessment", May 27, 1998. The method applied a risk informed approach that entailed calculating an "expectation dose" by multiplying the CEDE from DRP exposure by the annual probability of DRP exposure occurring. In a Staff Requirements Memorandum dated June 30, 1998, the NRC staff was directed by the Commission to apply the SECY-98-117 DRP assessment method to the review of Shelwell license termination request. The NRC terminated the license on July 14, 1999, using the SECY-98-117 risk informed approach as justification. The expectation dose is calculated using Equation A5-4.

Equation A5-4

$$ED = \frac{p_l}{t_o} D_{drp}$$

where:

ED = expectation dose (mrem/yr)
p_l = lifetime probability of DRP ingestion or inhalation (4.8×10^{-7} and 5.2×10^{-9} for ingestion and inhalation, respectively, as calculated in section A5.2)
t_0 = resident lifetime site occupancy time (30 y)
D_{drp} = dose from ingestion or inhalation of DRP (mrem)

TEDE from DRP Activity Distributed in Soil

The DRP assessment method at Rancho Seco was described in Attachment 2 of a June 8, 2009 letter from Einar Ronnington, SMUD, to John Hickman, USNRC, "Phased Release of the Ranch Seco Site". The method was approved in a September 25, 2009, letter from Keith McConnell, USNRC, to Einar Ronnington, SMUD, which states that "the NRC staff has reviewed your proposed partial site release, as described in your June 8, 2009, letter, and finds the proposed release to be acceptable". The Rancho Seco DRP assessment method assumed that the activity in the DRP is uniformly distributed within a volume of soil that is 1 m^2 in area and 0.15 m deep. The dose from the radionuclide concentrations uniformly distributed in the soil volume is then calculated using soil DCGLs and the unity rule. The result represents a DRP dose that can be compared to the TEDE dose units that are used to express the unrestricted use criteria in 10 CFR 20 Subpart E. The Rancho Seco approach was applied but modified to be more comprehensive by also assessing soil areas less than 1 m^2 and more realistic by using soil area factors in conjunction with soil DCGLs to properly account for the dose from small areas. See section A5.3 for details on the dose calculation using the Rancho Seco method.

Fatal Cancer Risk from DRP Ingestion and Inhalation

The third method that will be used to assess the risk from DRP, in a manner that can be compared to a dose expressed in units of TEDE, is to convert DRP ingestion and inhalation dose to a corresponding fatal cancer risk. In support of the promulgation of the LTR, SECY-97-046A states that the lifetime fatal cancer risk corresponding to the 25 mrem/yr unrestricted use criterion is 4×10^{-4} and that this risk is estimated assuming a risk coefficient of 5×10^{-4} rem^{-1} and a 30-year lifetime exposure. As shown in Section A5.1, exposure to a DRP is a low probability, once in a lifetime event, as compared to the assumed continuous exposure over a 30-year lifetime from uniformly distributed source terms such as soil. Therefore, the ingestion and inhalation doses (CEDE) from the hypothetical DRP will be multiplied by the risk coefficient applied in SECY-97-046A, i.e., 5×10^{-4} rem^{-1}, and compared to the risk of 4×10^{-4} that corresponds to the 25 mrem/year unrestricted use criterion. If the lifetime fatal cancer risk from the LLBP DRP ingestion and inhalation exposure scenarios is less than 4×10^{-4}, then the risk is not considered unacceptably high.

Fatal Cancer Risk from SDE Due to Skin Exposure

As described in section A.5.3, Varskin Version 6.2.1 will be used to calculate shallow dose equivalent (SDE) to the skin. However, the dose criterion in 10 CFR 20 Subpart E applies to

TEDE, not SDE to the skin, and therefore direct comparison of SDE to the TEDE criterion is not appropriate. To allow comparison of SDE to a dose in units of TEDE, the SDE was multiplied by a risk factor to calculate fatal cancer risk and compared to the fatal cancer risk corresponding to the 25 mrem/yr TEDE criterion as provided in SECY-97-046A, i.e., $4x10^{-4}$ yr^{-1}. The fatal cancer risk factor applied to the SDE dose is from the Final Rule, "Revision of the Skin Dose Limit", 67 FR 16298, April 5, 2002, which recommends a value of $6.6x10^{-10}$ rem^{-1}.

EDE from Skin Exposure

In addition to fatal cancer risk from SDE, the EDE from DRP will be calculated using the method authorized in NRC Regulatory Issue Summary (RIS) 2003-04, "Use of the Effective Dose Equivalent in Place of The Deep Dose Equivalent in Dose Assessments", February 13, 2003 (see section A5.3 for details).

Demonstration That "Unacceptably High Risks Would Not Result" from DRP Exposure

The final dose and risk from DRP ingestion, inhalation, and skin exposure will be calculated and provided in the DRP Survey Report. The acceptance criteria provided in Table A5-4, column 4, will be used to demonstrate that "unacceptably high risks would not result" from the LLBP exposure to hypothetical DRPs. Note that the ingestion and inhalation fatal cancer risks, and the skin doses in Table A5-4 assume that the exposure occurs notwithstanding the very low lifetime probability of such an exposure actually occurring. See column 2 of Table A5-4 for the lifetime probabilities of DRP exposure. The acceptance criteria in Table A5-4 are not intended to be the absolute limits at which the LLBP DRP scenario is assessed but are intended as criteria that if met, do demonstrate that unacceptably high risks do not result. Higher values may also be acceptable on a case-by-case basis if justified in the DRP Survey Report.

Table A5-4 Acceptance Criteria for Demonstrating that "unacceptably high risks would not result" from the LLBP DRP Exposure Scenario

DRP Exposure Pathway	Lifetime Probability of DRP Exposure Occurring	Assessment Criteria	Acceptance Criteria
Ingestion and Inhalation	NA[1]	Expectation Dose	<25 mrem/yr
Ingestion and Inhalation	Ingestion: $4.8x10^{-7}$ Inhalation: $5.2x10^{-9}$	Fatal Cancer Risk[2]	$<4x10^{-4}$
Ingestion and Inhalation	NA[3]	TEDE from DRP Activity Distributed in Soil	<25 mrem/yr
Skin	$3.7x10^{-6}$	Skin Dose (EDE)	<25 mrem
Skin	$3.7x10^{-6}$	Fatal Cancer Risk from SDE	$<4x10^{-4}$

1) The expectation dose calculation includes annual probability of exposure occurring
2) The $4x10^{-4}$ fatal cancer risk is the risk corresponding to the 25 mrem/yr unrestricted use criterion as stated in SECY-97-046A
3) The exposure to a small soil area of distributed activity is assumed to occur annually in the same manner as other small soil elevated areas