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Attachments: TSD-17-001 Rev 1 - ALARA Analysis for Use of Concrete Debris as Fill and Remediation of Aux Bldg..pdf

John, This document was sent from FSS per Gerry Van Noordennen request to be discussed at 1300 meeting today. There will be 3 more documents coming in separate emails due to Size.Thanks

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Zion*Solutions*, LLC.
Technical Support Document

TSD 17-001

ALARA ANALYSIS FOR USE OF CONCRETE DEBRIS AS FILL AND REMEDIATION OF AUXILIARY BUILDING 542 FT FLOOR DRAINS

Revision 1

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1. PURPOSE

When dismantlement and decontamination actions are completed, residual radioactivity may remain on building surfaces and in site soils at concentrations that correspond to the maximum annual dose criterion of 25 mrem/yr. The remaining residual radioactivity must also satisfy the ALARA criterion, which requires an evaluation as to whether it is feasible to further reduce residual radioactivity to levels below those necessary to meet the dose criterion (i.e., to levels that are ALARA). This Technical Support Document (TSD) presents the ALARA evaluation for the use of non-radioactive (or "clean") concrete demolition debris as clean hard fill for basement voids and for the remediation of the embedded floor drains in the Auxiliary Building 542 foot elevation floor.

2. DISCUSSION

In order to determine if additional remedial action is warranted by ALARA analysis, the desired beneficial effects (benefits) and the undesirable effects (costs) must be calculated. If the benefits from remedial action will be greater than the costs, then the remedial action is warranted and should be performed. However, if the costs exceed the benefit, then the remedial action is considered to be not ALARA and should not be performed.

3. METHODS FOR DETERMINING ALARA

Guidance for conducting ALARA analyses is provided in Appendix N of NUREG-1757, Volume 2, Revision 1, "Consolidated Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria, Final Report" (Reference 1), which describes acceptable methods for determining when further reduction of residual radioactivity is required to concentrations below the levels necessary to satisfy the 25 mrem/yr dose criterion.

3.1. Calculation of Benefits

The benefit from collective averted dose (B_{AD}) is calculated by determining the present worth of future collective averted dose and multiplying by a factor to convert the dose to a monetary value. In accordance with Appendix N of NUREG-1757, the equation is as follows;

$$B_{AD} = \$2{,}000 \times PW(AD_{Collective})$$

where:

B_{AD}	=	benefit from an averted dose for a remediation action, in US dollars,
$2,000	=	value in dollars of a person-rem averted and,
$PW(AD_{Collective})$	=	present worth of a future collective averted dose.

The present worth of future collective averted dose $PW(AD_{Collective})$ is then expressed in accordance with the following equation;

$$PW(AD_{Collective}) = (P_D)(A)(Dose)(F)\left(\frac{Conc}{DCGL_w}\right)\left(\frac{1-e^{-(r+\lambda)N}}{r+\lambda}\right)$$

where:

P_D	=	population density for the critical group scenario in people/m^2,
A	=	area being evaluated in square meters (m^2),
$Dose$	=	annual dose to an AMCG from residual radioactivity in rem/yr,
F	=	effectiveness, or fraction of the residual radioactivity removed by the remediation action,
$Conc$	=	average concentration of residual radioactivity in the area being evaluated in units of activity per unit volume,
$DCGL_w$	=	derived concentration equivalent to the average concentration of residual radioactivity that would result in the "*Dose*" variable to the AMCG,
r	=	monetary discount rate in units per year (yr^{-1}),
λ	=	radiological decay constant for the radionuclide in units per year and,
N	=	number of years over which the collective dose will be calculated.

3.2. ALARA Analysis Parameters

In accordance with Table N.2 of Appendix N of NUREG-1757, the acceptable and relevant parameters for use in performing ALARA analysis are as follows;

- Dollars per person-Rem - $2,000.00/person-rem (per NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission" [Reference 2])
- Population density (P_D) for the critical group (persons/m^2) - 0.0004 person/m^2 for land (per NUREG-1496, "Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities", Volume 2, [Reference 3] Appendix B, Table A.1)
- Monetary discount rate (r) - 0.00 yr^{-1} for soil

(Note; This variable was established at 0.03 yr^{-1} for soil in Table N.2 of Appendix N of NUREG-1757. The monetary discount for the ALARA analysis was removed from the equation through Federal Register Notice 72 FR 46102 – August 16, 2007. Consequently, the *r* variable has been conservatively set at 0.00 yr^{-1} for soil, i.e. no monetary discount for soils as well as basements.)

- Number of years (*N*) over which the collective averted dose is calculated - 1,000 yrs (per NUREG-1496, Appendix B, Table A.1)
- Area (*A*) used to calculate the population density (m^2) – 10,000 m^2 (size of reference area that was evaluated)

3.3. Calculation of Costs

The total cost, ($Cost_T$) which is balanced against the benefits; has several components and may be evaluated according to Equation N-3 of NUREG-1757, Appendix N below:

$$Cost_T = Cost_R + Cost_{WD} + Cost_{ACC} + Cost_{TF} + Cost_{WDose} + Cost_{PDose}$$

where:

$Cost_R$ = monetary cost of the remediation action (including mobilization costs);

$Cost_{WD}$ = monetary cost for transport and disposal of the waste generated by the action;

$Cost_{ACC}$ = monetary cost of worker accidents during the remediation action;

$Cost_{TF}$ = monetary cost of traffic fatalities during transportation of the waste;

$Cost_{WDose}$ = monetary cost of dose to the worker;

$Cost_{PDose}$ = monetary cost of dose to the public from excavation, transport and disposal of the waste;

For the ALARA analysis of the use of concrete as fill and remediation of the Auxiliary Building embedded floor drains, the variables for $Cost_{ACC}$, $Cost_{TF}$, $Cost_{WDose}$ *and* $Cost_{PDose}$ were not calculated for this evaluation based upon their anticipated unlikely impact on the total cost ($Cost_T$). This is consistent with the guidance provided in NUREG-1757 which states that if one or two of the costs can be shown to exceed the benefit, then the remediation cost is shown to be unnecessary without calculating all of the costs.

4. ALARA CALCULATION FOR USE OF CONCRETE AS CLEAN FILL

The current decommissioning approach for the Zion Station Restoration Project (ZSRP) calls for the beneficial reuse of concrete from building demolition as clean fill. Concrete that meets the non-radiological definition of clean concrete demolition debris and where surveys demonstrate that the concrete is free of plant derived radionuclides above background will be used.

Concrete structures that will be demolished and reused as clean hard fill for basement voids will be surveyed prior to demolition. The survey design for this survey will comply with all DQOs, statistical requirements, areal coverage, measurement spacing and decision error requirements specified in the Zion License Termination Plan (LTP) Rev 1, Chapter 5, section 5.6. However, instead of a Derived Concentration Guideline Levels (DCGL), compliance will be demonstrated to a limiting Minimum Detectable Concentration (MDC) of 5,000 dpm/100cm^2 commensurate with unconditional release.

For compliance with the radiological criteria for unrestricted use specified in 10 CFR 20.1402, concrete fill is another dose component applicable to any basement where concrete debris will be used as fill. The basement-specific, fixed dose attributed to concrete fill is based on the assumption that prior to demolition, residual radioactivity is present on the surfaces of the concrete structures that will be demolished and reused as fill at the MDC of 5,000 dpm/100cm^2 to a depth of ½ inch. The resultant basement-specific dose from the Zion LTP, Rev 1, Chapter 6 is presented in Table 4-1. It should be noted that use of the MDC of 5,000 dpm/100cm^2 is a bounding assumption as the determination of acceptance with the unconditional release criteria of "indistinguishable from background" will be based on the action level of the instrument used for the survey.

Table 4-1 Dose for Basement Unit Assuming Contamination at 5000 dpm/100cm^2

Basement Unit	Dose (rem/yr)
Auxiliary Building	0.00123
Containment	0.00160
SFP/Transfer Canal	0.00004
Turbine	0.00164
Crib House/Forebay	0.00201
WWTF	0.00158
Total Dose	0.00810

Based upon a simple ALARA analysis, the only benefit for not using the clean concrete as fill is to reduce the residual radioactivity in the Basement units and the monetary value of the collective averted dose to future occupants of the site. Averted dose is based upon the "resident farmer" scenario. For the purpose of the ALARA assessment for the use of concrete as fill, the dose averted is the total dose of 0.00810 rem/yr. This value then becomes the "*Dose*" variable in the ALARA equation.

4.1. Calculation of Costs

The two cost variables that were assessed for the ALARA analysis were waste transportation and off-site disposal as waste. The process of surveying, demolishing and size reduction are the same for use of the media as fill or disposal as waste. Consequently, the variable "$Cost_R$" is constant in both scenarios.

For the purposes of the ALARA analysis, it was assumed that the concrete would be transported and disposed of as clean (non-radioactive) waste. While it is true that if surveys detected plant-derived radioactivity in the concrete at concentrations greater than background, the concrete would be disposed of as radioactive waste, it would also not be considered as suitable for use as fill. Consequently, the ALARA analysis only considered the difference in cost between on-site use of non-radioactive material as fill and off-site disposal of the material as non-radioactive waste.

It is estimated that 74,947 cubic yards of concrete will be made available for use as clean hard fill from the demolition of above grade structures at Zion. This equates to 57,301 m^3 of concrete material. Performing unit conversion and assuming a concrete density of 1.4 g/cm^3, the weight of the concrete material that could be used as fill is 88,460 tons. Off-site disposal costs for the concrete waste were based on a unit disposal cost of $46.00/ton. This unit cost includes packaging and disposal fees. The transportation component of the cost is based on $200.00 per 15 ton shipment. Applying the waste disposal and transportation unit costs to the 88,460 tons of waste produces a value for $Cost_{WD}$ of $5,247,692.37. For this simplified calculation, $Cost_{WD}$ will equal $Cost_T$ in the equation.

4.2. ALARA Calculation

Determination of residual radioactivity in the concrete fill that are ALARA is the concentration at which benefit equals or exceeds the costs of removal and waste disposal. When the total cost ($Cost_T$) is set equal to the dose averted, the ratio of the concentration to the $DCGL_w$ is calculated as follows;

$$\frac{Conc}{DCGL_W} = \frac{(Cost_T)(r+\lambda)}{(\$2{,}000)(P_D)(Dose)(F)(A)(1-e^{-(r+\lambda)N})}$$

Assuming the following values for the remaining variables;

- the default parameter values from section 3.2,
- Cs-137 as the singular radionuclide
- a value of one for remediation effectiveness (*F*),

- a value for dose averted of 0.00810 from Table 4-1,

$$\frac{Conc}{DCGL_w} = \frac{(\$5{,}247{,}692.37)\left(0.00 + \frac{0.693}{30.17}\right)}{(\$2{,}000)(0.0004)(0.0081)(1)(10{,}000)\left(1 - e^{-\left(0.00+\frac{0.693}{30.17}\right)1{,}000}\right)}$$

the ratio of the concentration to the $DCGL_w$ when the total cost ($Cost_T$) is equal to the dose averted is 1,860.16

The present worth of future collective averted dose $PW(AD_{Collective})$ can be calculated as follows;

$$PW(AD_{Collective}) = (0.0004)(10{,}000)(0.0081)(1)(3122.42)\left(\frac{1 - e^{-\left(0.00+\frac{0.693}{30.17}\right)(1{,}000)}}{0.00 + \frac{0.693}{30.17}}\right)$$

resulting in a value for $PW(AD_{Collective})$ of 2,623.85 person rems. The benefit from collective averted dose (B_{AD}) is equal to $Cost_T$.

4.3. Conclusion

The simple analysis confirms that the benefit of using non-radioactive concrete debris on-site as clean hard fill for backfilling basement voids is clearly greater than the dose benefit of removing and disposing of the concrete off-site as clean waste.

5. ALARA CALCULATION FOR REMEDIATION OF AUXILIARY BUILDING EMBEDDED FLOOR DRAINS

An analysis was performed to satisfy the ALARA criterion, which requires an evaluation as to whether it is feasible and cost-effective to further reduce residual radioactivity in the Auxiliary Building 542 ft. embedded equipment and floor drain piping to levels below those necessary to meet the dose criterion (i.e., to levels that are ALARA).

Several more aggressive decontamination technologies could be used to further remediate the interior of the Auxiliary Building 542 ft. embedded pipe, including abrasive or grit blasting, honing and complete removal of the pipe. The complete removal of all the pipe was previously assessed by ZSRP. The original plan was to excavate the entire inventory of Auxiliary Building floor drain pipe and dispose of the material as radioactive waste. However, emergent concerns that the structural integrity of the basement floor may be compromised if the pipe was removed caused ZSRP to revise the decommissioning approach for the floor drain pipe that was embedded 3 to 4 feet in the concrete floor.

The most common, and most effective decontamination technology used to remediate the interior surfaces of embedded pipe is high pressure water blasting or hydrolasing. Consequently, hydrolasing was the remediation action that was evaluated for ALARA analysis for the further remediation of the Auxiliary Building 542 ft. embedded pipe.

5.1. ALARA Analysis Equation

For the ALARA analysis for the remediation of the Auxiliary Building 542 ft. embedded pipe by hydrolasing, the equation from NUREG-1757 for the ratio of the concentration to the $DCGL_w$ when the total cost ($Cost_T$) is set equal to the dose averted is modified as follows. The denominator must be summed and the individual dose contribution normalized to account for the multiple detectable radionuclides that are present in the radionuclide distribution for the Auxiliary Building.

$$\frac{Conc}{DCGL_w} = \frac{(Cost_T)(r+\lambda_i)}{\sum(\$2{,}000)\,(P_D)(f_i)(0.025)(F)(A)(1-e^{-(r+\lambda_i)N})}$$

where:

f_i = the mixture fractions for the Auxiliary Building for each ROC normalized to one

The total cost for the remedial action when divided by the total benefit of averted dose determines the cost effectiveness of the remedial action. Values greater than unity demonstrate that no further remediation is necessary beyond that required to meet the 25 mrem/yr dose criteria and are ALARA. Values less than one provide the fraction of the 25 mrem/yr dose criteria where it is necessary to remediate to achieve ALARA.

5.2. Calculation of Costs

5.2.1. Hydrolasing Costs

The action evaluated for ALARA for the remediation of the Auxiliary Building 542 ft. embedded pipe is hydrolasing. Hydrolasing is the most common and most effective decontamination technology used to remediate the interior surfaces of embedded pipe. There is 2,721 linear feet of pipe in the embedded pipe inventory that would require remediation.

The remediation activity rates that were used for this evaluation were based on previous experience. Current project labor costs and past operational experience were also used in developing these rates.

A production rate of 100 linear feet of pipe remediated per 8-hour work day was used for the assessment. This production rate is consistent with the rate observed at prior decommissioning projects where embedded pipe hydrolasing was performed, including the decommissioning of the Shoreham and Plum Brook facilities.

5.2.2. Labor Costs

An assumed crew size for this activity is one Project Engineer, a field supervisor, 3 full-time hydrolase technicians, 2 full-time laborers and 2 full-time Radiation

Protection Technicians (RPT). Using the current project labor rates for these positions of $139.00 per hour for the Project Engineer, $90.00 per hour for a supervisor, $75.00 per hour for a hydrolase technician, $66.78 per hour for a laborer and $55.59 per hour for a RPT, the hourly unit rate that will be used for the evaluation is $698.74.

Assuming the production rate of 100 linear feet of pipe remediated per 8-hour work day, it would take 27 work days to remediate 2,721 linear feet of pipe. A contingency of 25% was added which results in 34 total work days. This equates to a total of 272 man-hours, which is multiplied times the hourly unit rate of $698.74 to equal the labor cost for this evaluation of $190,127.15. $62,474.42 was added to the labor cost for expenses, including travel, lodging and meals for contracted personnel, resulting in a total cost for labor and expenses of $252,601.57.

5.2.3. Equipment Costs

Equipment costs are based on the rental of commercially available 20K hydrolaser unit and the purchase of consumable and ancillary equipment necessary to complete this work. The hydrolaser unit has an hourly rental cost of $224.00 per hour. The mobilization and demobilization costs associated with procuring this unit would be approximately $5,000.00. Other costs include the purchase of high pressure hoses, lances, cutting tips, an AOD pump, drums for waste, safety standpipes, exhaust hose and diesel fuel. The purchase cost for this material totals $96,068.37. The total equipment costs assumed for this evaluation is approximately $162,018.77.

5.2.4. Total Estimated Remediation Costs ($Cost_R$)

For the evaluation of the remediation activity of hydrolasing embedded pipe, the sum of the labor cost of $252,601.57 plus the equipment cost of $162,018.77 results in a total remediation action cost ($Cost_R$) for this activity of $414,620.35.

5.2.5. Transport and Disposal of Waste ($Cost_{WD}$)

Disposal costs for generated solid waste were based on an average total disposal cost of $2,500/m^3. This average cost includes packaging, transportation and disposal fees. The transportation component of this average cost is based on the average transportation cost of using either rail or highway hauling from the Zion site to Clive, Utah (Energy*Solutions* radioactive waste disposal facility). Based upon an assumed waste volume of 188.27 m^3 of dry waste, a value of $470,662.50 is calculated for the disposal of solid waste.

Disposal costs for generated liquid waste were based on an average total disposal cost of $0.40/gal. This is the cost for the use and operation of the liquid waste filtration equipment necessary to process this waste. Based upon an assumed volume of 237,054 gallons of liquid waste that would require processing, a value of \$94,821.41 is calculated for the disposal of liquid waste. A total waste disposal cost of \$565,483.91 is calculated for the $Cost_{WD}$ variable.

5.2.6. Non-Radiological Risks ($Cost_{ACC}$)

In accordance with NUREG-1496, Appendix B, Table A.1, a value of 4.2 E-08/hr was used for F_W. For T_A, in accordance with NUREG-1757 the same hours that was determined for labor cost (2,449 man-hours) was used for worker accident cost. Subsequently, a value of \$308.56 is calculated for the $Cost_{ACC}$ variable.

5.2.7. Transportation Risks ($Cost_{TF}$)

For this evaluation, the waste volume (V_A) is assumed to be 188.27 m^3 and the haul volume of an overland truck shipment per NUREG-1757 is assumed to be 13.6 m^3 (V_{SHIP}).

In accordance with NUREG-1496, Volume 2, Appendix B, Table A.1, a value of 3.8 E-08/hr was used for F_T.

The Clive, Utah round trip distance from the Zion site by highway is 1,463 miles (2,355 km). The distance for rail shipments is further than that for highway shipments because of the route rail shipments must follow, however the difference as it pertains to the calculation is insignificant. The highway shipment distance of 2,355 km (D_T) was used for the calculation of $Cost_{TF}$. For this evaluation, the value for the $Cost_{TF}$ variable is \$3,716.43.

5.2.8. Worker Dose Estimates ($Cost_{WDose}$)

Costs associated with worker dose are a function of the hours worked and the workers' radiation exposure for the task. A value of 5 mrem per man-hour was used for D_R. The time worked to remediate the area in units of person-hour calculated for this activity (T) was 2,449 man-hours. For this evaluation, the value for the $Cost_{WDose}$ variable is \$24,489.00.

5.2.9. Monetary Cost of Dose to the Public ($Cost_{PDose}$)

For this equation, a "worst-case" value of 0.5 mrem/hr was used for D_R. This assumes that the shipment is classified as Limited Specific Activity (LSA) in accordance with 49 CFR 173.427 and the package meets the Zion specific administrative limit of 0.5 mrem/hr on the exterior of the shipment. The exposure time (T) used for this calculation is based upon a transit time of 23 hours driving from Zion to the disposal site in Clive Utah times three shipments, for a total of 69 hours. For this evaluation, the value for the $Cost_{PDose}$ variable is \$69.00.

5.2.10. Total Cost ($Cost_T$)

The total cost, ($Cost_T$) assumed for this evaluation is $1,008,687.25

5.3. ALARA Assessment Parameters

The following parameters were used for performing the ALARA calculation using the equation from NUREG-1757:

- Population density (P_D) for the critical group (persons/m^2) - 0.0004 person/m^2 for soil (per NUREG-1496, Appendix B, Table A.1)
- Fraction of residual radioactivity removed by the remedial action (F) – 1 (Removal of desired residual contamination from the pipe interior surfaces is assumed 100% effective)
- Area (A) used to calculate the population density (m^2) – 10,000 m^2 (size of resident farmer reference area)
- Monetary discount rate (r) - 0.00 yr^{-1}
- Number of years (N) over which the collective averted dose is calculated (yr) - 1,000 yrs (per NUREG-1496, Appendix B, Table A.1)

5.4. Radionuclides Considered for ALARA Analysis

The Radionuclides of Concern (ROC) from Zion*Solutions* TSD 14-019, "Radionuclides of Concern for Soil and Basement Fill Model Source Terms" (Reference 4) was used for the ALARA analysis. The DCGLs for the Auxiliary Building 542 ft. embedded floor drains are calculated using the Basement Fill Model (BFM) Dose Factors (DF) for the Auxiliary Basement provided in Table 8 of Zion*Solutions* TSD 14-010, Rev. 2, "RESRAD Dose Modeling for Basement Fill Model, Soil DCGL, and Calculation of Basement Fill Model Dose Factors" (Reference 5). The Table 8 values were adjusted in this calculation to include a conservative insignificant contributor dose percentage of 5%.

The Auxiliary Building Embedded Pipe DCGLs ($DCGL_{AD}$) were calculated using the following equation.

$$DCGL_{AD}(i) = \frac{25}{BFM\ DF(i)} * \frac{1}{Drain\ SU\ Area} * 1.0E09$$

Where:

$DCGL_{AD}$ (i)	=	Auxiliary Drain DCGL for radionuclide (i) (pCi/m^2)
BFM DF (i)	=	Auxiliary Basement Fill Model Dose Factor for radionuclide (i) (mrem/yr per mCi)
25	=	25 mrem/yr release criterion

Drain SU Area = Total internal surface area of all drains in survey unit (m^2) – 299.41 m^2

1.0E+09 = conversion factor of 1E+09 pCi/mCi

The Auxiliary floor drain $DCGL_{AD}$ values for all ROC are provided in Table 5-1. Note that the DCGLs represent the dose that would occur with no grouting.

Table 5-1 - Auxiliary Building 542 ft. Embedded Floor Drain $DCGL_{AD}$

ROC	BFM DF(1) (mrem/yr per mCi)	$DCGL_{AD}$ (pCi/m^2)
Co-60	1.14E-02	7.33E+09
Cs-134	1.64E-02	5.10E+09
Cs-137	3.12E-02	2.68E+09
Ni-63	3.01E-04	2.78E+11
Sr-90	3.47E-01	2.41E+08

(1) Adjusted to 5% Insignificant Contributor Dose Percentage

The values for half-life, radiological decay constants (λ) and the radionuclide mixture fractions are presented in Table 5-2. The mixture fractions are based on the Unit 1 Floor Drain mixture. The Unit 1 Floor Drain mixture is the most limiting of the five mixtures calculated from the Auxiliary Building 542 ft. embedded pipe as the predominant radionuclide in the mixture is Co-60, which has a higher dose consequence than Cs-137.

Table 5-2 Radionuclide Half-Life(s), Decay Constant(s) and Mixture

Radionuclide (a)	Half-Life (yrs)	λ (yr^{-1})	Radionuclide Mixture(b)
Co-60	5.27 E+00	1.31 E-01	55.85%
Ni-63	9.60 E+01	7.22 E-03	28.19%
Sr-90	2.91 E+01	2.38 E-02	0.01%
Cs-134	2.06 E+00	3.36 E-01	0.00%
Cs-137	3.02 E+01	2.30 E-02	15.95%

(a) Dose significant ROC for the Auxiliary Building in accordance with TSD 14-019.

(b) Normalized radionuclide mixture for dose significant ROC for Unit 1 Floor Drain mixture.

5.5. Conclusion

The ALARA calculations performed to evaluate the hydrolasing of the Auxiliary Building 542 ft. embedded drains is presented in Table 5-3. The ALARA analysis based on cost benefit analysis shows that further remediation of embedded drains beyond that required to demonstrate compliance with the 25 mrem/yr dose criterion is not justified.

5.6. Remediation of the Auxiliary Building 542 foot Embedded Drains

Even though the ALARA analysis concluded that further remediation of the embedded pipe beyond that required to demonstrate compliance with the 25 mrem/yr dose criteria was not justified, a limited hydrolasing of the Auxiliary Building 542 ft. floor drain piping commenced on October 19, 2016 and was completed on October 26, 2016. At least one decontamination pass was achieved with the hydrolaser in all 2,721 feet of pipe, including the 85 feet of pipe that was deemed as not accessible for survey. The hydrolasing process injected approximately 24,734 gallons of water into the pipe interior at a lance tip pressure of approximately 10,000 psi. Approximately 3,400 lbs of debris (including desiccant material used as absorbent) was removed from the Auxiliary Building 542 ft. sumps after the completion of hydrolasing.

The estimates used to perform the ALARA analysis assumed a hydrolasing production rate of 100 linear feet of pipe remediated per 8-hour work day consistent with the production rates observed at Shoreham and Plum Brook with similar types of pipe. The actual production rate experienced at Zion was much higher, mostly due to the fact that the decontamination process was designed to remove gross debris in a single continuous pass whereas the decontamination process at Shoreham and Plum Brook was intended to achieve a larger decontamination factor. Using the actual production rate of approximately 525 linear feet per 8-hour work in the ALARA calculation would reduce the total cost ($Cost_T$) variable to $663,812.90. Using this value in the evaluation would result in the same conclusion.

Table 5-3 - ALARA Analysis for Hydrolasing of Embedded Drains – Auxiliary Building 542 ft.

$A = 10{,}000\ \text{m}^2$, $r = 0.00\ \text{yr}^{-1}$, $N = 1{,}000$ yr, $P_D = 0.0004$ person/m^2 Fraction of Activity removed by remedial action (F) = 1

Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J	Column K	Column L	Column M	
Nuclide	Half-Life (yrs)[a]	λ (yr^{-1})[a]	$(r+\lambda)$	$(r+\lambda)N$	$e^{-(r+\lambda)N}$	$1-e^{-(r+\lambda)N}$	$[1-e^{-(r+\lambda)}N]/(r+\lambda)$	Mixture Fraction	$DCGL_{AD}$	(Columns I*J)	f_i Column K divided by sum	Cost Benefit	
Co-60	5.27E+00	1.31E-01	1.31E-01	1.31E+02	7.77E-58	1.00E+00	7.60E+00	55.85%	7.33E+09	4.09E+09	2.14E+00	$ 427,606.03	
Ni-63	9.60E+01	7.22E-03	7.22E-03	7.22E+00	7.33E-04	9.99E-01	1.38E+02	28.19%	5.10E+09	1.44E+09	7.51E-01	$ 150,144.32	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	0.01%	2.68E+09	2.82E+05	1.47E-04	$ 29.47	
Cs-134	2.06E+00	3.36E-01	3.36E-01	3.36E+02	7.94E-147	1.00E+00	2.97E+00	0.00%	2.78E+11	0.00E+00	0.00E+00	$ 0.00	
Cs-137	3.02E+01	2.29E-02	2.29E-02	2.29E+01	1.08E-10	1.00E+00	4.36E+01	15.95%	2.41E+08	3.84E+07	2.01E-02	$ 4,015.73	
							Check Sum	100%	Sum	5.57E+09	2.91E+00	$ 581,795.55	$\sum(Cost_B)$
							(A result < 1 would justify remediation whereas a result > 1 would demonstrate that residual radioactivity is ALARA)					<u>1.73</u>	Conc/ DCGL

Cost (in dollars) of remedial action ($Cost_T$) = $1,008,687.25

6. REFERENCES

1 NUREG-1757, Volume 2, Revision 1, "Consolidated Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria, Final Report"

2 NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission"

3 NUREG-1496, "Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities", Volume 2

4 Zion*Solutions* TSD 14-019, "Radionuclides of Concern for Soil and Basement Fill Model Source Terms"

5 Zion*Solutions* TSD 14-010, Rev. 2, "RESRAD Dose Modeling for Basement Fill Model, Soil DCGL, and Calculation of Basement Fill Model Dose Factors"