LA CROSSE BOILING WATER REACTOR
LICENSE TERMINATION PLAN
CHAPTER 4, REVISION 1
REMEDIATION PLAN

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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
CVS	Contamination Verification Survey
DCGL	Derived Concentration Guideline Levels
EMC	Elevated Measurement Comparison
FSS	Final Status Survey
G-3	Genoa 3 Fossil Station
HEPA	High Efficiency Particulate Air
LACBWR	La Crosse Boiling Water Reactor
LLRW	Low Level Radioactive Waste
LSA	Low Specific Activity
LTP	License Termination Plan
ISOCS	*In Situ* Object Counting System
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
NRC	Nuclear Regulatory Commission
$OpDCGL_B$	Operational Basement Derived Concentration Guideline Level
ROC	Radionuclides of Concern
RPT	Radiation Protection Technician
SAFSTOR	SAFeSTORage
TEDE	Total Effective Dose Equivalent
TSD	Technical Support Document
WGTV	Waste Gas Tank Vault

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4. Site Remediation Plan

In accordance with 10 CFR 50.82(a)(9)(ii)(C), the License Termination Plan (LTP) must provide the "plans for site remediation". These plans must include the provisions to meet the criteria from Subpart E of 10 CFR 20 before the site may be released for unrestricted use. The two radiological criteria for unrestricted use specified in 10 CFR 20.1402 are: 1) the Total Effective Dose Equivalent (TEDE) from residual radioactivity that is distinguishable from background radiation must not be greater than 25 mrem/yr to the Average Member of the Critical Group (AMCG) and 2) residual radioactivity levels must be As-Low-As-Reasonably-Achievable (ALARA).

Decontamination and dismantlement activities will be conducted in accordance with established Radiation Protection, Safety and Waste Management programs which include approved written procedures. These programs and procedures are frequently audited for technical content and compliance. Revisions have been, and will continue to be made, to these programs and procedures to accommodate the changing work environment inherent to reactor decommissioning and, documented, processed and approved in accordance with existing La Crosse Boiling Water Reactor (LACBWR) administrative procedures using 10 CFR 50.59 and Regulatory Guide 1.187, *Guidance for Implementation of 10 CFR 50.59 Changes, Tests and Experiments* (1) as guidance. Consistent with Regulatory Guide 1.179, *Standard Format and Content for License Termination Plans for Nuclear Power Reactors* (2), details regarding changes to the Radiation Protection Program to address remediation and decommissioning activities are not provided in this LTP, but periodic updates to the *LACBWR Decommissioning Plan and Post-Shutdown Decommissioning Activities Report* (3) will provide such details.

This chapter describes the methods that may be used to remediate contaminated systems, components and structures. The methods for demonstrating compliance with the ALARA criterion in 10 CFR 20.1402 is also described. Note that Chapter 6 provides the methods for demonstrating compliance with the 25 mrem/yr dose criterion. Also note that Chapter 3 describes in detail the remaining site remediation and dismantlement activities and the order in which they will occur for each structure, system and/or component.

This chapter also provides a summary of the radiation protection methods and control procedures that will be employed to address the impact of dismantlement and remediation activities.

4.1. Remediation Actions and ALARA Evaluations

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).

The ALARA evaluation calculates the concentration (or activity) at which the averted collective radiation dose, converted into dollars, is equal to the costs of continued remediation (e.g., risk of transportation accidents converted into dollars, worker and public doses associated with the remediation action converted into dollars, and the actual costs to perform the remediation activity). If this concentration or activity is below the concentrations or activities that correspond to the maximum annual dose criterion, then further reduction of residual radioactivity is justified by ALARA.

Regardless of the outcome of the quantified cost/benefit calculation provided in this chapter, the final dose from residual radioactivity is expected to be well below the dose criterion. The majority of the basement surfaces to be backfilled have minimal contamination. In addition, any areas that are identified as potentially containing activity at levels that could exceed the Derived Concentration Guideline Level (DCGL), as measured during Final Status Survey (FSS) by the *In Situ* Object Counting System (ISOCS), will be remediated. Industry standard remediation methods have been shown to remove contamination to levels significantly below the target levels, in this case the DCGL, and this result is expected for any LACBWR remediation. The combination of low current contamination levels over the majority of the basement surfaces combined with remediated areas likely containing activity well below the DCGL, ensures that the final dose from residual radioactivity at license termination will be well below the 25 mrem/yr dose criterion. Based on characterization results, there is very limited contamination expected in soil, buried pipe, or above grade buildings with a corresponding dose that is also expected to be well below 25 mrem/yr.

4.2. Remediation Actions

Remediation actions are performed throughout the decommissioning process and the techniques, methods and technologies are standard to the commercial nuclear industry. All of the remediation actions described may not necessarily be required, but are listed as possible actions that may be taken during the decommissioning of LACBWR. The appropriate remediation technique(s), method(s) and/or technologies that will be employed is dependent on the physical composition and configuration of the contaminated media requiring remediation. At LACBWR, the principal media that will be subjected to remediation are concrete structural surfaces. Characterization survey results and historical survey data indicate that generally there is minimal soil and groundwater contamination identified to date.

4.2.1. Structures

As indicated in Chapter 3 of this License Termination Plan (LTP), the Reactor Building and the Waste Gas Tank Vault (WGTV) will be demolished and removed to a depth of at least 3 feet below grade. All other impacted LACBWR buildings, structures and components, other than the following structures, will be demolished and removed in their entirety. The impacted above grade structures that will remain are: The impacted above grade structures that will remain are;

- LACBWR Administration building
- G-3 Crib House
- LACBWR Crib House
- Transmission Sub-Station Switch House
- G-1 Crib House

- Barge Wash Break Room
- Back-up Control Center
- Security Station

The site and public roads and railways that traverse through the site will also remain. None of the buildings and structures associated with the Genoa 3 Fossil Station (G-3) are expected to be radiologically impacted. Therefore, the structures associated with G-3 will remain intact and functional for G-3 power operations. The G-3 Crib House is classified as impacted due to its location in an impacted soil survey unit. The above grade structures listed above will be subjected to FSS using the acceptable screening values for building surface contamination from Table H.1 of Appendix H from NUREG-1757, Volume 2, Revision 1, *Consolidated Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria, Final Report* (4). Section N.1.5 of NUREG-1757 states that "*licensees who have remediated surface soil and surfaces to the NRC default screening criteria have remediated soil such that it meets the unrestricted use criteria in 10 CFR 20.1402, or if no residual radioactivity distinguishable from background, may be left at the site would not be required to demonstrate that these levels are ALARA*." Therefore, there is no ALARA analysis for above grade structures in this Chapter.

All impacted systems, components and structural surfaces above the 636 foot elevation in Class 1 buildings will be removed during the decommissioning process and disposed of as a waste stream. Grade level at LACBWR is at the 639 foot elevation. The below-grade structural surfaces, or basements, that will remain at LACBWR following the termination of the license are solid concrete structures, and the steel liner in the Reactor Building, which will be covered by at least three 3 feet of soil and physically altered to a condition which would not allow the remaining structural surfaces, if excavated, to be realistically occupied. The concrete walls and floors of the basements will be remediated to levels that will provide high confidence that FSS measurements with ISOCS will not exceed radionuclide-specific DCGLs that represent the annual dose criterion for unrestricted use specified in 10 CFR 20.1402.

Examples of remediation techniques that may be used for the below grade structural surfaces include washing, wiping, pressure washing, vacuuming, scabbling, chipping, and sponge or abrasive blasting. Cost estimates for these techniques also include the amount of water generated and the cost to process, package and ship this waste. Concrete removal may include using machines with hydraulic-assisted, remote-operated, articulating tools. These machines have the ability to exchange scabbling, shear, chisel and other tool heads.

4.2.1.1. Scabbling and Shaving

The principal remediation method expected to be used for removing contaminants from concrete surfaces is scabbling and shaving. Scabbling entails the removal of concrete from a surface by the high-velocity impact of a tool with the concrete surface which transforms the solid surface to a volumetric particulate which can be removed. One method of scabbling is a surface removal process that uses pneumatically operated air pistons with tungsten-carbide tips that fracture the concrete surface to a nominal depth of 0.125 inches at a nominal rate of about 130 ft^2 (in accordance with NUREG/CR-5884, Volume 2, *Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station* (5), section G.3.1) or 12.08 m^2 per hour.

The scabbling pistons (feet) are contained in a close-capture enclosure that is connected by hoses to a sealed vacuum and collector system. Shaving uses a series of diamond cutting wheels on a spindle, and performs at similar rates to scabbling. The wheels are also contained in a close capture enclosure similar to scabbling equipment. The fractured media and dusts from both methods are deposited into a sealed removable container. The exhaust air passes through both roughing and absolute High Efficiency Particulate Air (HEPA) filtration devices. Dust and debris generated through these remediation processes is collected and controlled during the operation.

4.2.1.2. Needle Guns

A second method of scabbling is accomplished using needle guns. The needle gun is a pneumatic air-operated tool containing a series of tungsten-carbide or hardened steel rods enclosed in housing. The rods are connected to an air-driven piston to abrade and fracture the media surface. The media removal depth is a function of the residence time of the rods over the surface. Typically, one to two millimeters are removed per pass. Generated debris collection, transport and dust control are accomplished in the same manner as other scabbling methods. Use of needle guns for removal and chipping of media is usually reserved for areas not accessible to normal scabbling operations. These include, but are not limited to, inside corners, cracks, joints and crevices. Needle gunning techniques can also be applied to painted and oxidized surfaces.

4.2.1.3. Chipping

Chipping includes the use of pneumatically operated chisels and similar tools coupled to vacuum-assisted collection devices. Chipping activities are usually reserved for cracks and crevices. This action is also a form of scabbling.

4.2.1.4. Sponge and Abrasive Blasting

Sponge and abrasive blasting are similar techniques that use media or materials coated with abrasive compounds such as silica sands, garnet, aluminum oxide, and walnut hulls. Sponge blasting is less aggressive, incorporating a foam media that, upon impact and compression, absorbs contaminants. The medium is collected by vacuum and the contaminants are washed from the medium so the medium may be reused. Abrasive blasting is more aggressive than sponge blasting but less aggressive than scabbling. Both operations use intermediate air pressures. Sponge and abrasive blasting are intended for the removal of surface films and paints.

4.2.1.5. Pressure Washing

Pressure washing uses a nozzle of intermediate water pressure to direct a jet of pressurized water that removes superficial materials from the suspect surface. A header may be used to minimize over-spray. A wet vacuum system is used to suction the potentially contaminated water into containers for filtration or processing.

4.2.1.6. Washing and Wiping

Washing and wiping decontamination techniques are actions that are typically performed during the course of remediation activities for housekeeping and to minimize the spread of loose surface contamination. It is not anticipated that this remediation approach will be employed at

LACBWR to reduce the residual activity in structural surfaces for the purpose of meeting the 25 mrem/yr dose criterion but rather, to comply with the open air demolition criteria in Energy*Solutions* Technical Support Document (TSD) RS-TD-313196-005, *La Crosse Open Air Demolition Limits* (6) and, to ensure that loose surface contamination is removed prior to evaluating the surface for acceptable concentrations of residual activity.

4.2.1.7. High-Pressure Water Blasting

Most contaminated piping will be removed and disposed of as radioactive waste. Any pipe systems or sections of pipe systems that reside below grade that will remain in service (i.e., pipe to G3 Crib House) or be abandoned in place will be inspected and surveyed as described in Chapter 5. If radiological conditions inside the pipe are in excess of the release criteria, then *in situ* remediation will be performed. One method that may be used to remediate the pipe interior surfaces is high pressure water blasting. A typical High-Pressure Liquid-Jetting System has a high pressure water pump capable of producing a water pressure of 10,000 psi to 20,000 psi at an actual flow rate that ranges from 44 gallons per minute at 10,000 psi to 23 gallons per minute at 20,000 psi. A rotating jet-mole tip is used for 360 degree coverage of pipe interiors. The jet-mole is attached to a lance and high-pressure hose. The lance is manually advanced though the interior of the pipe. As the lance is advanced, the high-pressure water abrades the interior surface of the pipe, removing the corrosive layer, internal debris and radiological contamination. The waste water containing the removed contamination is then collected and stored for processing as liquid radiological waste.

4.2.1.8. Grit Blasting

Another approach that may be used to remediate the surfaces of pipe interior surfaces is grit blasting. Grit blasting uses grit media such as garnet or sand under intermediate air pressure directed through a nozzle that is pulled through the closed piping at a fixed rate. The grit blasting action removes the interior surface layer of the piping. A HEPA vacuum system maintains the sections being cleaned under negative pressure and collects the media for reuse or disposal. The final system pass is performed with clean grit to remove any residual contamination.

4.2.1.9. Removal of Activated/Contaminated Concrete

As previously stated, the principal means of remediating concrete surfaces is scabbling/shaving. If the concrete structure is designated for complete removal, such as interior concrete walls, the primary method that will be used to completely remove the concrete is through large scale demolition using hydraulic-operated crushing shears and jack-hammers fitted to large tracked excavators. Concrete structures will be fractured and crushed by these tools. As the concrete is reduced to rubble, the embedded rebar will be exposed and segregated from the concrete rubble. In situations where a more surgical removal is required, activated and/or contaminated concrete removal may be accomplished using a machine mounted, remote-operated articulating arm with interchangeable tooling heads. As concrete is fractured and rebar exposed, the metal is cut using flame cutting equipment. The concrete rubble and exposed rebar is collected and transferred into containers for later disposal in both techniques. Dusts, fumes and generated debris are locally collected and as necessary, controlled using temporary enclosures coupled with close-capture

HEPA systems or controlled water misting systems. Bulk concrete such as floors and walls may be removed as intact sections after sawing with blades, wires or other cutting methods.

4.2.1.10. Additional Remedial Actions

Mechanical abrasive equipment, such as hones, may be used to remove contamination from the surfaces of embedded/buried piping. Chemical removal means may be used, as appropriate, for the removal of certain contaminants.

4.2.2. Soil

The soil $DCGL_w$ that will be used to demonstrate compliance with the dose criterion in 10 CFR 20, Subpart E for the unrestricted release of open land survey units are provided in Table 5-5 of Chapter 5. Section 2.5.1.1 of NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (7) addresses the concern for the presence of small areas of elevated radioactivity. A simple comparison is used to assess the dose impact of potential elevated areas. This is referred to as the Elevated Measurement Comparison (EMC). The action level for this comparison is the $DCGL_{EMC}$, which is the $DCGL_w$ modified by an Area Factor (AF) to account for the small area of the elevated radioactivity. In general, a conservative remediation approach will be used which entails removal of soil exceeding the $DCGL_w$. However, soil concentrations at levels between the $DCGL_w$ and $DCGL_{EMC}$ may remain after remediation with such areas demarcated and accounted for during FSS design and assessment. Any radiological contamination in soils identified in concentrations greater than the $DCGL_{EMC}$ will be removed and disposed of as radioactive waste.

The site characterization process has established the location and extent of soil contamination at LACBWR. Characterization survey results and historical survey data indicate that there is generally minimal residual radioactivity in soil and groundwater identified to date. As needed, additional surveys will be performed to ensure that any changing soil radiological contamination profile during the remediation actions is adequately identified and addressed. Chapter 5 discusses soil sampling and survey methods.

Soil remediation equipment will include, but not be limited to, shovels, back hoe and track hoe excavators. Other equipment including soil dredges and vacuum trucks may also be used. As practical, when the remediation depth approaches the soil interface region between unacceptable and acceptable contamination, a squared edge excavator bucket design or similar technique may be used. This simple methodology minimizes the mixing of contaminated soils with acceptable lower soil layers as would occur with a toothed excavator bucket.

Remediation of soils will be performed using established excavation safety and environmental control procedures. Operational constraints and dust control will be addressed in site excavation and soil control procedures. In addition, work package instructions for remediation of soil may include additional constraints and mitigation or control methods to ensure adequate erosion, sediment, and air emission controls during soil remediation.

4.3. Remediation Activities Impact on the Radiation Protection Program

The Radiation Protection Program approved for decommissioning at LACBWR is similar to the regulatory approved program that was implemented during commercial power operation and the subsequent SAFSTOR period. During these periods, in a manner similar to remediation activities during decommissioning, contaminated structures, systems and components were decontaminated in order to perform maintenance or repair actions.

The current approved Radiation Protection Program at LACBWR is adequate to comply with all federal and state regulatory requirements for the protection of occupational personnel from radiological hazards encountered or expected to be encountered during the decommissioning of a single unit commercial reactor facility. In addition, the program ensures the protection of the public from radiological hazards and ensures occupational, effluent and environmental dose from exposure to radioactive materials is, and remains ALARA. To ensure that adequate and proper engineering controls and hazard mitigation techniques are employed, work control programs and procedural requirements allow radiation protection personnel to integrate radiation protection and radiological hazard mitigation measures directly into the work planning and scheduling process. Consequently, the necessary radiological controls are correctly implemented to accommodate each remediation technology as appropriate.

The spread of loose surface contamination is mitigated by the routine remediation of work areas by washing and wiping. Water washing with a detergent is effective in reducing low levels of loose surface contamination over large surface areas. Wiping with detergent soaked or oil-impregnated media is an effective technique to reduce loose surface contamination on small items, overhead spaces and small hand tools. These same techniques are also effective in reducing low levels of surface contamination on structural surfaces.

For intermediate levels of surface contamination, more aggressive methods such as pressure washing, high-pressure water blasting and grit blasting may be more appropriate. Pipes, surfaces and drain lines can be cleaned and hot spots removed using these techniques and technologies. Small tools, hoses and cables can also be pressure washed in a containment to reduce contamination levels. A paint coating may be applied after surface cleaning to prevent surface contamination from drying out and becoming airborne. To mitigate high levels of fixed surface contamination embedded in concrete, scabbling or other surface removal techniques may be appropriate.

The Radiation Protection Program approved for decommissioning is similar to the program in place during commercial power operation. During power operations, contaminated structures, systems and components were decontaminated in order to perform maintenance or repair actions. These techniques are the same or similar to the radiological controls implemented at LACBWR for the decommissioning to reduce personnel exposure to radiation and contamination and to prevent the spread of contamination from established contaminated areas. The current Radiation Protection Program provides adequate controls for these actions.

Decommissioning does not present any new challenge to the Radiation Protection Program above those encountered during recent maintenance activities, such as the removal of the resins and sludges from plant systems. Decommissioning planning allows radiation protection personnel to focus on each area of the site and plan each activity well before execution of the remediation technique.

The decommissioning organization is experienced in and capable of applying these remediation techniques on contaminated systems, structures or components during decommissioning. The Radiation Protection Program is adequate to safely control the radiological aspects of this work.

The activities expected during decommissioning are the same or similar to those encountered during operations, as described above. Therefore, the approval of any changes to the existing approved Radiation Protection Program is not requested in this LTP.

4.4. ALARA Evaluation

Guidance for conducting ALARA analyses is provided in Appendix N of NUREG-1757, 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.

Section N.1.5 of NUREG-1757 states that *"For residual radioactivity in soil at sites that may have unrestricted release, generic analyses show that shipping soil to a low-level waste disposal facility is unlikely to be cost effective for unrestricted release, largely because of the high costs of waste disposal. Therefore shipping soil to a low-level waste disposal facility generally does not have to be evaluated for unrestricted release."* To illustrate that this is a reasonable approach and applicable to LACBWR, a simple ALARA analysis for the excavation and disposal of soils as low-level radioactive waste is provided in section 4.4.1.

For the subsurface structures that will remain at license termination, the ALARA analysis will determine whether further concrete remediation is necessary by comparing the desired beneficial effects to the undesired costs. Benefits are the averted collective radiation dose (converted into dollars) following the removal of radioactivity. The costs of remediation include transportation accidents, worker and public dose associated with remedial action (converted into dollars), and the actual costs to perform the remediation. If the costs exceed the benefits, then the dose reduction achieved by further remediation is not ALARA. The methods and results of the ALARA evaluation for concrete remediation in below grade structures is provided in section 4.4.2.

The ALARA criterion specified in 10 CFR 20.1402 is not met by solely performing remediation. The ALARA analysis is a planning tool to justify that further remediation is not necessary. When remediation is performed, there is no need to analyze whether the action was necessary to meet the ALARA requirement. For example, the remediation required to meet the open air demolition criteria specified in Reference (5), including cleaning loose surface contamination to concentrations below 1,000 dpm/100cm^2 and the remediation of concrete surfaces to meet the 2 mR/h exposure rate criteria, will be performed regardless of the outcome of the ALARA evaluation.

4.4.1. ALARA Analysis of Soil Remediation

The soil $DCGL_w$ that will be used to demonstrate compliance with the 25 mrem/yr dose criterion are provided in Table 5-5 of Chapter 5. Characterization survey results and historical survey data indicate that there is minimal residual radioactivity in soil at LACBWR. Throughout the course of the decommissioning and through to site closure, LACBWR will continue to survey and characterize soils as they are exposed by excavation during building demolition or made accessible by the removal of structures or components. If residual radioactivity is discovered at concentrations greater than the $DCGL_{EMC}$ in surface or subsurface soils, LACBWR will excavate, package and dispose of the soil as Low-Level Radioactive Waste (LLRW).

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.

Based upon a simple ALARA analysis, the only benefit of reducing residual radioactivity in soil is the monetary value of the collective averted dose to future occupants of the site. For soils, the averted dose is based upon the "industrial use" scenario.

4.4.1.1. 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;

Equation 4-1

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

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;

Equation 4-2

$$PW(AD_{Collective}) = (P_D)(A)(0.025)(F)\left(\frac{Conc}{DCGL_w}\right)\left(\frac{1-e^{-(r+\lambda)N}}{r+\lambda}\right)$$

where:

P_D = population density for the critical group scenario in people/m^2,

A = area being evaluated in square meters (m^2),

0.025 = annual dose to an AMCG from residual radioactivity at the $DCGL_w$ concentration 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 (pCi/g),

$DCGL_w$	=	derived concentration equivalent to the average concentration of residual radioactivity that would give a dose of 25 mrem/yr to the AMCG (pCi/g),
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.

4.4.1.2. 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* (8))
- Population density (P_D) for the critical group (persons/m^2) - 0.01 person/m^2 for land in industrial reuse scenario (per NUREG-1496, *Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities*, Volume 2 (9), 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) – 7,500 m^2 (size of reference area that was evaluated)

4.4.1.3. 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:

Equation 4-3

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

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

4.4.1.4. Calculation of Total Cost for Soil Remediation by Excavation and Disposal

For the analysis of soil excavation and disposal as low-level radioactive waste, the variables for $Cost_{R}$, $Cost_{ACC}$, $Cost_{WDose}$ *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.

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

The cost of waste transport and disposal ($Cost_{WD}$) was calculated using Equation N-4 of NUREG-1757, Appendix N which is expressed as follows:

Equation 4-4

$$Cost_{WD} = V_A \times Cost_V$$

where:

V_A	=	volume of waste produced, remediated in units of m^3;
$Cost_V$	=	cost of waste disposal per unit volume, including transportation cost, in units of $\$/m^3$.

Disposal costs for generated 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 LACBWR site to Clive, Utah (Energy*Solutions* radioactive waste disposal facility). The details of the average total disposal cost ($Cost_V$) of $\$2,500/m^3$ of waste are considered proprietary values defined by negotiated contract.

The volume of waste produced by remediation (V_A) assumes that the reference area of 7,500 m^2 (A) is remediated to a depth of 0.15 meters. This results in a value for waste volume (V_A) of 1,500 m^3, which produces a value for $Cost_{WD}$ of $2,812,500.00.

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

The cost of traffic fatalities incurred during the transportation of waste ($Cost_{TF}$) was calculated using Equation N-6 of NUREG-1757, Appendix N which is expressed as follows:

Equation 4-5

$$Cost_{TF}=\$3{,}000{,}000 \times \frac{V_A}{V_{SHIP}} \times F_T \times D_T$$

where:

\$3,000,000	=	monetary value of a fatality equivalent to \$2,000/person-rem (NUREG-1530 *Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy* (10))
V_A	=	volume of waste produced in units of m^3;
V_{SHIP}	=	volume of a truck shipment in m^3;
F_T	=	fatality rate per truck-kilometer traveled in units of fatalities/truck-km;
D_T	=	distance traveled in km.

For this evaluation, the waste volume (V_A) is assumed to be 1,125 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, 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 LACBWR site by highway is 1,348 miles (2,169 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 2,169 km (D_T) was used for the calculation of $Cost_{TF}$. For this evaluation, the value for the $Cost_{TF}$ variable is \$20,453.99.

4.4.1.4.3. Total Cost ($Cost_T$)

The total cost, ($Cost_T$) assumed for this evaluation is \$2,832,953.99.

4.4.1.5. <u>Residual Radioactivity in Soils that are ALARA</u>

Determination of residual radioactivity in soils 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;

Equation 4-6

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

Assuming the following values for the remaining variables;

- the parameter values from section 4.4.1.2,
- a value of one for remediation effectiveness (F), assuming all residual radioactivity is removed during the excavation,

- a soil $DCGL_w$ of 48.3 pCi/gm for Cs-137 from Table 5-5 of Chapter 5,

Equation 4-7

$$\frac{Conc}{DCGL_w} = \frac{(\$2{,}832{,}953.99)\left(0.00 + \frac{0.693}{30.17}\right)}{(\$2{,}000)(0.01)(0.025)(1)(7{,}500)\left(1 - e^{-\left(0.00+\frac{0.693}{30.17}\right)1{,}000}\right)}$$

the ratio of the concentration to the $DCGL_w$ when the total cost ($Cost_T$) is equal to the dose averted is 17.35.

Assuming a concentration set at 50% of the $DCGL_w$ (based on the investigation level for a Class 3 area), the present worth of future collective averted dose $PW(AD_{Collective})$ can be calculated as follows;

Equation 4-8

$$PW(AD_{Collective}) = (0.01)(7{,}500)(0.025)(1)\left(\frac{24.15}{48.3}\right)\left(\frac{1 - e^{-\left(0.00+\frac{0.693}{30.17}\right)(1{,}000)}}{0.00 + \frac{0.693}{30.17}}\right)$$

resulting in a value for $PW(AD_{Collective})$ of 40.81 person rems. The benefit from collective averted dose (B_{AD}) is then calculated as follows;

Equation 4-9

$$B_{AD} = \$2{,}000 \times 40.81 = \$81{,}628.79$$

This simple analysis confirms the statement in section N.1.5 of NUREG-1757 that the cost of disposing excavated soil as low-level radioactive waste is clearly greater than the benefit of removing and disposing of soil with residual radioactivity concentrations less than the dose criterion. Since the cost is greater than the benefit, it is not ALARA to excavate and dispose of soils with residual radioactivity concentrations below the $DCGL_w$.

4.4.2. ALARA Analysis for Remediation of Basement Structures

With the exception of some buried piping, all contaminated and non-contaminated systems will be disassembled, removed, packaged and shipped off-site as a waste stream commodity. Once commodity removal is complete, structural surfaces will be remediated as necessary to meet the open-air demolition criteria specified in RS-TD-313196-005. These criteria provide the removable contamination levels and contact exposure rates that will allow structures to be safely demolished without containment. Prior to demolition, a contamination verification survey (CVS) will be performed to identify areas requiring remediation to meet the open-air demolition limits. Additionally, a Radiological Assessment (RA) will also be performed to identify areas on surfaces to remain at license termination (i.e., at least three feet below grade) that could potentially result in a FSS measurement (using ISOCS) to exceed the Operational DCGLs ($OpDCGL_B$) listed in LTP Chapter 5, Table 5-4. The dose rate target for this objective will be lower than that required for open-air demolition. Identified areas will be remediated to provide high confidence that no FSS ISOCS measurement will exceed the $OpDCGL_B$. After remediation is complete, above grade structural surfaces and non-load-bearing interior concrete walls below the 636 foot elevation will be demolished, reduced in size, packaged and shipped off-site to a licensed disposal facility.

The below grade impacted end state structures consist of the Reactor Building and WGTV basement structures located below the 636 foot elevation.

All concrete inside the steel liner will be removed from the interior of the Reactor Building prior to demolition. This includes all activated and contaminated concrete. The source term in the Reactor Building basement remaining after demolition will be low levels of surface contamination on the exposed liner surfaces. It is also assumed that contaminated concrete that would exceed the $OPDCGL_B$, as measured by ISOCS during FSS, will be removed from the interior of the WGTV prior to demolition. The remaining source terms in the Reactor Building and WGTV survey units after demolition are expected to be at levels corresponding to a dose at license termination that is well below the 25 mrem/yr criteria.

An ALARA analysis was performed for each of the two basement survey units (Reactor Building and WGTV) and is summarized in Table 4-4. The ALARA analysis of the WGTV will bound the ALARA analyses for the Reactor Building because it is comprised of the smallest surface area which minimizes remediation costs. Therefore, the WGTV is used as an example for the calculation of remediation cost in the discussion of the ALARA calculation methods below. However, building specific remediation costs are also calculated for the Reactor Building survey unit). The results of the ALARA analysis calculations for both basements are presented in Table 4-4.

4.4.2.1. ALARA Analysis Equation

The ALARA analyses for the remediation of basement structures uses Equation 4-6 from section 4.4.1.5. The DCGLs for concrete are expressed in units of pCi/m^2.

The calculation of dose averted in Equation 4-10 is modified to account for the presence of multiple radionuclides. The denominator must be summed and the individual dose contributions normalized to account for the multiple radionuclides that are present in the radionuclide distribution. The equation from NUREG-1757 therefore becomes:

Equation 4-10

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

where:

f_i = the mixture fraction for each individual Radionuclide of Concern (ROC) normalized to one.

$DOSE_{AMCG}$ = averted dose to the AMCG (Rem).

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 dose criterion and are

ALARA. Values less than one provide the fraction of the dose criterion where it is necessary to remediate to achieve ALARA.

4.4.2.2. Remedial Action Costs

The only structures that will remain as potential candidate surfaces for remediation are the concrete walls and floors from the Reactor Building and WGTV. With the exception of some sections of buried pipe, all impacted systems and components, as well as all Class 1 structures above the 636 foot elevation, will be removed during the decommissioning process and disposed of as a waste stream. Several Class 2 and Class 3 above grade structures, including the LACBWR Administration Building, G-3 Crib House and LACBWR Crib House will remain in place but are expected to contain negligible, if any, residual contamination.

As previously discussed, all structures will be remediated to provide high confidence that ISOCS measurements during FSS will not exceed the $DCGL_B$ from Table 5-3. The remediation approach for this action will likely be through the use of large hydraulic breaking tools to scabble concrete surfaces. As these efforts will occur prior to evaluating the remaining structural surfaces for acceptable concentrations of residual activity, this remediation action will not be evaluated for ALARA.

The ALARA analysis assumes that the remediation of basement structures is by scabbling the concrete surfaces. Based on LACBWR concrete core data described in Energy*Solutions* TSD RS-TD-313196-001, *Radionuclides of Concern During LACBWR Decommissioning* (11), it is anticipated that the majority of the radionuclide source inventory in the floor resides within the first ½-inch of concrete. For the purposes of the ALARA evaluation, it is conservatively assumed that 100% of the contamination resides in the first ½ inch. In accordance with the guidance in section G.3.1 of NUREG/CR-5884, one pass of scabbling is assumed to remove 0.125 inches (0.635 cm) of concrete. The basement floor surface areas used in the calculation are listed in Energy*Solutions* TSD RS-TD-313196-002, *La Crosse End State Basement Concrete Surface Areas, Volumes, and Void Spaces* (12).

4.4.2.2.1. Remediation Activity Rates

The remediation activity rates that were used for this evaluation were based on previous experience, from published literature, or from groups or vendors currently performing these or similar activities. Current project labor costs and past operational experience were also used in developing these rates.

In accordance with NUREG/CR-5884, an assumed crew size for performing concrete scabbling or shaving activities is three full-time laborers, a supervisor at a ¼-time involvement and a Radiation Protection Technician (RPT), also at a ¼-time involvement. Using the current project labor rates for these positions of $66.78 per hour for a laborer, $90.00 per hour for a supervisor and $55.59 per hour for a RPT, the hourly unit rate that will be used for the evaluation is $236.74.

Using the guidance found in NUREG/CR-5884 it is assumed that the concrete scabbling or shaving activity will remove approximately 0.125 inches of concrete per pass and the effective nominal removal rate is approximately 130 ft^2 or 12.08 m^2 per hour. The ALARA evaluation assumes that 100% of the radioactive contamination resides within the first ½ inch.

Consequently, using the WGTV as an example, removing ½ inch of concrete over an assumed surface area of 71.26 m^2, scabbling at a nominal rate of 12.08 m^2 per hour to a depth of 0.125 inch per pass, equates to approximately 23.59 man-hours of work.

Also in accordance with NUREG/CR-5884 it is assumed that the actual remediation time in a typical eight-hour shift is 5.33 hours. To account for non-remediation work hours for work preparation, donning and removing protective clothing and work breaks, the total man-hours were increased by a factor of 33% which equates to an additional 7.79 man-hours. In addition, a contingency of 25% was added to the manpower hours. This equates to a total of 39.23 man-hours for the WGTV, which is multiplied times the hourly unit rate of $236.74 to equal the labor cost for this evaluation of $9,286.39.

4.4.2.2.2. Equipment Costs

Using the guidance found in NUREG/CR-5884 equipment costs are based on the rental of commercially available scabbling equipment, a compressor, a vacuum unit and consumables such as cutting bits, vacuum filters and waste drums for containing waste debris. At 40-hours per work week, the 39.23 man-hours in the WGTV example equates to approximately 1 work-week. This evaluation assumes that two different commercially available concrete removal units will be procured, the Pentek Squirrel Scabbler & Vacuum System with a nominal rental rate of $685.00 per week and a Pentek Moose Scabbler & Vacuum System with a nominal rental rate of $950.00 per week. The compressor required for pneumatic equipment operation can be rented at a nominal rate of $115.00 per week. The cutting bits for the units are assumed to be replaced every 80 hours of operation, for an equivalent cost of about $13.00 per hour of operation. Additional costs include filter replacements at about $2.50 per hour of operation and waste drums for the collected debris. A 55-gallon drum holds approximately 7 ft^3 of waste and cost approximately $100.00 per drum. As it is assumed that the scabbing activity will generate approximately 31.96 ft^3 (0.90 m^3) of concrete waste, this will require the procurement of approximately 5 drums at a total cost of $500. The mobilization and demobilization costs associated with procuring this equipment would be approximately $2,200.00 per piece of equipment for a total of approximately $6,600.00. The total equipment costs assumed for this evaluation is approximately $9,470.00.

4.4.2.2.3. Total Remediation Action Cost ($Cost_R$)

For the evaluation of the remediation activity of concrete scabbling or shaving, the sum of the labor cost of $9,286.39 plus the equipment cost of $9,470.00 results in a total remediation action cost ($Cost_R$) for this activity of $18,756.39 for the WGTV.

4.4.2.3. <u>Transport and Disposal of the Waste ($Cost_{WD}$)</u>

As previously described in section 4.4.1.4.1, the cost of waste transport and disposal ($Cost_{WD}$) is expressed as follows:

Equation 4-11

$$Cost_{WD} = V_A \times Cost_V$$

Disposal costs for generated 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 Genoa, Wisconsin to Clive, Utah (Energy*Solutions* radioactive waste disposal facility). Based upon an assumed waste volume of 0.90 m^3 for the WGTV, a value of $ $2,262.41 is calculated for the $Cost_{WD}$ variable.

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

The cost of non-radiological workplace accidents ($Cost_{ACC}$) was calculated using Equation N-5 of NUREG-1757, Appendix N which is expressed as follows:

Equation 4-12

$$Cost_{ACC} = \$3{,}000{,}000.00 \times F_W \times T_A$$

where:

$3,000,000	=	monetary value of a fatality equivalent to $2000/person-rem (NUREG-1530)
F_W	=	workplace fatality rate in fatalities/hour worked;
T_A	=	worker time required for remediation in units of worker-hours.

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 (39.23 man-hours) was used for worker accident cost. Subsequently, a value of $4.94 is calculated for the $Cost_{ACC}$ variable.

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

As previously described in section 4.4.1.4.2, the cost of traffic fatalities incurred during the transportation of waste ($Cost_{TF}$) is expressed as follows:

Equation 4-13

$$Cost_{TF} = \$3{,}000{,}000.00 \times \frac{V_A}{V_{SHIP}} \times F_T \times D_T$$

For this evaluation, the waste volume (V_A) is assumed to be 0.90 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 Genoa, Wisconsin by highway is 1,348 miles (2,169 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 2,169 km (D_T) was used for the calculation of $Cost_{TF}$. For this evaluation, the value for the $Cost_{TF}$ variable is $16.45 .

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

The cost of remediation worker dose ($Cost_{WDose}$) was calculated using Equation N-7 of NUREG-1757, Appendix N which is expressed as follows:

Equation 4-14

$$Cost_{WDose} = \$2{,}000.00 \times D_R \times T$$

where:

D_R = total effective dose equivalent (TEDE) rate to remediation workers in units of Rem/hr;

T = time worked (site labor) to remediate the area in units of person-hour.

Costs associated with worker dose are a function of the hours worked and the workers' radiation exposure for the task. A value of 3 mrem per man-hour was used for D_R. This assumes that a majority of the source inventory will be removed prior to performing the concrete scabbling or shaving activity. The time worked to remediate the area in units of person-hour calculated for this activity (T) was 39.23 man-hours. For this evaluation, the value for the $Cost_{WDose}$ variable is $235.36 .

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

The cost of remediation worker dose ($Cost_{PDose}$) was calculated using Equation N-7 of NUREG-1757, Appendix N which is expressed as follows:

Equation 4-15

$$Cost_{PDose} = \$2{,}000.00 \times D_R \times T$$

where:

D_R = total effective dose equivalent (TEDE) rate to public in units of Rem/hr;

T = time spent near waste shipments in parking lots in units of person-hour.

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 Low Specific Activity (LSA) in accordance with 49 CFR 173.427 and the package meets an 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 22 hours driving from Genoa, Wisconsin to the disposal site in Clive Utah. For this evaluation, the value for the $Cost_{PDose}$ variable is $22.00.

4.4.2.8. Total Cost ($Cost_T$)

The total cost, ($Cost_T$) assumed for the ALARA evaluation of the WGTV is $21,297.55. The same approach is used to determine the $Cost_T$ variable for the ALARA evaluation of the Reactor Building which is $80,964.12.

4.4.2.9. Residual Radioactivity in Basement Structures that are ALARA

The following parameters were used for performing the ALARA calculation using the equation from NUREG-1757 and presented in section 4.4.2.1:

- Population density (P_D) for the critical group (persons/m^2) - 0.01 person/m^2 for soil in industrial use scenario (per NUREG-1496, Appendix B, Table A.1).
- Fraction of residual radioactivity removed by the remedial action (*F*) – 1 (Removal of desired concrete volume is assumed 100% effective).
- Area (*A*) used to calculate the population density (m^2)
  - Groundwater scenario – 7,500 m^2 which is the assumed contaminated area in the dose model (see LTP Chapter 6),
  - Drilling Spoils scenario – 100 m^2 is assumed in order to allow the calculation to generate a population of 1 person exposed to drilling spoils. The actual surface area of the drilling spoils is much smaller at 0.46 m^2 (see LTP Chapter 6),
  - Excavation scenario – the volume of concrete for each basement from Table 4-1 spread over a 1 meter lift (see LTP Chapter 6).
- Monetary discount rate (*r*) - 0.00 yr^{-1} for soils.
- Number of years (*N*) over which the collective averted dose is calculated (yr) - 1,000 yrs (per Table N.2 of Appendix N of NUREG-1757).

Table 4-1 Volume of Concrete in Basement Structures[a]

Basement	Concrete Volume (m^3)
Reactor Building	538.63
WGTV	121.91

(a) Volumes from Reference (13), Energy*Solutions* TSD RS-TD-313196-004 *LACBWR Soil DCGL, Basement Concrete DCGL and Buried Pipe DCGL* (13).

4.4.2.9.1. Radionuclides Considered for ALARA Analysis

The ALARA analysis was conducted for both basements. The values for half-life, radiological decay constants (λ) and the radionuclide mixture fractions for contaminated concrete developed in TSD RS-TD-313196-001 are presented in Table 4-2.

The ALARA calculation was performed in three parts for each basement, the first representing the BFM Groundwater scenario, the second representing the BFM Drilling Spoils scenario and the third representing the BFM Excavation scenario. Three dose values were required to accurately calculate the averted dose because the compliance dose is based on the sum of all three scenarios. This results in a maximum compliance dose that is driven primarily by the BFM Excavation scenario. In addition, each scenario is applicable to a different area. The BFM Groundwater dose applies to the full 7500 m^2 site area, the BFM Drilling Spoils dose applies only to the area of material brought to the surface by the well drilling action and the BFM

Excavation dose applies only to the basement-specific area of concrete on the ground surface after excavation.

Table 4-2 Radionuclide Half-Life(s) and Decay Constant(s)

Radionuclide [a]	Half-Life (yrs)	λ (yr^{-})
Co-60	5.27 E 00	1.31 E-01
Sr-90	2.91 E+01	2.38 E-02
Cs-137	3.00 E+01	2.31 E-02
Eu-152	1.35E+01	5.12E-02
Eu-154	8.80E+00	7.88E-02

(a) Dose significant ROC in accordance with TSD RS-TD-313196-001.

The actual dose from each scenario, assuming a summation of the dose from each scenario equaled 25 mrem/yr is presented in Table 4-3. Therefore, the dose values for each ROC from Table 4-3 were used to derive the AMCG ($DOSE_{AMCG}$) variable in Equation 4-10 for each scenario in each basement.

Table 4-3 Dose for Individual Scenarios ($DOSE_{AMCG}$)

	Reactor Building (mrem/yr)			WGTV (mrem/yr)		
	GW	DS	EX	GW	DS	EX
Co-60	1.07	0.27	23.67	1.65	0.27	23.14
Sr-90	24.83	0.00	0.13	24.92	0.00	0.07
Cs-137	2.74	0.28	21.96	2.89	0.28	21.89
Eu-152	0.11	0.30	24.59	0.11	0.30	24.62
Eu-154	0.15	0.29	24.55	0.14	0.29	24.59

4.4.2.9.2. ALARA Calculation

The ALARA calculations performed to evaluate the concrete scabbling or shaving remediation activities are presented in Table 4-4. A result for the Conc/DCGL ratio that is less than one would justify remediation whereas a result greater than one would demonstrate that residual radioactivity is ALARA. The lowest Conc/DCGL ratio was calculated for the Excavation scenario in the WGTV at 1.33.

4.4.2.10. Conclusion

Concrete structural surfaces (and the steel liner in the Reactor Building) below the 636 foot elevation will remain in place after license termination. The site dose contribution from remaining residual radioactivity remaining in these buried plant structures will be accounted for by the BFM. The ALARA analysis based on cost benefit analysis shows that further remediation of concrete beyond that required to demonstrate compliance with the 25 mrem/yr dose criterion is not justified.

Table 4-4 ALARA Analysis for Volumetrically Contaminated Subsurface Structures

Reactor Building **Cost (in dollars) of remedial action (*$Cost_T$*) = $80,964.12**

Summation of Insitu Scenarios (Groundwater + Drilling Spoils)

Groundwater Scenario (Groundwater Scenario)

A = 7,500 m^2, r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 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(1)	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	$DCGL_{GW}$	(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	7.41%	1.21E+08	8.97E+06	4.87E-02	$59.24	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	12.30%	1.46E+07	1.80E+06	9.76E-03	$1,525.72	
Cs-137	3.02E+01	2.30E-02	2.30E-02	2.30E+01	1.06E-10	1.00E+00	4.35E+01	79.60%	1.98E+08	1.58E+08	8.56E-01	$15,319.89	
Eu-152	1.35E+01	5.12E-02	5.12E-02	5.12E+01	5.85E-23	1.00E+00	1.95E+01	0.30%	2.73E+09	8.11E+06	4.40E-02	$14.06	
Eu-154	8.80E+00	7.88E-02	7.88E-02	7.88E+01	6.30E-35	1.00E+00	1.27E+01	0.40%	1.88E+09	7.60E+06	4.13E-02	$11.50	
							Check Sum	100%	Sum	1.84E+08	1.00E+00	$16,930.40	$\sum(Cost_B)$

Drilling Spoils Scenario A = 100.00 m^2 (2), r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 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(1)	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	$DCGL_{DS}$	(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	7.41%	4.75E+08	3.52E+07	1.01E-03	$ 0.00	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	12.30%	2.70E+11	3.32E+10	9.54E-01	$0.11	
Cs-137	3.02E+01	2.30E-02	2.30E-02	2.30E+01	1.06E-10	1.00E+00	4.35E+01	79.60%	1.94E+09	1.54E+09	4.44E-02	$1.08	
Eu-152	1.35E+01	5.12E-02	5.12E-02	5.12E+01	5.85E-23	1.00E+00	1.95E+01	0.30%	1.00E+09	2.97E+06	8.54E-05	$0.00	
Eu-154	8.80E+00	7.88E-02	7.88E-02	7.88E+01	6.30E-35	1.00E+00	1.27E+01	0.40%	9.43E+08	3.81E+06	1.09E-04	$0.00	
							Check Sum	100%	Sum	3.48E+10	1.00E+00	$1.19	$\sum(Cost_B)$

Summation of Insitu Cost Benefit (Groundwater + Drilling Spoils)

Conc/ DCGL (A result < 1 would justify remediation whereas a result > 1 would demonstrate that residual radioactivity is ALARA) **4.78**

Excavation Scenario A = 538.63 m^2, r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 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(1)	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	$DCGL_{EX}$	(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	7.41%	5.45E+06	4.04E+05	1.11E-03	$2.15	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	12.30%	2.80E+09	3.44E+08	9.45E-01	$55.33	
Cs-137	3.02E+01	2.30E-02	2.30E-02	2.30E+01	1.06E-10	1.00E+00	4.35E+01	79.60%	2.47E+07	1.97E+07	5.39E-02	$555.55	
Eu-152	1.35E+01	5.12E-02	5.12E-02	5.12E+01	5.85E-23	1.00E+00	1.95E+01	0.30%	1.21E+07	3.59E+04	9.86E-05	$0.51	
Eu-154	8.80E+00	7.88E-02	7.88E-02	7.88E+01	6.30E-35	1.00E+00	1.27E+01	0.40%	1.12E+07	4.52E+04	1.24E-04	$0.42	
							Check Sum	100%	Sum	3.65E+08	1.00E+00	$613.95	$\sum(Cost_B)$

Conc/ DCGL (A result < 1 would justify remediation whereas a result > 1 would demonstrate that residual radioactivity is ALARA) **131.87**

Table 4-4 (continued) ALARA Analysis for Volumetrically Contaminated Subsurface Structures

WGTV **Cost (in dollars) of remedial action ($Cost_T$) = $21,297.55**

Summation of Insitu Scenarios (Groundwater + Drilling Spoils)

Groundwater Scenario A = 7,500 m^2, r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 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[(1)]	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	$DCGL_{GW}$	(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	1.01E-02	6.23E+07	6.29E+05	3.63E-03	$6.81	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	1.94E-02	6.42E+06	1.25E+05	7.18E-04	$112.76	
Cs-137	3.02E+01	2.30E-02	2.30E-02	2.30E+01	1.06E-10	1.00E+00	4.35E+01	9.57E-01	1.52E+08	1.45E+08	8.39E-01	$15,859.48	
Eu-152	1.35E+01	5.12E-02	5.12E-02	5.12E+01	5.85E-23	1.00E+00	1.95E+01	9.56E-03	2.28E+09	2.18E+07	1.26E-01	$39.14	
Eu-154	8.80E+00	7.88E-02	7.88E-02	7.88E+01	6.30E-35	1.00E+00	1.27E+01	3.42E-03	1.57E+09	5.37E+06	3.10E-02	$8.43	
							Check Sum	100%	Sum	1.73E+08	1.00E+00	$16,026.62	∑(Cost$_B$)

Drilling Spoils Scenario A = 100.00 m$^{2\,(2)}$, r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 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[(1)]	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	$DCGL_{DS}$	(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	1.01%	3.86E+08	3.90E+06	6.73E-04	$0.00	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	1.94%	2.20E+11	4.27E+09	7.37E-01	$0.04	
Cs-137	3.02E+01	2.30E-02	2.30E-02	2.30E+01	1.06E-10	1.00E+00	4.35E+01	95.70%	1.58E+09	1.51E+09	2.61E-01	$6.33	
Eu-152	1.35E+01	5.12E-02	5.12E-02	5.12E+01	5.85E-23	1.00E+00	1.95E+01	0.96%	8.16E+08	7.80E+06	1.35E-03	$0.02	
Eu-154	8.80E+00	7.88E-02	7.88E-02	7.88E+01	6.30E-35	1.00E+00	1.27E+01	0.34%	7.67E+08	2.62E+06	4.53E-04	$0.00	
							Check Sum	100%	Sum	5.79E+09	1.00E+00	$ 6.39	∑(Cost$_B$)

Summation of Insitu Cost Benefit (Groundwater + Drilling Spoils)

Conc/ DCGL (A result < 1 would justify remediation whereas a result > 1 would demonstrate that residual radioactivity is ALARA) **1.33**

Excavation Scenario A = 121.91 m^2, r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 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[(1)]	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	$DCGL_{EX}$	(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	1.01E-02	4.43E+06	4.47E+04	7.03E-04	$0.30	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	1.94E-02	2.28E+09	4.42E+07	6.95E-01	$4.99	
Cs-137	3.02E+01	2.30E-02	2.30E-02	2.30E+01	1.06E-10	1.00E+00	4.35E+01	9.57E-01	2.01E+07	1.92E+07	3.02E-01	$702.36	
Eu-152	1.35E+01	5.12E-02	5.12E-02	5.12E+01	5.85E-23	1.00E+00	1.95E+01	9.56E-03	9.84E+06	9.41E+04	1.48E-03	$1.73	
Eu-154	8.80E+00	7.88E-02	7.88E-02	7.88E+01	6.30E-35	1.00E+00	1.27E+01	3.42E-03	9.12E+06	3.12E+04	4.90E-04	$0.37	
							Check Sum	100%	Sum	6.36E+07	1.00E+00	$709.76	∑(Cost$_B$)

Conc/ DCGL (A result < 1 would justify remediation whereas a result > 1 would demonstrate that residual radioactivity is ALARA) **30.01**

(1) DCGLs taken from Table 5-4 from Chapter 5, (2) Actual drilling spoils area 0.457 m2, 100 m2 used in calculation to ensure 1 person exposed

4.5. References

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