Appendix 4A
ALARA Evaluations

4A.1 Determining ALARA Action Levels

Per Appendix N of NUREG-1757, the residual radioactivity level that is as low as reasonably achievable, or ALARA, is the concentration, Conc, at which the benefit from additional clean-up exceeds the cost of that clean-up. If the total clean-up cost, $Cost_T$, is set equal to the present worth of the collective doses averted, the ratio of the concentration (Conc) to the $DCGL_W$ is as follows:

$$AL = \frac{Conc}{DCGL_w} = \frac{Cost_T}{\$2000 \times PD \times 0.025 \times F \times A} \times \frac{r+\lambda}{1-e^{-(r+\lambda)N}} \quad \text{(Equation 4A-1)}$$

Where

AL	=	ALARA action level, as a fraction of $DCGL_W$
Conc	=	Average concentration of residual activity in the area being evaluated
DCGLw	=	Derived concentration guideline equivalent to the average concentration of residual radioactivity that would give a dose of 25 mrem/yr to the average member of the critical group
$Cost_T$	=	Total cost of clean-up action, in dollars
$2000	=	Monetary value of one person-rem averted (NUREG-1757, Appendix N, Table N.2)
PD	=	Population density for critical group scenario, people/m^2
0.025	=	Annual dose to average member of critical group from residual radioactivity at DGCLW concentration, rem/yr
A	=	Area being evaluated, m^2
F	=	Removable fraction for clean-up action being evaluated
r	=	Monetary discount rate, yr^{-1}
λ	=	Radiological decay constant, yr^{-1}
N	=	Number of years over which the collective dose is calculated

Acceptable values for population density (PD), monetary discount rate (r), and the number of years over which the collective dose is calculated (N) are given in NUREG -1757, Appendix N, Table N.2 and are provided in Table 4A-1

Table 4A-1

Parameter Values for Use in ALARA Analyses

Parameter	Acceptable Value	
	Building	**Land**
PD	0.09 person/m^2	0.0004 person/m^2
R	0.07 per year	0.03 per year
N	70 years	1000 years

The development of values for the equation parameters of total Cost ($Cost_T$), and removable fraction for remediation action being evaluated, F, are described in Sections 4.A.1.1 and 4.A.1.2. Where values other than those in the table above or in Section 4.2.3 are used, justification is provided.

4.A.1.1 Calculation of Total Cost

Calculations of total cost generally include the monetary costs of:

- The clean-up action being evaluated ($Cost_R$)
- Transportation and disposal of wastes generated ($Cost_{WD}$)
- Workplace accidents that occur because of the clean-up action ($Cost_{ACC}$)
- Traffic fatalities resulting from transporting the waste generated by the action ($Cost_{TF}$)
- Doses received by workers performing the clean-up action ($Cost_{WDose}$)
- Doses to the public from excavation, transportation, and disposal of the waste ($Cost_{PDose}$)

Thus,

$Cost_T = Cost_R + Cost_{WD} + Cost_{ACC} + Cost_{TF} + Cost_{WDose} + Cost_{PDose}$ (Equation B-2)

Other monetary costs may be included as appropriate for the specific situation.

The cost of waste transport and disposal, $Cost_{WD}$, is calculated using the following equation:

$$Cost_{WD} = V_A \times Cost_V \qquad \text{(Equation 4A-3)}$$

Where

V_A = volume of waste produced, m^3
$Cost_V$ = cost of waste disposal, $/$m^3$

The cost of workplace accidents, $Cost_{ACC}$, is calculated using the following equation:

$$Cost_{ACC} = \$3{,}000{,}000 \times F_W \times T_A \qquad \text{(Equation 4A-4)}$$

Where

$3,000,000	=	Monetary value of a fatality equivalent to $2000 per person-rem (NUREG-1757, Appendix N)
F_W	=	Workplace fatality rate, in fatalities per hour worked, or 4.2×10^{-8}/hr (NUREG -1757, Appendix N)
T_A	=	Worker time required for clean-up, person-hours

The cost of traffic fatalities incurred during the shipment of waste, $Cost_{TF}$, is calculated using the following equation:

$$Cost_{TF} = \frac{\$3{,}000{,}000 \times V_A \times F_T \times D_T}{V_{ship}} \qquad \text{(Equation 4A-5)}$$

Where

$3,000,000	=	Monetary value of a fatality equivalent to $2000 per person-rem (NUREG-1757, Appendix n)
V_A	=	Volume of waste produced, m^3
F_T	=	Fatality rate per truck-kilometer traveled, in unites of fatalities per truck-kilometer or 3.8×10^{-8}/km (NUREG -1757, Appendix N, Table N.2)
D_T	=	Distance traveled, km
V_{ship}	=	Volume of waste shipped per truckload, or 13.6 m^3 from NUREG-1757, Appendix N, Table N.2

The cost of clean-up worker dose, $Cost_{WDose}$, is calculated using the following equation:

$$Cost_{WDose} = \$2000 \times D_R \times T_R \qquad \text{(Equation 4A-6)}$$

Where

$2,000	=	Dollars per person-rem from Appendix N, Table N.2)
D_R	=	Total effective dose equivalent to workers, rem/hr
T_R	=	Time worked to remediate area, person-hours

4.A.1.2 Determination of Clean-up Action Effectiveness

The clean-up action effectiveness, F, is the fraction of the residual radioactivity removed by the clean-up action. It is determined by collecting and analyzing pre- and post-clean-up measurements in the area in which the clean-up action is performed. A sufficient number of measurements are made to establish a consistent value.

4A.2 ALARA Evaluation

When dismantlement actions are completed, residual radioactivity may remain. 10CFR20.1402 requires assurance that residual radioactivity has been reduced to levels that are ALARA. For evaluations prior to additional clean-up actions, the ALARA analysis for data evaluation will be performed using data from operational Radiation Protection surveys in accordance with NUREG-1757 and will take into account:

- Radiation doses and environmental impacts for the decommissioning process and from the residual radiation remaining on site after the completion of decommissioning.

- Other costs and risks associated with the decontamination and decommissioning of the site.

Once the total cost, $Cost_T$, for a clean-up action has been calculated, an ALARA action level, expressed as a fraction of a $DCGL_W$, can be determined and the ALARA evaluation can be performed using the previously presented equations.

As discussed above this evaluation determines the point at which clean-up is cost beneficial and then compares existing residual radioactivity levels to that ALARA action level. When the residual radioactivity is in excess of the calculated ALARA action level, additional clean-up action is considered to be cost beneficial and should be taken. If residual activity is below the ALARA action level, the ALARA criterion is considered to be met already and no additional remedial action is required to be performed.

ALARA evaluations will be performed when justification is needed for not performing additional clean-up in an area. This is consistent with the recommendations provided in NUREG-1757. As appropriate, the final status survey report will appropriately document that all concentrations in the survey unit are below the ALARA action level. As previously discussed, if the decision to perform a given clean-up action has been made, then the activity does not require an ALARA justification.

The ALARA action levels calculated do not represent activity values that cannot be exceeded, as they only represent the threshold at which a clean-up action is cost beneficial. As previously noted, the ALARA criteria is met by performing the clean-up action, not by achieving results below a specific ALARA action level. An ALARA analysis ensures that the efforts to remove residual contamination are commensurate with the risk that exists with leaving the residual contamination in place.

4A.3 Example

The following example is one provided in NUREG -1757. The values for the cost of the clean-up activity and the clean-up action effectiveness are those presented in NUREG-1757. At the time that an actual ALARA evaluation is performed, site-specific costs and clean-up action effectiveness will be used.

The following example considers a building with residual Cs-137 radioactivity (λ=0.023/yr). The clean-up activity being evaluated is washing a floor of 100 m^2 area. The estimated total cost is $400 and may remove 20% (F = 0.2) of the residual radioactivity. Using these values in Equation 4A-1 gives:

$$AL = \frac{\$400}{\$2000 \times 0.09 \times 0.025 \times 0.2 \times 100\,\text{sq m}} \times \frac{0.07 + 0.023}{1 - e^{-(0.07+0.023)\times 70}}$$

AL = 0.41

Thus, the determination to perform the additional clean-up would be based on an AL of 0.41. If the residual radioactivity on the building floor is demonstrated to be less than 0.41 DCGL, then washing would not be necessary.