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Environmental Programs Directorate

Standard Operating Procedure

for

PERFORMING ALARA ANALYSIS FOR PUBLIC EXPOSURES

APPROVAL SIGNATURES:

Subject Matter Expert:	**Organization**	**Signature**	**Date**
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1.0 PURPOSE AND SCOPE

This standard operating procedure (SOP) states the responsibilities and describes the process for conducting and reporting "as low as reasonably achievable" (ALARA) analyses of public exposures to LANL-derived radioactive materials for the Los Alamos National Laboratory (LANL) and the Environmental Programs (EP) Directorate. This procedure integrates the institutional environmental ALARA policy outlined in "Los Alamos National Laboratory Environmental ALARA Program" report PD-410. All **EP Directorate participants and subcontractors** shall implement this procedure when performing ALARA assessments for public exposure.

Environmental ALARA analyses (quantitative or qualitative analyses as specified in PD-410) is required for investigation reports for individual solid waste management units/ areas of concern (SWMUs/AOCs), aggregate areas, and canyons, and remedy completion reports, as appropriate, and for land transfers by DOE, for the following types of sites:

- Parcels of US Department of Energy (DOE) land in the vicinity of or within LANL boundaries that *have been* transferred to:
    - The Incorporated County of Los Alamos, New Mexico, and to the Secretary of the Interior, in trust for the Pueblo of San Ildefonso as directed by Section 632 of Public Law 105-119 (Public Law 105-119); and
    - Private owners, the U.S. Forest Service, and the National Park Service.
- Parcels of DOE land in the vicinity of or within LANL boundaries that *will be* transferred to:
    - The Incorporated County of Los Alamos, New Mexico, and to the Secretary of the Interior, in trust for the Pueblo of San Ildefonso as directed by Section 632 of Public Law 105-119 (Public Law 105-119); and
    - Private owners, the US Forest Service, and the National Park Service.
- Those parcels of land in the vicinity of or within LANL boundaries that do not meet the land transfer criteria stated above, i.e., will remain within DOE ownership for the foreseeable future, but can be reasonably accessed by members of the public. Parcels of land with reasonable public access would include those locations that are not fenced off, are not access controlled by guard stations, or are not posted with signs that prohibit public access. These locations typically have established hiking trails on them or are otherwise easily accessed from public roads.

2.0 BACKGROUND AND PRECAUTIONS

2.1 Background

ALARA is not a dose limit but rather a philosophy that promotes keeping radiation doses to not only below federal guidelines, but to levels as low as reasonably achievable. ALARA is based on three components. The first is based on dose limits, i.e., doses to the public shall be less than the regulated/authorized thresholds. The second component is based on the justification principle requiring that there is a net benefit for exposure to radiation outside of background sources. Optimization is the final component of the ALARA philosophy and requires that the radiation dose be balanced with the cost of the dose reduction alternative. As stated in the DOE (1997) ALARA document for public exposures, "The goal of the ALARA process is to identify, from among several candidate alternative radiological protection systems, the system that would result in the minimal overall cost and maximum benefit." Requirements and responsibilities for the LANL ALARA program are outlined in PD-410 (LANL 2008).

2.2 Precautions

ALARA assessors must organize and present the analysis consistent with this procedure and conduct an appropriate subject matter expert review of assumptions, technical approaches, and calculations prior to incorporation into site decisions.

3.0 EQUIPMENT AND TOOLS

The investigation report and annotated outlines of the report and risk screening assessments serve as starting points for the ALARA analysis and contain much of the information needed, especially the conceptual site model describing potential receptors, analytical data for each site, and individual doses for each site and scenario evaluated.

4.0 STEP-BY-STEP PROCESS DESCRIPTION

4.1 Extract needed information from the investigation report

ALARA Assessor	1.	Obtain relevant investigation report and other relevant documentation, such as the risk assessment appendix. The investigation report serves as the primary source for information used in the ALARA analysis.
	2.	Extract information needed for the ALARA analysis from the relevant documents. This data should include: • site identification and characteristics, • exposure point concentration (EPC) for each radionuclide, • Background concentrations for each radionuclide in soil • the media (air, soil, vegetation, groundwater, etc.) in which the contamination was reported, • potential complete pathways for human exposure, • appropriate screening action levels (SALs) for each radionuclide at the site, • total individual dose rate (mrem/yr) for the site and scenario of concern, • anticipated use(s) for the site and characteristics of potentially exposed population

4.2 Compare total individual dose rate to screening level of 3 mrem/yr

ALARA Assessor	1.	If there are no radiation doses to the public (e.g., no public access), document this condition using text similar to that presented in Attachment 1. (NOTE: The text in Attachment 1 is an example and may be modified to reflect the site-specific conditions, as described in the investigation report.).
	2.	If there is a radiation dose to the public, near term or in the future, provide justification for the radiation exposures (i.e., there must be a net benefit to justify any radiation exposure).

	3.	If the total individual effective dose rate to the public is ≤ 3 mrem/yr, document the results of dose assessment in the ALARA section of the investigation report (see annotated outlines for appropriate sections) using text similar to that presented in Attachment 2. (NOTE: The text in Attachment 2 is an example and may be modified to reflect the site-specific conditions, as described in the investigation report.)
ALARA Assessor (cont.)	4.	ALARA analyses are based solely on exposures to LANL-derived sources of radiation exposure. If the total individual effective dose rate for the site and scenario of concern is > 3 mrem/yr, calculate radiation doses from the net concentration (C_{Net-i}) for each radionuclide *(i)* using the *EP*C and the background concentration (C_{BKG-i}) provided in LANL (1998). $$C_{Net-i} = EPC_i - C_{BKG-i} \qquad \text{(Eqn. 1)}$$ The background corrected total individual dose using the 15 mrem/yr *SAL* for each radionuclide *i* is $$Dose(mrem/yr) = \sum_{i=1}^{r} \frac{15 mrem/yr}{SAL_i} \times (C_{net-i}) \qquad \text{(Eqn.2)}$$ If the background corrected total individual effective dose rate is still > 3 mrem/yr, but < 15 mrem/yr, perform and document a quantitative ALARA analysis.
	5.	If the background corrected total individual effective dose rate is > 15 mrem/yr, remediation is generally required, and a quantitative ALARA analysis may be useful for determining the optimal remediation protocol. In addition, an ALARA analysis is applicable following remediation, if the resultant total individual effective dose is > 3 mrem/yr.

4.3 Perform and document results of quantitative ALARA analysis

	1.	Identify possible environmental dose-reduction alternatives that are reasonably achievable. The options should range from the most rudimentary (base case) to the most technologically sophisticated.
	2.	Determine cost estimates for each of the alternatives. Standard costing methods should be used in arriving at cost estimates. Costs should include purchasing, installing, operating and maintaining dose reduction systems, costs of performing environmental remediation to meet specific dose goals, and the potential health effects associated with the exposures of people (both public and workers) and any other direct or indirect costs resulting in exposure to radiation. Example alternatives are provided below. • Alternative 1: without mitigation (no action) • Alternative 2: remediate site using Plan 1 • Alternative 3: remediate site using Plan 2 Additional alternatives beyond evaluating a minimum of a no action alternative versus a removal of contaminated soil alternative are often not warranted.

3. Identify and estimate other health and non-health detriments and benefits, if any, for each alternative. Include societal and environmental considerations, if applicable. Positive and negative aspects associated with each alternative should be included in the analysis.

4. Document the current/most likely exposure scenario and the related exposure parameters and assumptions for each alternative. Scenarios include residential, industrial, and/or recreational. (NOTE: Land transfers must use a residential exposure scenario.)

   The selected exposure parameters should be realistic ["The dose estimates should address dose to actual people, rather than maximum doses to hypothetical people" (DOE 1997)]. The goal for selection of the exposure parameters is to ensure that the estimated doses are not substantially underestimated.

5. Calculate the collective dose for each alternative using Eqn. 3. To calculate the collective dose, S_A, summed over all radionuclides *(r)* the number of residents living on the potentially impacted area (*N*) needs to be determined. If unknown, use the average number of 2.2 persons per residence in Los Alamos County (LANL 2008). The net concentration ($C_{Net\text{-}i}$) for each radionuclide *i* as calculated in Section 4.2, step 5 should be used in the calculations, and in the case of airborne emissions, the collective dose should include affected residents within an 80 km radius of LANL.

$$S_A(person-mrem) = \sum_{i=1}^{r} \frac{15 mrem/yr}{SAL_i} \times C_{net-i} \times N \times T \qquad \text{(Eqn. 3)}$$

   Selection of integration time, *T*, depends on the exposure scenario, and the justification of the selected *T* must be documented. Exposure times for finite radiation exposures (e.g., those limited by rapid decay of the radionuclide or from a facility with a limited life time) should reflect the appropriate time frame.

   In contrast, long-lived radionuclides could expose people to radiation for extended time periods. For individual dose calculations, a person could theoretically be exposed for up to 70 years, but exposures to an individual from a single source would not be expected to extend beyond 20 years because people rarely live in one house longer than this. For collective doses from long-lived radionuclides in the environment, the radiation exposures could occur across generations, with a 200 year integration time being an appropriate selection for *T* in those cases (DOE 1997).

6. Perform optimization calculations using Eqn. 4, which is based on a monetary equivalent for radiation exposure for each alternative (Y_A):

$$Y_A = C_A + (S_A \times \beta) \qquad \text{(Eqn. 4)}$$

Here C_A is the financial cost associated with the alternative, S_A is the collective dose (person-rem) for the alternative and β is the monetary value per unit of collective dose. S_A is calculated using Eqn. 3 for the alternative, and the recommended β value is $2000 per person-rem (DOE 1997). Optimization requires that the alternative with the lowest monetary equivalent (Eqn. 4) be selected, unless other non-monetary/health considerations are applied.

An example calculation is provided below with alternatives of 1) no remediation, and 2) clean up with a dose reduction goal of 50%. For this example, assume that the individual dose is ≤ 15 mrem per year (i.e., below the regulatory limit), S_A = 10 person-rem and C_A = $0.0 for the no remediation alternative.

$$Y_A = \$0 + \left[(10\text{person} - \text{rem}) \times (\$2{,}000\text{per person} - \text{rem})\right] = \$20{,}000$$

For the remediation alternative, assume that the cost of clean up is $15,000 with a predicted collective dose reduction of 50%, or 5 person-rem.

$$Y_A = \$15{,}000 + \left[(5\text{person} - \text{rem}) \times (\$2{,}000\text{per person} - \text{rem})\right] = \$25{,}000$$

Comparing the costs (Y_A) between the two alternatives in this example shows that the optimal solution is no remediation.

7. Document the results. Attachment 3 can be used for organizing and recording the results of the ALARA analysis for all alternatives.

4.4 Perform uncertainty analysis (quantitative ALARA analysis only)

ALARA Assessor

1. Generally, ALARA evaluations are based on expected exposure conditions, but there can be significant uncertainties in key parameters impacting the decision. The most common technique in an uncertainty analysis would be to perform quantitative ALARA analyses while varying the key parameters, then assess whether the initial decision changed. Key elements in the ALARA analysis that impact the uncertainty include:

- soil concentration,
- time-integration period,
- number of residents occupying the impacted area, and
- cost estimates (societal, environmental, remediation, and monitoring).

2. Perform an ALARA analysis, as described in step 4.3, but vary the parameters based on the conclusion of the initial ALARA analysis. For example, if the initial decision was not to remediate, use the bounding parameters listed in column (c) in the table below. In contrast, for decisions to remediate, use the bounding parameters listed in column (d). If the decision remains the same after an ALARA analysis using upper or lower bounding conditions, one can reasonably conclude that uncertainty did not impact the decision.

(a)	(b)	(c)	(d)
Parameter	Standard default used in ALARA analysis	Example bounding values for uncertainty analysis if initial decision is to not remediate	Example bounding values for uncertainty analysis if initial decision is to remediate
Soil concentration	EPC	Maximum concentration in area	Average soil concentration in area
Time integration period	200 yrs	1000 yrs	100 yrs
Number of residents	2.2 people per home	4 people per home or apartment complex	Industrial or recreational use rather than residential
Cost estimates	Average estimated cost ($)	Average estimated cost minus 20%	Average estimated cost plus 20%

The values listed in this table are good examples, but other parameter selections can be used and justified in the ALARA analysis report. When selecting the parameter values, it is important to remember the goal of the ALARA analysis is not to make decisions using very unlikely extreme values, but to ensure the dose estimates are not significantly underestimated or the remediation costs significantly overestimated.

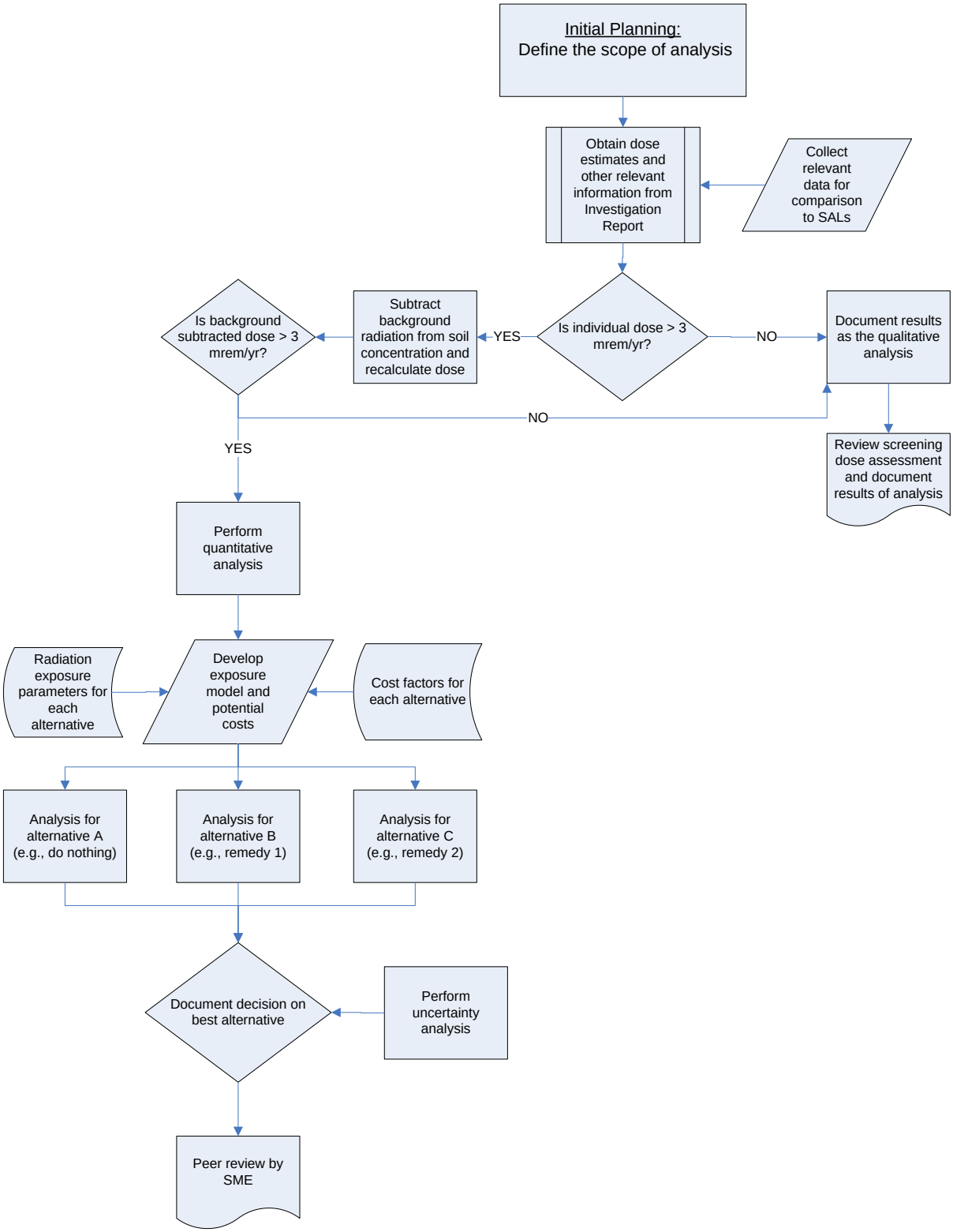
3. In the case where the decision is significantly impacted by dose and cost uncertainty, other, more sophisticated techniques for uncertainty analyses, such as Monte Carlo analysis and the probabilistic option in RESRAD, can be used to provide insight through uncertainty and sensitivity analysis. These techniques would be reserved for the most complicated ALARA analyses and require collaboration with LANL environmental health physicists. Choosing the remediation alternative in the “close calls” may be prudent in many of these cases.

4.5	**Document decision on best alternative accounting for uncertainties**	
ALARA Assessor	1.	Document the results of the ALARA analysis (dose estimates and cost optimization) using Attachment 3 or an equivalent format, and write a summary of the results of the ALARA analysis for submittal to the appropriate project leader and risk assessor for inclusion in the investigation report. Attachment 4 provides an example of a summary report of an ALARA analysis.
4.6	**Peer-review ALARA analysis and incorporate into investigation report**	
ALARA Assessor	1.	Submit ALARA results and recommendations to LANL subject matter expert for peer-review and final approval.
	2.	Document the results of the analysis in the appropriate section of the investigation report (main text conclusions and risk assessment appendix conclusions). If a quantitative ALARA analysis is conducted include the summary report and calculations as an attachment to the risk assessment appendix. Keep records of the calculations.

5.0 DEFINITIONS AND ACRONYMS

ALARA	As Low As Reasonably Achievable
DOE	Department of Energy (U.S.)
EP	Environmental Programs
EPC	Exposure Point Concentration
EPA	Environmental Protection Agency (U.S.)
LANL	Los Alamos National Laboratory
RESRAD	RESidual RADioactive material computer code
SAL	Screening Action Level

6.0 PROCESS FLOW CHART (FIGURE 1) ALARA PROCESS FLOW



7.0 ATTACHMENTS

Attachment 1 Example text for no public dose

Attachment 2 Example text for doses ≤ 3 mrem/yr

Attachment 3 Quantitative ALARA analysis checklist from PD-410.

Attachment 4 Example of complete quantitative ALARA document

8.0 REFERENCES

DOE (Department of Energy). 1990. Radiation protection of the public and the environment. DOE Order 5400.5.

DOE (Department of Energy). 1997. Applying the ALARA process for radiation protection of the public and environmental compliance with 10 CFR Part 834 and DOE 5400.5 ALARA program requirements.

LANL (Los Alamos National Laboratory). 2008. Los Alamos National Laboratory Environmental ALARA Program-report number PD410

LANL (Los Alamos National Laboratory), 2005. Derivation and Use of Radionuclide Screening Action Levels, Revision 1. Los Alamos National Laboratory report LA-UR-05-1849.

LANL (Los Alamos National Laboratory), September 22, 1998. "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico.

9.0 REVISION HISTORY

Revision No. *[Enter current revision number, beginning with Rev.0]*	Effective Date *[DCC inserts effective date for revision]*	Description of Changes *[List specific changes made since the previous revision]*	Type of Change *[Technical (T) or Editorial (E)]*
0	11/08/2009	New document	T/E

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ATTACHMENT 1	
SOP-5254-1 **Example Text for No Public Dose**	Records Use only Los Alamos NATIONAL LABORATORY EST. 1943

Sites at TA-03, TA-41, and TA-43 are inaccessible by the public and are not planned for release by DOE in the foreseeable future. Therefore, an ALARA evaluation for radiological exposure to the public is not currently required. Should DOE's plans for releasing these areas change, an ALARA evaluation will be conducted at that time. It should be noted that the Laboratory addresses considerations for radiation exposures to workers under the Laboratory's occupational radiological protection program in compliance with 10 Code of Federal Regulations 835. The Laboratory's radiation protection program implements ALARA and consists of the following elements: management commitment, training, design review, radiological work review, performance assessments, and documentation.

ATTACHMENT 2	
SOP-5254-2 **Example Text for Doses to the Public ≤ 3 mrem/yr**	Records Use only Los Alamos NATIONAL LABORATORY EST. 1943

The Laboratory's "as low as reasonably achievable" (ALARA) program description ("Los Alamos National Laboratory Environmental ALARA Program", PD410, pg 7, effective date 9/8/08) states that "…quantitative ALARA evaluations are not necessary for Laboratory activities that have a potential for annual public exposure less than a 3-mrem TEDE individual dose…". For SWMUs 01-001(e), 01-006(d), 01-006(e), 01-007(d), 01-007(e), 01-007(j), and AOC 00-031(a), where there is public access, radiological dose was not calculated because there were no radionuclide COPCs at these sites. The calculated radiation dose(s) for the residential scenario at the other sites where there is public access ranged from 0.05 mrem/yr to 2.6 mrem/yr. Therefore, radiation exposures to the public at the sites evaluated within the Upper Los Alamos Canyon Aggregate Area in this report are ALARA.

ATTACHMENT 3	
SOP-5254-3 **Quantitative ALARA Analysis Documentation**	Records Use only Los Alamos NATIONAL LABORATORY EST. 1943

ALARA Analysis Checklist

Project: _____ Date: _____

Summarize the details of the potential remediation:

A. Describe the details of radiation dose calculations **without mitigation** under likely and conservative exposure parameters including exposure scenario (e.g., residential, recreational, industrial), the number of potentially exposed people, and the time-length of exposure.

B. Describe the details of radiation dose calculations **with mitigation** under likely and conservative exposure parameters including exposure scenario (e.g., residential, recreational, industrial), the number of potentially exposed people, and the time-length of exposure. Provide the cost of the mitigation alternatives.

Quantitative comparison data for each alternative

A. Doses for each alternative process evaluated:

1. Alternative 1 description: _____ Remediation Cost: $_____
   a. Individual public dose: _____ mrem per year
   b. Collective public dose:_____ person-rem
   c. Total cost (Alt. 1):_____ person-rem × $2000/person-rem + remediation cost = $_____
2. Alternative 2 description: _____ Remediation Cost: $_____
   a. Individual public dose: _____ mrem
   b. Collective public dose: _____ person-rem
   c. Total cost (Alt. 2):_____ person-rem × $2000/person-rem + remediation cost = $ _____
3. Alternative 3 description:_____Cost: $_____
   a. Individual public dose: _____ mrem
   b. Collective public dose: _____ person-rem × $2000/person-rem = $_____
   c. Total cost (Alt. 3): _____person-rem × $2000/person-rem + remediation cost = $ ____
4. Difference in costs among alternatives:
   a. Alternative 1 – Alternative 2 = $ _____
   b. Alternative 1 – Alternative 3 = $_____
   c. Alternative 2 – Alternative 3 = $ _____

ATTACHMENT 4	
SOP-5254-4 **Example of complete quantitative ALARA analysis**	Records Use only

Dose Optimization Analysis for Land Transfer Tract 8a

Calculate Number of Persons Expected to Reside on Tract:

http://quickfacts.census.gov/qfd/states/35/35028.html: Persons living in LA County in 2006 19,022 persons

Number of housing units in 2005: 8,607

Persons per housing unit in LA County: 2.2 persons

Trinity Site Plan: 190 condominiums and 36 residential lots = 226 housing units

2.2 persons x 226 housing units = 497 persons ~500 persons

Calculate Collective Dose (Person-Rem):

Use highest dose rate calculated (SWMU 21-021-99) for COPCs: 4.1 mrem/year (0.0041 rem/year)

Assume that collective dose integration period is 200 years (refer to DOE ALARA Standard, Vol. 2, pg. E-20)

0.0041 rem/year x 200 years x 500 persons = 410 person-rem

Calculate Cost That Should be Spent to Avert Collective Dose Above:

Assume use of $2000 per person-rem as nominal value recommended in DOE ALARA Standard.

410 person-rem x $2000/person-rem = $820,000

Estimate Cost of Remediating Tract 8A:

Based on personal communication with project leader and using standard calculation methods, the cost of remediating Tract 8A to fallout background levels would be approximately $25M. The remediation effort would only involve the removal of soil down to a one foot depth across the 27 acre site. It is assumed that the soil contamination is not at depth, but only deposited on the surface or slightly below the surface (radionuclide samples were taken at 0.08 and 0.5 foot depths) from legacy operations at TA-21 DP West. This cost does not involve any additional sampling, site restoration, or documentation of the remediation effort. It only considers the cost of removing the soil and subsequent packaging and disposal.

Conclusion:

The ICRP system of dose limitations has been met for this project:

Justification: The exposure of persons to radiation in this case results in a net positive benefit. This benefit is the use and occupancy of the land parcel by Los Alamos County and members of the public.

Optimization: The cost of remediating the soil concentrations down to fallout background levels (approximately $25M) far exceeds the funds that should be spent to avert the collective dose projected to be received over a 200 year period of time ($820,000). Therefore, the currently projected collective dose has been optimized.

Dose Limits: The DOE Order 5400.5 dose limit for members of the public, 100 mrem/year from all pathways, has been met in this case. The highest projected dose for this site is 4.1 mrem/year. This dose is also below the residential screening level of 15 mrem/year.