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Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for Maywood, New Jersey

U.S. Department of Energy

0489-0613.1

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93.753

Department of Energy

Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831— 8723

September 30, 1993

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Dear Members of the Senior Executive Committee:

MAYWOOD SITE - REVISED DOE STATEMENT OF POSITION REGARDING THE DISPUTE ON CLEANUP CRITERIA

The purpose of this letter is to provide Revision 1 of the Department of Energy's (DOE) Statement of Position on the cleanup criteria for the Maywood site. This revision contains results from a recently completed cost-benefit analysis. Details of this analysis are presented in Attachment B to the Statement of Position, and summary information from the analysis has been included in the body of the Statement of Position.

In summary, results from this additional analysis indicate that reducing the cleanup criterion for subsurface soils from 15 pCi/g to 5 pCi/g would yield a reduction in collective dose of approximately 280 person-rem over a 200 year period, at a cost of approximately $110,000 to $430,000 per person-rem avoided. This cost is more than two orders of magnitude higher than the values generally considered appropriate in the nuclear industry as a benchmark of cost-effective dose reduction. Similarly, by reducing the subsurface soil cleanup criterion, the likelihood of contracting cancer is estimated to be reduced by approximately 0.2 cancers over a 200 year period. The corresponding cost for this risk reduction is estimated at approximately $200-700 million per health effect avoided.

Moreover, the current focus on the optimal cleanup criterion for subsurface soils at the site should be considered within the context of DOE's policy to keep all radiation exposures as low as reasonably achievable (ALARA). Within the Formerly Utilized Sites Remedial Action Program (FUSRAP), the ALARA program includes both prospective cost-benefit analysis as a part of remedy selection, such as that presented in Attachment B to the Statement of Position, and also additional ALARA considerations during field implementation of the remedy. This approach has proven highly effective in reducing residual contamination at remediated properties to levels well below predetermined cleanup criteria, where reasonably achievable.

If I can be of any further assistance to you, please call me at (615) 576-0948.

Sincerely,

Lester K. Price, Director
Former Sites Restoration Division

Enclosure

cc:
G. Pavlou, EPA II
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DOE STATEMENT OF POSITION

CLEANUP CRITERIA FOR THE MAYWOOD SITE
BERGEN COUNTY, NJ

Revision 1 - September 30, 1993

1. INTRODUCTION & BACKGROUND

The U. S. Department of Energy (DOE), under its Formerly Utilized Sites Remedial Action Program (FUSRAP), has developed a Feasibility Study (DOE 1993a) and Proposed Plan (DOE 1993b) for remediation of the Maywood site, in Bergen County, New Jersey. The preferred remedy calls for a two-phased remedial action. Phase I includes excavation of all contaminated soils at residential vicinity properties, excavation of one commercial property that was once part of the former thorium processing plant, removal of the interim waste storage pile, and continuation of institutional controls at the Maywood Interim Storage Site (MISS); excavated soils would be disposed of off-site at a licensed and approved commercial disposal facility. Phase II would begin immediately upon completion of Phase I, and involves the excavation of contaminated soils at the remaining properties and treatment by soil washing. Cleaned soils would be backfilled on-site, while concentrated residuals from the treatment process would be disposed at an off-site commercial disposal facility.

The primary contaminant of concern at the Maywood site is thorium-232 and its radioactive decay products; other contaminants include lesser amounts of uranium (primarily uranium-238 and uranium-234) and its radioactive decay products, including radium-226. The soil cleanup criteria selected for the site call for excavation of soils with concentrations of thorium-232 greater than 5 picocuries per gram (pCi/g) above background concentrations averaged over the first 15 centimeters (cm) of soil below the surface, and 15 pCi/g averaged over any 15-cm layer below the surface layer, averaged over any area of 100 square meters (m^2) (herein termed "5/15 pCi/g criteria"); the same numerical criteria are specified for radium-226. These criteria are specified in the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA; PL 95-604) regulations promulgated in 40 CFR 192 for radium contaminated soils and specified in DOE Order 5400.5 (DOE 1990). While the 40 CFR 192 regulations are specific to UMTRCA cleanups, both DOE and EPA have identified these standards as relevant and appropriate for remediation of other properties with similar characteristics. In issuing DOE Order 5400.5, DOE recognized the potential to misapply the 5/15 pCi/g criteria and, as a result, included an additional requirement to apply the ALARA (as low as reasonably achievable) process in addition to the 5/15 pCi/g constraint. The ALARA process has been and is being applied at the Maywood site and has demonstrated the appropriateness of the 5/15 pCi/g criteria for Maywood.

The draft final Feasibility Study (DOE 1993a) and Proposed Plan (DOE 1993b) for the Maywood site were submitted to the U.S. Environmental Protection Agency (EPA) for review and approval on April 20, 1993, following a lengthy development process which included extensive consultation with EPA - i.e., previous drafts of these documents were submitted to EPA for review as early as July 31, 1992, and EPA comments on these draft documents, dated September 3, 1992, and February 1, 1993, did not question the suitability of DOE's proposed cleanup criteria. On May 21, 1993, EPA submitted one substantive comment, specifically disputing the cleanup criteria selected for the site (EPA 1993a). DOE and EPA were not successful in resolving the disputed issue informally during the 30-day informal dispute resolution period. On June 21, 1993, EPA issued a formal statement of dispute (EPA 1993b) challenging the subsurface cleanup criterion and proposing an alternative cleanup standard of 5 pCi/g for thorium-232 and radium-226 at all depths (herein termed "5/5 pCi/g criteria"). In accordance with Section XV of the Federal Facility Agreement (FFA) entered into by DOE and EPA for the Maywood site, this issue is now presented to the Dispute Resolution Committee for consideration. The basis for DOE's position is summarized in Section 2.

2. RATIONALE FOR PROPOSED CLEANUP CRITERIA

2.1 Protectiveness

DOE's position is that the proposed cleanup criteria of 5 pCi/g for surface soils and 15 pCi/g for subsurface soils are protective of human health and the environment at the Maywood site. The Department, in assessing potential risks and impacts associated with the cleanup criteria in support of the Feasibility Study (DOE 1993a) and the DOE-required ALARA analyses, has demonstrated that the application of the 5/15 pCi/g criteria at the Maywood site is protective and cost effective.

EPA's assertion that the 15 pCi/g standard for subsurface soil is not adequately protective is not supported by site-specific analysis. As part of the detailed evaluation of remedial action alternatives for the Maywood site in the Feasibility Study (DOE 1993a), DOE conducted an assessment of the risks to current and potential future receptors from residual contaminants remaining after remediation. Results of this analysis (summarized in Attachment A) indicate the maximum reasonable exposure estimate of residual risk to be within the EPA's target risk range of 10^{-4} to 10^{-6} specified in the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300) and CERCLA risk assessment guidance.

DOE's primary radiation protection standard applicable to the Maywood site requires that the effective dose equivalent to any member of the public from exposure to residual radioactive materials (excluding radon) shall not exceed 100 millirem/year (mrem/year) above background for all plausible land uses (DOE Order 5400.5, DOE 1990); DOE further requires that all radiation doses should be reduced as low as reasonably achievable (ALARA) below this primary dose limit. The 100 mrem/year dose limit plus ALARA is a health-based limit, recommended by national and international radiation protection organizations, including the International Commission on Radiological Protection (ICRP 1991), the National Council on Radiation Protection and Measurements (NCRP 1993), and the U.S. Nuclear Regulatory Commission (NRC 1991). Additional limits in DOE Order 5400.5 (DOE 1990) specify that, within any occupied or habitable building, gamma radiation shall not exceed background by more than 20 microroentgens/hour (μR/hr), and radon decay product concentrations (including background) shall not exceed 0.02 WL where reasonably achievable and 0.03 WL in any case; these requirements are adopted from 40 CFR 192 Subpart B. Based on discussions with EPA staff, both DOE and EPA are in agreement that these dose limits are appropriate for the Maywood site, and DOE is committed to attaining these dose limits. The 5/15 pCi/g soil cleanup standards (with ALARA) specified in DOE Order 5400.5 are concentration limits derived to achieve the primary dose limits and radon progeny concentration limits; DOE's site-specific analysis confirms that the 5/15 pCi/g soil cleanup criteria would attain these limits at the Maywood site.

EPA has presented no information to indicate that the 5/15 pCi/g criteria are not fully protective of human health and the environment for the conditions at the Maywood site. With regard to the two Attachments submitted by EPA in support of the statement of dispute, DOE notes the following:

1) Russell and Richardson (1992) identified the potential to exceed a radon-222 concentration of 2 pCi/liter in indoor air in buildings constructed on soils with radium-226 concentrations approaching 15 pCi/g (i.e., a radon concentration of 4 pCi/liter is assumed, at 50 % equilibrium with radon decay products, to equate to the radon daughter concentration limit of 0.02 WL specified in 40 CFR 192, and this value is reduced by half to allow for other sources of radon), based solely upon mathematical modeling; this analysis may be overly conservative in allowing only one-half of the 0.02 WL limit from radium contaminated soils, as the standard makes no such provision, but specifies only that the annual average radon decay product concentration shall not exceed 0.02 WL where reasonably achievable and 0.03 WL in any case, in both cases "including background" - the relative contribution of background is not specified. The EPA analysis also estimates indoor gamma exposure rate to be "very close to" the limit specified in 40 CFR 192 (20 μR/hour) for soil concentrations approaching 15 pCi/g. These concerns may be valid for sites where the primary contaminant of concern is radium-226, although the underlying models of radon migration into structures from soils contain large uncertainties and may be a questionable basis for risk management decisions involving large expenditures of public funds.

Such concerns are not valid, however, for thorium-232 contamination at the Maywood site. The radioactive decay series for radium-226 and thorium-232 include the noble gases radon-222 (radon) and radon-220 (thoron), respectively. However, the radioactive half-life of radon-220 (55.6 seconds) is very short relative to the half-life of radon-222 (3.8 days), which precludes significant migration of radon-220 from subsurface soils. EPA estimates that the potential for release of radon gas from contaminated soils is 25 times lower for radon-220 than for radon-222 (EPA 1991). Thus, the potential for accumulation of radon-220 in indoor air in buildings constructed on soils containing thorium-232 is much lower than that for radon-222 in radium-226 contaminated soils, and the analysis of Russell and Richardson (1992) is not directly applicable to the Maywood site. Furthermore, the health risk from radon-220 decay products has been estimated to be lower than that for radon-222 decay products by a factor of three for an equal concentration of inhaled alpha energy (ICRP 1981). The application of the 5/15 pCi/g standards derived for radium-226 contaminated soils to the Maywood site, where thorium-232 is the primary contaminant of concern, therefore is highly conservative.

2) The Health Physics Society's "Position Statement on Radiation Standards for Site Cleanup and Restoration" (HPS 1993) was developed as input to the NRC's enhanced

participatory rulemaking to establish radiological criteria for decommissioning of NRC-licensed facilities and DOE's proposed 10 CFR 834. This position statement endorses the primary dose limit of 100 mrem/year and the reduction of all radiation exposures as low as reasonably achievable, consistent with DOE policy noted above as well as current recommendations of the International Commission on Radiological Protection (ICRP 1991) and the National Council on Radiation Protection and Measurements (NCRP 1993). A soil concentration limit of 5 pCi/g above background is also proposed, again based on limiting radon concentrations in indoor air; however, this criterion is suggested only for application to near surface soils, with a depth limit of "no less than 0.5 and no greater than 1 meter". As noted above, DOE's analysis for the Maywood site indicates that compliance with both the radon concentration limit and primary dose limit will be achieved by the 5/15 pCi/g cleanup criteria.

The Health Physics Society's primary recommendation cautions, however, that "standards for site cleanup and restoration should be based on the principle of balancing the societal costs and risks of cleanup against the societal benefits of actual radiological risk reduction, to assure that the net benefit to society is maximized." Further, as part of its considerations, the position statement concurs with the ICRP recommendation that "the proposed intervention should do more good than harm, i.e., the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention." Reduction of the cleanup criteria for the Maywood site would impose very significant additional costs to achieve marginal risk reduction, in direct conflict with this recommendation.

Prediction of potential health impacts from radiation exposures is subject to very large uncertainties, based on numerous assumptions and extrapolations upon which knowledgeable scientists disagree (e.g., NAS 1990). Therefore, it is not possible to draw such clear lines of demarcation to indicate that a subsurface soil concentration of 15 pCi/g of radium or thorium is "unsafe" whereas a concentration of 5 pCi/g is "safe"; rather, both values must be considered to lie in a common risk range (i.e., a common order of magnitude). Depending on the site-specific exposure conditions, both values may fall either within or outside the EPA's target risk range of 10^{-4} to 10^{-6}; however, in either case, the predicted radiation dose and health risk would be within or below the range of that from natural background radiation. In the Final Environmental Impact Statement for the 40 CFR 192 rulemaking (EPA 1982, pp 110-111), EPA acknowledged this situation in estimating identical residual risks for the 5/15 pCi/g standards and 5/5 pCi/g alternative, both outside the 10^{-4} to 10^{-6} target risk range.

It should also be noted that the primary dose limit of 100 mrem/year for members of the public, which represents a consensus of the radiation protection community, yields an excess cancer risk estimate of approximately 6×10^{-5} per year of exposure. The average natural background radiation in the United States results in an annual effective dose equivalent of approximately 300 mrem/year (NCRP 1987), with a lifetime excess cancer risk of 10^{-2} (EPA 1989). Natural background radiation levels much higher than this average occur in many areas underlain by uranium-rich granites and shales; for example, indoor radon concentrations exceeding 200 pCi/liter (i.e., 50 times EPA's 4 pCi/liter guideline) in indoor air have been attributed to natural sources in areas such as Pennsylvania's Reading Prong (NCRP 1984). The excess cancer risk to a person exposed to the 4 pCi/liter concentration guideline for radon-222 in indoor air over a lifetime is estimated to exceed 10^{-2}. The risk from residual radioactive materials at the Maywood site is a small increment to these background radiation risks, comparable to the variability in natural background risks.

In response to EPA's concern (EPA 1993c) that 15 pCi/g may not be suitable as a criterion for replacement of treated soils at the Maywood site, DOE has reevaluated the proposed replacement criterion. An important consideration in the selection of criteria for replacement of treated soils is the large volume of soils proposed for treatment at the Maywood site; replacement of treated soils which meet the selected criteria as subsurface backfill at selected properties could provide a large, relatively homogenous layer of soils with residual contaminant concentrations approaching the selected limit. This situation would be in marked contrast to the implementation of the same criteria as cleanup standards, where only small localized areas of contamination approaching the specified limits would remain after remediation. Under DOE's proposed remedy, treated soils would be used as backfill only at the Maywood Interim Storage Site, the Stepan Company property, and possibly adjacent commercial/industrial properties, and would be covered by 30 cm of clean fill; only clean backfill from an off-site borrow area would be used at properties where residential use is considered plausible. To clarify this issue, DOE has conducted additional analyses to develop performance-based criteria for replacement of treated soils, such that the post-remediation conditions at the site would meet pertinent dose limits and ALARA considerations. Results of this analysis, summarized in Section A.4 of Attachment A, indicate that replacement of treated soils with residual radionuclide concentrations below 15 pCi/g would satisfy dose and risk objectives. However, if the soil treatment technology, at the time of implementation, proves capable of treating soils to lower residual concentrations in a cost-effective manner, then DOE would adopt a lower concentration limit for replacement of treated soils, based on ALARA considerations.

2.2 Relevance and Appropriateness of 40 CFR 192 Soil Criteria and Supporting Analyses to the Maywood Site

While the 40 CFR 192 Subpart B standards are directly applicable only to the inactive uranium processing sites specifically designated under Title I of UMTRCA, they are relevant and appropriate for the Maywood site. EPA's assertion that the contamination situation at Maywood "differ[s] substantially from those for which [the standard] was derived" is erroneous. Conditions at the Maywood site are not significantly different from those at the uranium mill sites for which the 40 CFR 192 standards were developed. Both Maywood and the sites managed under the Uranium Mill Tailings Remedial Action Program (UMTRAP) are the result of radioactive ore processing activities, and include numerous "vicinity properties" contaminated by relocation of contaminants by erosion, use of contaminated materials as fill material, and spillage during transportation. Both programs address identical contaminants of concern at sites characterized by large volumes of contaminated soil, widely ranging soil contaminant concentrations, and land use ranging from residential to industrial. The distribution of radioactive contamination at the Maywood site is very similar to that at uranium mill tailings sites. Radioactive materials which eroded from the site are spread in thin layers, much the same as the windblown tailings at some uranium mill sites. Radioactive materials that were removed from the site were used as a soil conditioner and for other purposes, again much the same as at the uranium mill sites. The tailings that were removed at the uranium mill sites were the sand fractions which typically have radium concentrations of less than 100 pCi/g, also similar to the removed contaminated materials at Maywood.

EPA also promulgated standards for radium-228 contaminated soils at licensed commercial thorium processing sites in 40 CFR 192 Subpart E, "Standards for Management of Thorium Byproduct Materials Pursuant to Section 84 of the Atomic Energy Act of 1954, as Amended." The standards for radium-228 at thorium processing sites in Subpart E are numerically the same as those specified for radium-226 in Subparts B and D. These standards apply to the management of thorium byproduct materials, such as those at the Maywood site, during and following processing of thorium ores, and to the restoration of disposal sites. While the Maywood site is not an NRC licensed facility for which Subpart E requirements are directly applicable, DOE's analyses indicate that the proposed 5/15 pCi/g cleanup criteria would attain Subpart E requirements.

Moreover, the 5/15 pCi/g soil criteria are also specified in DOE Order 5400.5 (DOE 1990) as generic guidelines for residual concentrations of thorium and radium in soil. These generic guidelines may be reduced, where appropriate, based on site-specific ALARA analyses; however, the ALARA analysis for the Maywood site (Attachment B) indicates that reduction of the generic guidelines at this site is not warranted. The requirements of DOE Order 5400.5 are directly applicable to all FUSRAP sites, including Maywood, and compliance with the requirements of this and all DOE Orders is mandated for all DOE operations.

If the 15 pCi/g standard for subsurface soils had been determined not to be adequately protective for the Maywood site, it would be necessary to derive a risk-based cleanup standard for the site-specific conditions, rather than arbitrarily adopting the 5 pCi/g criterion suggested by EPA; however, based on the site-specific analysis, the 5/15 pCi/g standards are adequately protective for the Maywood site. The 5/15 pCi/g soil cleanup criteria were originally developed through formal rulemaking and deemed protective by EPA. In the 40 CFR 192 rulemaking (48 FR 590), the supporting Final Environmental Impact Statement (EPA 1982) and subsequent legal challenges (U.S. Court of Appeals for the Tenth Circuit 1985), EPA formally defended the protectiveness of this standard. Independent site-specific analyses conducted by DOE have confirmed this evaluation.

2.3 Precedent

The 5/15 pCi/g cleanup criteria have been successfully used for remediation of more than 4500 properties under UMTRAP, FUSRAP, and other programs. In each case these criteria have been determined to be protective of human health and the environment. Selection of the alternative criteria proposed by EPA could bring into question the previous remedial activities at the Maywood site (where 25 vicinity properties have been previously remediated and certified for unrestricted release using the 5/15 pCi/g criteria) and at numerous other sites. At a minimum, implementation of dissimilar cleanup criteria at neighboring properties would raise significant, and unnecessary, equity concerns. Alternatively, it might become necessary to undertake additional site characterization and/or remedial actions at previously remediated properties to demonstrate compliance with the revised cleanup criteria. While such an investigation would increase costs, DOE's analysis indicates no added health benefits.

The 5/15 pCi/g cleanup criteria also have been specified in the Records of Decision (RODs) signed by EPA for several other CERCLA sites containing radium and/or thorium as contaminants of concern - e.g., Denver Radium Site, Monticello Mill Tailings Site, Maxey Flats Disposal Site; in each case, the 40 CFR 192 Subpart B standards (including the 15 pCi/g concentration limit for subsurface soils) are explicitly stated to be relevant and appropriate requirements, and determined to be protective of human health and the environment. Thus, the recent assertion by EPA that only the surface concentration limit is appropriate for consideration as an ARAR is inconsistent with these previous determinations.

2.4 Cost Effectiveness

Lowering the cleanup criteria would have significant impacts on the cost and schedule for remedial actions at the Maywood site and other FUSRAP sites without a commensurate benefit to public health or the environment. The 5/15 pCi/g criteria have been used for designation of radioactively contaminated properties at the Maywood site for consideration under FUSRAP, for characterization of radioactive contamination at designated properties, and for verification of completed remedial actions. Consequently, the sampling and analysis protocols used at the site and throughout the FUSRAP program have been designed primarily to identify and characterize the contamination exceeding these concentration limits. The Work Plan for the site (DOE 1992a) and the Remedial Investigation Report (DOE 1992b), which were reviewed and approved by EPA, specifically identify the 5/15 pCi/g criteria used in the current DOE guidelines for acceptable concentrations of residual contamination in soils. Selection of lower criteria for remediation of these properties would necessitate reevaluation of the designation process, and potentially would require additional radiological survey activities at some previously undesignated properties, as well as additional site characterization at previously characterized and any newly designated properties. These additional characterization activities would have significant cost impacts, and ongoing and planned remediation activities might need to be suspended or delayed, pending the additional characterization data. Revision of the cleanup criteria might also alter the range and relative ranking of alternatives considered for remediation, which would require revision of the Feasibility Study analyses, adding further schedule delays and increased costs. Analyses to date indicate little or no potential for health benefits associated with these actions.

Because the remedial investigation for the Maywood site was not designed to delineate areas of contamination between 5 pCi/g and 15 pCi/g in subsurface soils, it is not possible to accurately estimate incremental waste volumes and costs which would result from the 5/5 pCi/g cleanup criteria with current information. Based upon the available data, incremental costs at Maywood have been estimated to range from $30,000,0000 to $120,000,000, or 20% to 80% over current cost estimates for the preferred alternative. The lower estimate assumes that waste volumes will increase by only 20% and the costs for the preferred alternative will increase linearly with the waste volume; however, it is possible that the cost growth will be greater than this estimate due to factors such as increased treatment costs to achieve the lower performance objective and reduced efficiency in excavating more diffuse residual contamination. The upper cost estimate could be realized if either (a) the waste volume increases by 80% over baseline volume estimates and costs increase linearly, or (b) the proposed treatment technology fails to achieve the 5 pCi/g performance criterion, in which case a more costly disposal alternative might be required. Costs for additional remedial investigation activities at the site to better define the extent of contamination between 15 pCi/g and 5 pCi/g in the subsurface soils would be in addition to this estimate, but are not currently defined.

The cost impact throughout the FUSRAP program from implementation of the lower criteria is estimated to be $1,000,000,000 to $4,000,000,000, again assuming an increase of 20% to 80% over baseline cost estimates. The additional volume of contaminated materials requiring management under the revised criteria is estimated at 400,000 yd^3 to 1,500,000 yd^3 across FUSRAP. This additional cost would impact the schedule for remediation of the Maywood site and other FUSRAP sites.

In accordance with DOE requirements to reduce radiation exposures as low as reasonably achievable (ALARA), taking into account technical, economic, and social considerations, an analysis of the costs and benefits (i.e., predicted reduction in collective dose and risk) associated with remediation of the Maywood site to various cleanup criteria has been prepared (Attachment B). This analysis indicates that reduction of the cleanup criterion for subsurface soils from 15 pCi/g to 5 pCi/g would yield a collective dose reduction of approximately 280 person-rem over a 200-year period, at a cost of $110,000 to $430,000 per person-rem avoided. This estimate significantly exceeds the typical benchmark of $1,000 per person-rem avoided typically used in the nuclear industry as the upper limit for cost-effective dose reduction. The corresponding cost per potential health effect avoided is estimated at approximately $200 - 700 million, assuming a risk factor of 6 x 10^{-4} lifetime excess cancer incidence per person-rem.

EPA's analysis in the Final Environmental Impact Statement identifies the 5/15 standard as the "optimized cost-benefit standards", whereas the 5/5 pCi/g alternative "approaches a high-cost nondegradation alternative" below which compliance cannot be readily measured with field instrumentation (EPA 1982, p 107); it further notes that this proposed alternative "would require more skill and training of personnel, and greater use of more expensive measuring techniques, but cleanup would only be marginally more complete" (EPA 1982, p 136). Based on the cost-benefit analysis presented in Attachment B, DOE agrees with the EPA conclusion in the Final Environmental Impact Statement that the 5/15 pCi/g cleanup criteria represent sensible risk management, and the expenditure of large additional costs for marginal risk reduction benefit is clearly unwarranted.

2.5 Implementability

Lowering the subsurface cleanup criterion from 15 pCi/g to 5 pCi/g would significantly reduce the utility of field screening techniques, requiring much more costly and less efficient measurement techniques - i.e., greater reliance on radioanalytical laboratory measurements would be required in place of real-time field measurements, with resultant loss of efficiency in remediation. Also, use of modern remote-data-logging systems, such as the Ultrasonic Ranging and Detection System (USRADS), would not be feasible at the reduced concentration limit. These practical limitations were acknowledged by EPA in the 40 CFR 192 rulemaking and Final Environmental Impact Statement, and contributed to the selection of the 15 pCi/g criterion for subsurface contamination. Both the Final Environmental Impact Statement and preamble to the final rule note that "these standards will result in essentially the same health protection, but will be much easier to implement."

In practice, the actual cleanup levels achieved during remedial actions at FUSRAP sites are generally well below the 5/15 target levels. Due to the imprecise nature of field excavation equipment relative to the typical configuration of contaminated materials in thin discrete layers, and to allow for uncertainties in field measurements, excavation of contaminated soils continues until concentrations clearly below the target levels are achieved. Such practices reduce the need for remobilization to excavate additional soils at a later time. Historical cleanup activities conducted by DOE have resulted in residual concentrations well below predetermined criteria, and in many cases near background levels. Review of the post-remedial action data for the previous removal actions at the Maywood site, for example, indicates that the cleanup levels actually achieved at most of the remediated properties already meet the 5 pCi/g level; of 1105 soil samples collected following completion of the remedial action at these properties, 1053 (95%) were determined to be within 5 pCi/g above background. However, the site characterization program and independent verification program were designed primarily to provide assurance that the 5/15 pCi/g cleanup criteria were attained, and data were not collected specifically to evaluate residual concentrations below 15 pCi/g in subsurface soils.

It is DOE's policy that all radiation exposures should be kept as low as reasonably achievable (ALARA). In the context of DOE's ALARA program, the cleanup criteria specified for a remedial action are considered as upper limits only, and the actual level of remediation attained may be significantly greater, such as that noted above for the previous remedial actions at the Maywood site. DOE is committed to pursuing an aggressive ALARA program throughout the remediation of the Maywood site, which may include removal of contaminated soils below target cleanup criteria in situations where implementation costs are reasonable and incremental risks to remedial action personnel are low. The combination of DOE's proposed 5/15 pCi/g soil cleanup criteria in concert with this ALARA program will provide a level of protection approximately equivalent to EPA's proposed alternative criteria of 5 pCi/g at all depths, but allows for recognition of technological limitations and provides opportunities for greater cost effectiveness.

3. CONCLUSION

The cleanup criteria proposed by DOE for remediation of radioactive contamination at the Maywood site specify that concentrations of thorium-232 and radium-226 shall not exceed 5 pCi/g above background concentrations averaged over the surface 15 cm layer of soil and 15 pCi/g averaged over any 15-cm layer below the surface layer. Selection of these criteria is based on thorough analysis of site-specific conditions, which has determined the criteria to be protective of human health and the environment, compliant with all regulatory requirements, implementable, and cost effective. The proposed criteria are specified in 40 CFR 192 regulations and DOE Order 5400.5.

In the 40 CFR 192 rulemaking and the supporting Final Environmental Impact Statement, EPA determined that the 5/15 pCi/g standards were protective of human health for uranium mill tailings sites. The situation at the Maywood site is not significantly different from that at uranium mill sites, and site-specific analyses have confirmed the protectiveness of these criteria under current and future site conditions. The 5/15 pCi/g soil standards are considered relevant and appropriate for the Maywood site because the site characteristics and distribution of radioactive contaminants at the site are substantially similar to that for which the standards were developed. In fact, use of these standards at the Maywood site, where the primary contaminant of concern is thorium-232, provides a greater degree of protectiveness than at uranium mill sites, where radon-222 contributes significantly to the potential radiation risk. Furthermore, DOE's aggressive ALARA program during field implementation of the remedial action is expected to achieve actual cleanup levels well below the specified soil concentration limits.

EPA has indicated concerns that the 15 pCi/g criterion specified in the draft Feasibility Study and Proposed Plan may not be appropriate for determining on-site replacement of treated soils during Phase II of the proposed remedy, due to the potentially large quantities of such treated soils. Additional analyses conducted by DOE indicate that replacement of treated soils with residual radionuclide concentrations below 15 pCi/g would satisfy dose and risk objectives, such that the post-remediation conditions at the site would meet pertinent dose limits and ALARA requirements; however, if the soil treatment technology, at the time of implementation, proves capable of treating soils to lower residual concentrations in a cost-effective manner, then DOE would adopt a lower concentration limit for replacement of treated soils, based on ALARA considerations.

DOE continues to feel that the proposed remedy and cleanup criteria represent the optimal alternative for remediation of the Maywood site, based upon evaluation criteria specified in the National Contingency Plan and EPA CERCLA guidance, as documented in the Feasibility Study and Proposed Plan, and DOE's ALARA analysis. The additional costs and technical difficulties imposed by EPA's proposed alternative criteria, as well as the inconsistency with previous actions at Maywood and similar radioactively contaminated sites, are not commensurate with the marginal risk reduction benefits. **Therefore, it is DOE's position that the cleanup criteria of 5 pCi/g for surface soils and 15 pCi/g for subsurface soils, as proposed in the Feasibility Study and Proposed Plan, are appropriate for the Maywood site.**

4. REFERENCES

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ATTACHMENT A

Assessment for Residual Radioactive Contamination at the Maywood Site

(Revision 2 - August 23, 1993)

A.0 Summary

The U.S. Department of Energy proposes to remediate radioactively contaminated soils at the Maywood site to concentrations that result in residual risks that are conservatively estimated to be within the Environmental Protection Agency's target risk range of 10^{-6} to 10^{-4} specified in the National Contingency Plan. The approach is (1) to reduce the source of contamination to levels used for similar situations, and (2) to eliminate or reduce pathways for transport and exposure by providing additional soil cover over residual contamination. Receptor scenarios are based on reasonable future land use and additional controls and restrictions are not imposed. The analyses indicate that adding additional soil cover over the residual contaminated soils is an effective approach to reducing risk.

Soils containing radionuclide concentrations greater than 5 pCi/g above background of thorium-232 and/or radium-226 in the surface 15-cm layer and greater than 15 pCi/g above background in any 15-cm layer below the surface layer would be remediated. During Phase II of the proposed remedy, excavated soils would be treated using a physical separation process, and treated soils with residual radionuclide concentrations (thorium-232 + radium-226) less than 15 pCi/g would be replaced as subsurface backfill at the MISS, Stepan Company property, and possibly adjacent commercial/industrial properties. These replacement soils would be covered with clean soil to a depth of at least 0.3 m (1 ft). At other properties only clean soil would be used for fill material at all depths. In all cases, predicted radiation doses are below the DOE's primary dose limit of 100 mrem/year effective dose equivalent, and the estimates of excess cancer risk are within the EPA's 10^{-6} to 10^{-4} target risk range.

The provision of a clean soil cover of 0.3 m (1 ft) or greater is a reasonable risk management approach and is preferred over additional reductions in residual concentration limits; due to the nature of the contaminant distribution at most vicinity properties (particularly residential properties), the residual contaminated soils would generally be at depths greater than 1 m (3 ft) following remediation, providing an additional measure of safety. The risk estimates are based on conservative assumptions regarding the extent and concentration of residual contaminants (i.e., residual concentrations assumed for the analysis are significantly higher than those achieved in previous cleanup actions at the Maywood site, and higher than the area-averaged pre-remediation soil concentrations), reasonable maximum exposure parameters for resident and employee receptors, and evaluation of future excavation intrusions into the contaminated zone.

Evaluation of key sensitivities, such as the mix of contaminants, extent of contamination, and radiation shielding assumptions, indicate that the scenarios provide conservative estimates of potential dose and risk, and provide a reasonable basis for decision making.

A.1 Introduction

This analysis presents estimates of radiation dose and incremental cancer risk to potential receptors following remediation of the Maywood site to the cleanup criteria proposed in the "Feasibility Study-Environmental Impact Statement for the Maywood Site" (DOE 1993a) and the "Proposed Plan for the Maywood Site" (DOE 1993b). These dose and risk estimates were computed using the RESRAD computer code (Gilbert et al. 1989, Yu et al. 1993a), which has been developed to implement the DOE guidelines for residual radioactive material as specified in DOE Order 5400.5 (DOE 1990). Parameter values and assumptions conform with those in the "Baseline Risk Assessment for the Maywood Site" (DOE 1993c), which has been formally approved by EPA, and in the Feasibility Study, except as specifically discussed below.

For the purpose of evaluating residual risks following remediation, it is important to consider the specific characteristics of the Maywood site, particularly with respect to distribution of contaminants at the affected properties. The residual risk analysis considers two primary categories of properties, based on contaminant distributions and current and future land use:

o The majority of affected properties (i.e., vicinity properties) are thought to have become contaminated as a result of surface water migration from the former Maywood Chemical Works through Lodi Brook; contaminants were deposited along the stream channel and associated floodplains. Subsequent development of these properties included significant fill and grading operations, in which the former stream channel and contaminated soils were covered with up to 10 feet of clean fill. Due to the location of contamination at these properties, remediation will require excavation to the depth of contamination, followed by backfilling with clean soil from an offsite borrow area. Any residual contamination left in place below cleanup criteria, therefore, would be covered by a substantial layer of clean soil. For these properties, the residual risk analysis is based upon a residential land use scenario, as further discussed below.

o The Maywood Interim Storage Site, the Stepan Company property, and some adjacent vicinity properties which were more directly associated with the operations of the former Maywood Chemical Works have much different distributions of contaminants, in some cases including former lagoons and waste burial areas. Volumes and concentrations of contaminated soils at these properties are significantly greater than for the vicinity properties discussed above. Furthermore, the proposed remedy calls for excavation and treatment of contaminated soils, followed by replacement of soils treated to below residual criteria as subsurface backfill at MISS, Stepan, and adjacent vicinity properties (if necessary, depending on volume of treated soils); a residual radionuclide criterion of 15 pCi/g for the replacement soils has been determined to be protective of human health and the environment. A layer of 0.3 meter (1 ft) of clean soil from an off-site borrow area would be emplaced as a surface cover. For these properties, which have been under heavy commercial/industrial use for many years, future residential land use is not considered likely, and the residual risk analysis is based upon a commercial/industrial land use scenario, as further discussed below.

A.2 Source Term Assumed for Residual Risk Analysis

Under the proposed cleanup criteria, concentrations of thorium-232 and radium-226 (and their respective decay products) would not exceed 5 pCi/g above background in the surface 15-cm layer of soil or 15 pCi/g above background in any 15-cm layer below the surface layer. However, as noted above, clean surface fill will be used at all remediated properties, so the 5 pCi/g criterion for surficial soils would not be invoked; as discussed above, for the properties contaminated as a result of surface water migration along Lodi Brook, the depth of clean cover would typically be 1 to 2 meters. At properties where treated soils are replaced as subsurface backfill material, a minimum clean surface cover of at least 0.3 m (1 ft) will be provided. For the purpose of the residual risk evaluation, the 15 pCi/g residual concentration limit for radium and thorium in subsurface soils is assumed, allocated as indicated in Table A-1.

Table A-1. Assumed Residual Soil Concentrations

Radionuclide	Assumed Residual Soil Concentration Above Background (pCi/g)	
	Surface[a]	Subsurface
Th-232 + Progeny	0	12
Ra-226 + Progeny Th-230	0	3[b]
U-238 + Progeny, U-234	0	12[c]
U-235 + Progeny	0	0.6[d]

[a]Proposed remedy calls for clean surface fill at all remediated properties.
[b]Assumed 25% of Th-232 concentration, based on site characterization data.
[c]Assumed equal to Th-232 concentration, based on site characterization data.
[d]Assumed 5% of U-238 concentration, based on relative isotopic abundance.

This relative allocation is based on the relative magnitude of measured thorium-232, radium-226, and uranium-238 concentrations in soils at the Maywood site. The concentration of radium-226 is assumed to be approximately 25% of the thorium-232 concentration, based on a review of site characterization data (the radium-226:thorium-232 concentration ratio ranges from approximately 0.05 to 0.28 for residential properties, and from 0.005 to 0.26 for commercial/industrial properties, with a site-wide average of 0.23), and the composite concentration of radium-226 and thorium-232 is constrained to 15 pCi/g. Thorium-230 concentrations are assumed to be equivalent to radium-226 concentrations in soil. The 15 pCi/g limit is not applicable to uranium, for which a site-specific concentration limit is derived; however, a review of the site characterization data indicates that the uranium-238 concentration measurements in soil are similar to the thorium-232 concentrations (the uranium-238:thorium-232 ratio ranges from 0.35 to 1.7 for residential properties and from 0.14 to 3.3 for commercial/industrial properties, with a site-wide average of 1.0), and the concentration of uranium-238 and progeny is assumed to be equal to the residual thorium-232 concentration for evaluation of residual risk.

The residual radionuclide concentrations assumed for this analysis are considered to be extremely conservative based on an analysis of post-remediation characterization data at the vicinity properties cleaned up during 1984 and 1985. A review of these data indicate that residual concentrations of thorium-232 are generally below 5 pCi/g in the subsurface soils (i.e., in 1053 of the 1105 soil samples collected; average ≈ 2 pCi/g above background), and radium-226 and uranium concentrations are typically at or near background levels. Therefore, the source term considered in this analysis may be conservative by approximately a factor of 3 to 6. Furthermore, the residual radionuclide concentrations evaluated in this analysis are significantly higher than the pre-remediation radionuclide concentrations in soil as determined by the site characterization data; the site-wide upper 95% confidence limit mean soil concentrations are estimated as 4 pCi/g for thorium-232, 0.9 pCi/g for radium-226, and 4 pCi/g for uranium-238. Thus, the analysis of residual risks based on the upper bound of the soil concentration limit may overestimate the likely risks by a factor of 3 or more.

During Phase II of the remedial action for the Maywood site, excavated soils will be treated using a physical separation treatment process. Treated soils with residual radionuclide concentrations below 15 pCi/g for thorium-232 and radium-226 will be replaced as subsurface fill material at the MISS property, Stepan Company property, and possibly at adjacent commercial properties, whereas concentrated wastes from the treatment process will be transported for off-site commercial disposal. The 15 pCi/g treatment criteria is considered an upper bound, and treatment will be performed to levels as low as reasonably achievable, as determined by the technology capabilities and economics. Thus, the source term considered in this analysis for the treated replacement soils is also very conservative.

A.3 Residential Land Use Scenario

A.3.1 Exposure Assumptions

Exposure assumptions for the residual risk analysis were selected to maintain consistency with those previously approved by EPA in the Baseline Risk Assessment (DOE 1993c) where possible; parameters for which different assumptions were made to better reflect site-specific conditions are discussed below. Key parameter values assumed for the residual risk analysis are summarized in Table A-2. Parameter values assumed for site-specific geotechnical characteristics are summarized in Table A-3. As discussed below, the exposure assumptions are considered to be conservative, such that actual doses and risks are expected to be much lower than those estimated here.

Table A-2. Exposure Parameter Assumptions - Resident[a]			
Parameter	Units	Mean Resident	RME Resident
Exposure time indoors	h/d	16.4	16.4
Exposure time outdoors	h/d	0.44	0.44
Exposure frequency	d/yr	350	350
Exposure duration	yr	9	30
Area of exposure unit	m^2	300	300
Contaminated zone thickness	m	0.6	0.6
Depth of clean cover soil	m	0.15 - 1	0.15 - 1
Indoor gamma shielding factor Concrete floor slab Building walls	-	 0.3 0.85	 0.3 0.85
Inhalation rate	m^3/hr	0.62	0.83
Dust loading	μg/m^3	100	200
Dust from soil origin	%	50	50
Dust respirable fraction	%	30	30
Amount of outdoor dust present indoors	%	40	40
Soil ingestion rate	mg/d	60	100
Water ingestion rate	l/d	1.4	2.0
Fraction of drinking water from onsite well	-	1	1
Ingestion of home-grown produce	g/d	80	80

[a]The basis for assumed parameter values is discussed in the Baseline Risk Assessment (DOE 1993c), except as noted in text.

Table A-3. Site-Specific Geotechnical Assumptions[a]	
Parameter	Assumed Value
Contaminated zone total porosity	0.45
Contaminated zone hydraulic conductivity	1.23 m/yr (unsaturated)
Saturated zone total porosity	0.45
Saturated zone hydraulic conductivity	123 m/yr
Saturated zone hydraulic gradient	0.01
Unsaturated zone thickness	1 to 4.6 m (1 m assumed)
Unsaturated zone total porosity	0.45
Unsaturated zone effective porosity	0.26
Unsaturated zone hydraulic conductivity	1.23 m/yr
Precipitation Rate	1.07 m/yr
Runoff Coefficient	0.25
Dilution/Attenuation Factor [b]	100/500 ft
Soil-specific b parameter	5.3
Soil density	1.6 g/cm^3
Well pump intake depth	1 m
Soil erosion rate [c]	6 x 10^{-5} m/yr
Distribution coefficient, K_d [d]	Thorium - 60,000 Radium - 450 Uranium - 450 Lead - 900 Actinium - 1,500 Protactinium-2,500

[a]Assumed parameter values are taken from the Baseline Risk Assessment (DOE 1993c), except as noted.
[b]Radionuclide concentrations in groundwater are assumed to decrease by a factor of 100 for every 500 ft distance from the site.
[c]Reference: Yu et al. 1993b
[d]Reference: Baes et al. 1984; Sheppard and Thibault 1990

Site-specific data have been reviewed to better define the characteristics (area, depth, and thickness) of the contaminated zone that would be left following remediation. As noted previously, contaminated soils at most of the vicinity properties along the former course of Lodi Brook are located below substantial layers of clean fill material. Following excavation of contaminated soils, the excavation sites would be backfilled with clean soil (typically 1 to 3 m). For purposes of this analysis, it is conservatively assumed that 1 meter of clean fill would be emplaced over the residual contamination; results are also provided for a "minimum-cover" case, assuming a cover of only 0.15 m of clean fill. Site characterization data indicate that the area of the contaminated zone at the residential properties would be approximately 300 m^2, and the thickness of the residual contamination (i.e., the layer of soils with residual radionuclide concentrations below the 15 pCi/g criterion but above background) would be approximately 0.6 m. Surface soils are assumed to be subject to erosion, with an average erosion rate of 6×10^{-5} m/year (Yu et al., 1993b), representing a typical non-agricultural site with an average 2% slope.

Estimates of residual dose and risk are presented both for the conditions immediately following remediation, and also for the future time following remediation where the greatest residual risk is predicted, out to a period of 1000 years. While some further increases in residual dose and risk may be predicted at future times beyond 1000 years for some scenarios, the 1000-year period was selected as a reasonable maximum time horizon, as predictions at longer times become increasingly uncertain; impacts of different time horizons are discussed in the uncertainty analysis.

The effective shielding provided by buildings for the external gamma exposure pathway has been evaluated, based upon the actual gamma energies and intensities of the radionuclides of concern, various configurations of contaminated soil relative to the building, and the typical shielding provided by standard construction materials. For contaminated soils directly beneath buildings, an indoor shielding factor of 0.3 is assumed; this value represents the shielding that would be afforded by a 10-cm (4-in.) concrete slab (density=2.35 g/cm^3, half-value-layer [HVL]=6 cm for the maximum gamma energy of concern [Tl-208 2.6 MeV] and HVL=4 cm for the average gamma energy of the decay series [0.88 MeV]). Building walls are assumed to be less effective in shielding gamma radiation, with an effective indoor shielding factor of approximately 0.85, based on frame-siding construction; brick or masonary construction would provide additional shielding. Radiation shielding analyses have been performed using the MICROSHIELD (Grove 1992) computer code to support the shielding factors assumed for building floors and walls. Multiple configurations of contaminated soils relative to the location of the house were evaluated to ensure conservatism in the analysis, as depicted in Figure 1. Shielding geometry was analyzed by calculating the dose rate for a building occupant with contamination distributed beneath the building and outside the building using the RESRAD code. The results indicate that the dose rate is higher for the case with contamination directly beneath the building than for the case with the buiding covering only a portion of the contaminated area, i.e. allowing side shine radiation through walls. Thus for a given area of contamination, the reduction in dose rate due to increasing distance between the contaminated soils and the building is more important than the increase in dose rate due to the lower shielding afforded by the walls

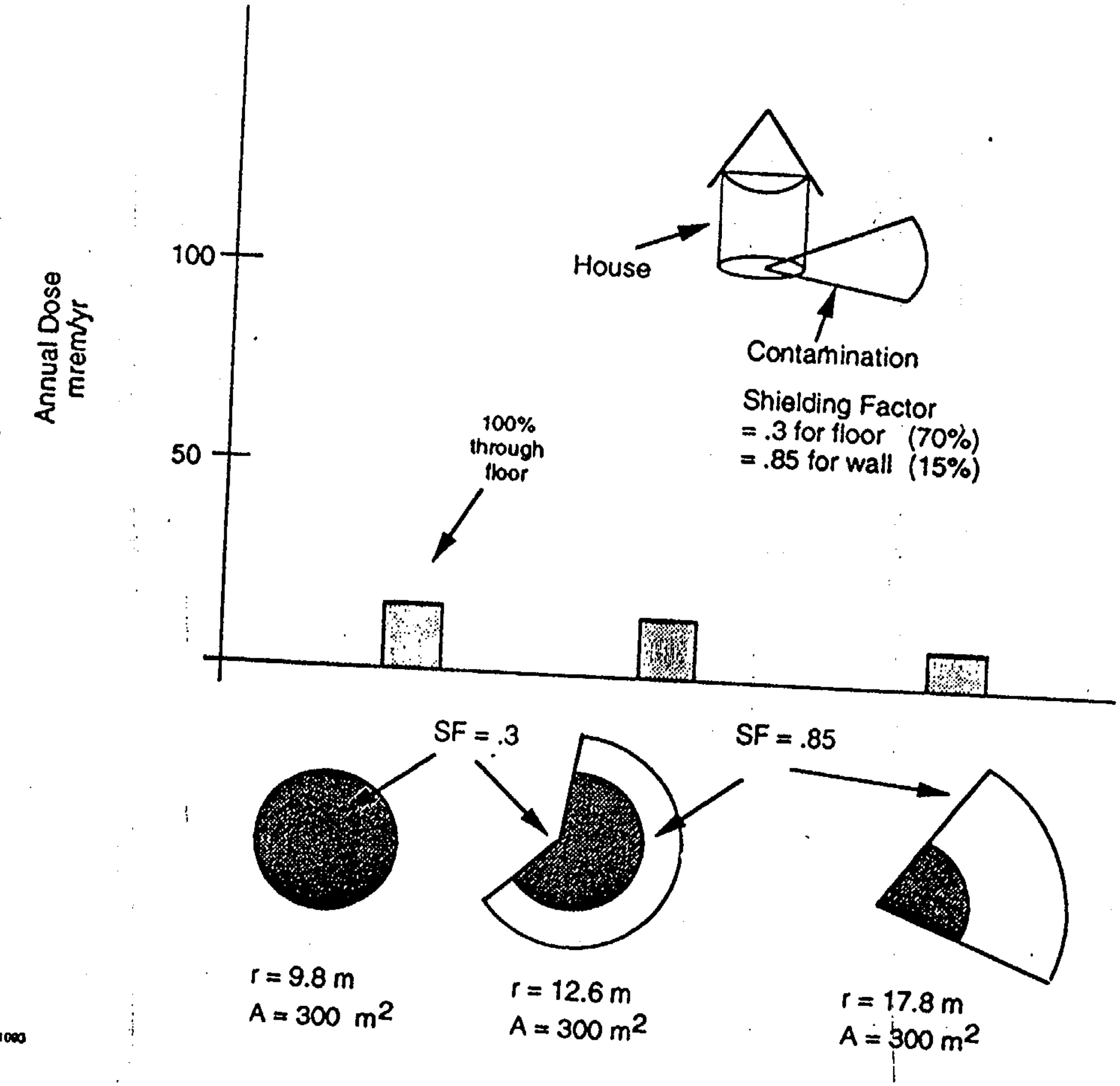


Figure 1. Comparison of Building Shielding Effects on External Gamma Dose Rate to an Indoor Receptor from Contaminated Soil Beneath and Outside the Building.

relative to the floor; these results are consistent with recent recommendations of the U.S. Nuclear Regulatory Commission (NRC 1992), which provide a default value of 0.33 for the indoor shielding factor. These results indicate that the location of contaminated soils beneath the structure provides a reasonable maximum exposure estimate, and this is the assumed configuration in the dose and risk estimates presented below.

A.3.2 Estimates of Dose and Risk

Estimates of total effective dose equivalent and lifetime excess cancer risk to potential residents at the site following completion of remedial action are summarized in Table A-4. Results of this analysis indicate that the total effective dose equivalent from the residual soil contamination will not exceed the primary dose limit of 100 mrem/year (DOE 1990), under expected (mean) and reasonable maximum exposure (RME) conditions. Furthermore, estimates of excess cancer risk are within EPA's target risk range of 10^{-6} to 10^{-4}. These estimates are based upon conservative assumptions, such that actual doses and risks are expected to be lower.

Table A-4. Estimated Dose and Risk from Residual Soil Contamination - Resident

Resident Scenario	Effective Dose Equivalent (mrem/year)	Lifetime Excess Cancer Risk
Expected-Condition[a]		
Mean	1.2 (1.5)[c]	1×10^{-6} (1×10^{-6})[c]
RME	1.2 (1.8)[c]	6×10^{-6} (6×10^{-6})[c]
Minimum-Cover[b]		
Mean	16 (21)[c]	4×10^{-5} (6×10^{-5})[c]
RME	16 (22)[c]	1×10^{-4} (2×10^{-4})[c]

[a]Expected condition: 1 meter clean cover over residual contamination.
[b]Minimum-cover conditions: 0.15 m clean cover over residual contamination.
[c]First value represents time=0; parenthetical value is maximum dose/risk over the period of analysis (t=1000 years), if different from t=0.

Under expected conditions, the 1-meter clean soil cover over residual contaminants significantly limits potential exposure pathways. Direct gamma exposure is effectively shielded by the uncontaminated surficial soils and only small quantities of radon are released through the surface soils to contribute to the effective dose equivalent; at distant times groundwater ingestion is predicted to become the dominant exposure pathway. Under the assumed minimum-cover conditions (i.e., 0.15 m clean soil cover over contaminated zone), external gamma exposure is the dominant exposure pathway (~70%), with a significant contribution from ingestion of homegrown produce from a home garden (~29%); the later contribution to dose is due almost exclusively to lead-210 and is considered to be particularly conservative. Since the exposure parameters impacting the external dose rate estimates do not differ for the mean and RME conditions, the mean and RME estimates of effective dose equivalent are not significantly different; differences in mean and RME estimates of excess cancer risk are more pronounced due to the different exposure durations.

A.3.3 Intrusion

Potential dose and risk which might result from intrusion into the residual contaminated soil during construction activities at the affected properties was also evaluated. For the residential properties, this analysis considered excavation of a basement of assumed dimensions 9 m x 12 m x 2 m (30 ft x 40 ft x 6.5 ft), as depicted in Figure 2. Excavated soils were assumed to be spread on the ground surface surrounding the excavation site, with an average depth of approximately 0.3 m (1 ft) over an area of approximately 1000 m^2 (0.25 acre). Since the thickness of the contaminated zone at the residential properties is small relative to the depth of excavation, the radionuclide concentrations in the residual soils would be mixed with the uncontaminated cover material and clean soil beneath the contaminated zone. This effect would apply to both cover depths considered in Section A.3.2, and the estimated dose and risk are not significantly different for either cover scenario. Surface cover by clean topsoil would likely be added to support vegetation; such a topsoil layer would provide some reduction in predicted exposure rates and resultant risks, but was not considered in this analysis.

Predicted dose rates and residual risks to a resident at this property are summarized in Table A-5. The maximum dose rate and risk are predicted to occur immediately following remediation for both the mean and RME receptor conditions. External gamma exposure is predicted to be the dominant exposure pathway (~85%), with smaller contributions from the plant ingestion, particulate inhalation, soil ingestion, and radon inhalation pathways. The predicted dose rate is well below the primary dose limit of 100 mrem/year, and the residual risk estimate is still within EPA's target risk range. These estimates are considered to be highly conservative, due to the assumptions of spreading all excavated soils at the ground surface (as opposed to use as subsurface fill in some areas) and the assumed absence of a clean topsoil cover.

Table A-5. Estimated Dose and Risk from Residential Basement Excavation Scenario

Receptor Scenario	Effective Dose Equivalent (mrem/year)	Lifetime Excess Cancer Risk
Resident		
Mean	23	7×10^{-5}
RME	24	2×10^{-4}

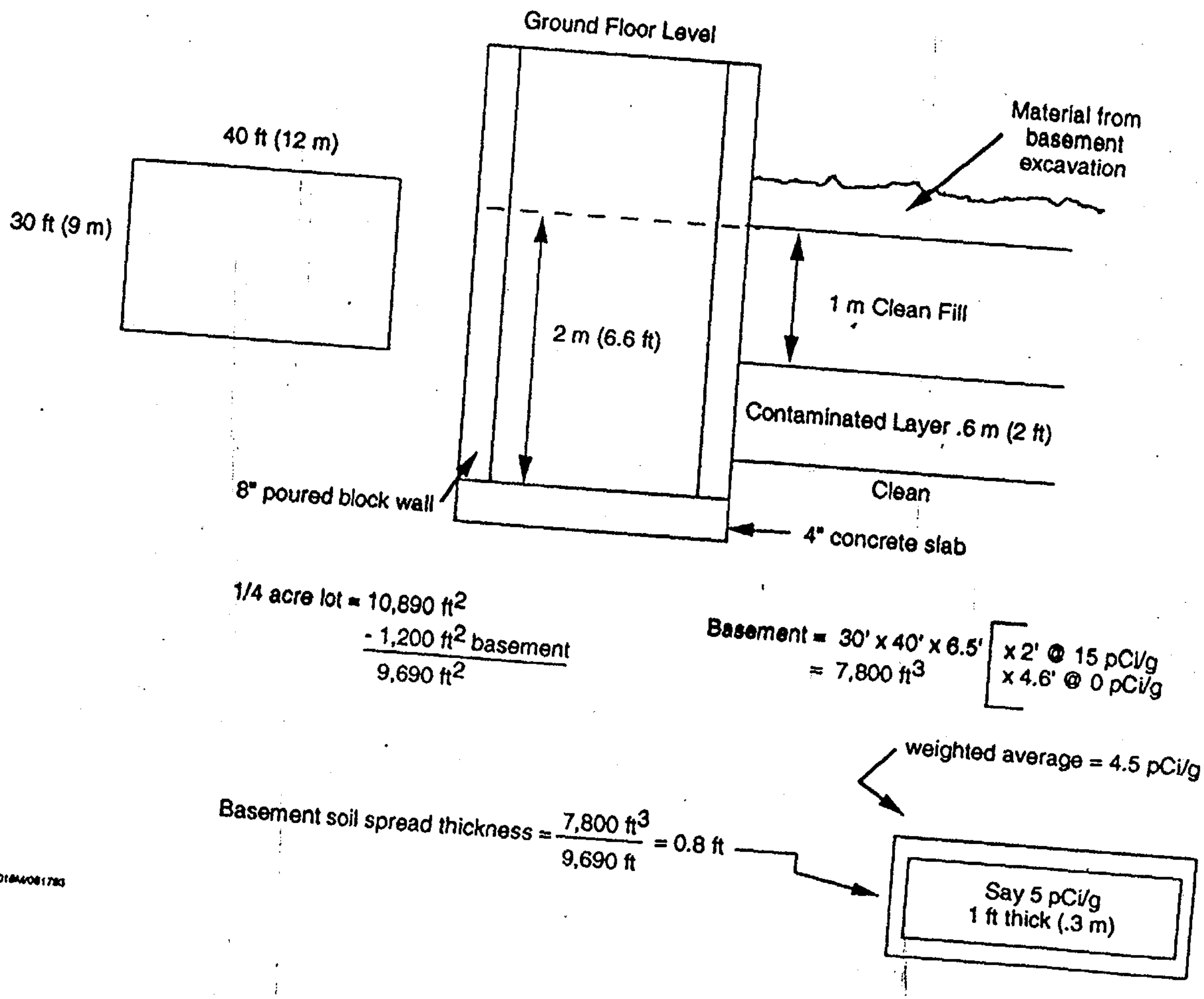


Figure 2. Intrusion Scenario for Residential Vicinity Properties - Basement Excavation/Redistribution.

A.4 Commercial/Industrial Land Use Scenario

A.4.1 Exposure Assumptions

As noted in Section A.1 and discussed in the Baseline Risk Assessment, future residential land use was not considered for the MISS, Stepan, and adjacent heavily industrial/commercial properties. Therefore, a commercial/industrial land use scenario was evaluated for these properties. As for the case of the residential land use scenarios, exposure assumptions for the residual risk analysis for these properties were selected to maintain consistency with those previously approved by EPA in the Baseline Risk Assessment (DOE 1993c) where possible, with some changes to better reflect site-specific conditions as discussed below. Parameter values assumed for the residual risk analysis for these properties are summarized in Table A-6. Geotechnical parameters are the same as for the residential scenario (Table A-3).

The characteristics of the contaminated zone that would be left following remediation are considerably different for some of the commercial/industrial properties. The proposed remedy calls for excavation of contaminated soils, treatment using a physical separation technology, and replacement of treated soils on-site as subsurface backfill, which would be covered by 0.3 m (1 ft) of clean soil. For purposes of this analysis, the contaminated zone is assumed to be 1000 m^2 in area, with a thickness of 2 m. While the actual areas of residual contamination at some locations may be slightly larger, these values are considered to adequately characterize the exposure area for a given employee. Further, the analysis of residual risk is very insensitive to further increases in the areal extent and thickness of the contaminated zone beyond these levels. Under the expected conditions, residual soils are assumed to be covered by clean fill to a depth of 0.3 m (1 ft); a mimimum-cover scenario is also evaluated assuming a clean cover depth of 0.15 m (6 in.).

The average erosion rate assumed for the commercial/industrial scenario is the same as that for the residential scenario, at 6×10^{-5} m/year (Yu et al., 1993b), representing a typical non-agricultural site with an average 2% slope.

The effective shielding provided by buildings is also considered in the same manner as for the residential scenario, with effective shielding factors of 0.3 for the floors and 0.85 for the remainder of the structure, as discussed in Section A.3.1.

A.4.2 Estimates of Dose and Risk

Estimates of total effective dose equivalent and lifetime excess cancer risk to potential employees at the site following completion of remedial action are summarized in Table A-7. Results of this analysis indicate that the total effective dose equivalent from the residual soil contamination will not exceed the primary dose limit of 100 mrem/year (DOE 1990), under expected (mean) or reasonable maximum exposure (RME) conditions. Furthermore, estimates of excess cancer risk are within the EPA's target risk range of 10^{-6} to 10^{-4}. These estimates are based upon conservative assumptions, and actual doses and risks are expected to be lower.

Table A-6. Exposure Parameter Assumptions - Employee[a]			
Parameter	Units	Mean Employee	RME Employee
Exposure time indoors	h/d	7	7
Exposure time outdoors	h/d	1.75	1.75
Exposure frequency	d/yr	250	250
Exposure duration	yr	7	25
Area of exposure unit	m^2	1000	1000
Contaminated zone thickness	m	2	2
Depth of clean cover soil	m	0.15 to 0.3	0.15 to 0.3
Indoor gamma shielding factor Concrete floor slab Building walls	-	 0.3 0.85	 0.3 0.85
Inhalation rate	m^3/hr	1.875	2.5
Dust loading	$\mu g/m^3$	100	200
Dust from soil origin	%	50	50
Dust respirable fraction	%	30	30
Amount of outdoor dust present indoors	%	40	40
Soil ingestion rate	mg/d	30	50
Water ingestion rate	l/d	0.7	1.0
Fraction of drinking water from onsite well	-	1	1
Ingestion of home-grown produce	g/d	-	-

[a]The basis for assumed parameter values is discussed in the Baseline Risk Assessment (DOE 1993c), except as noted in text.

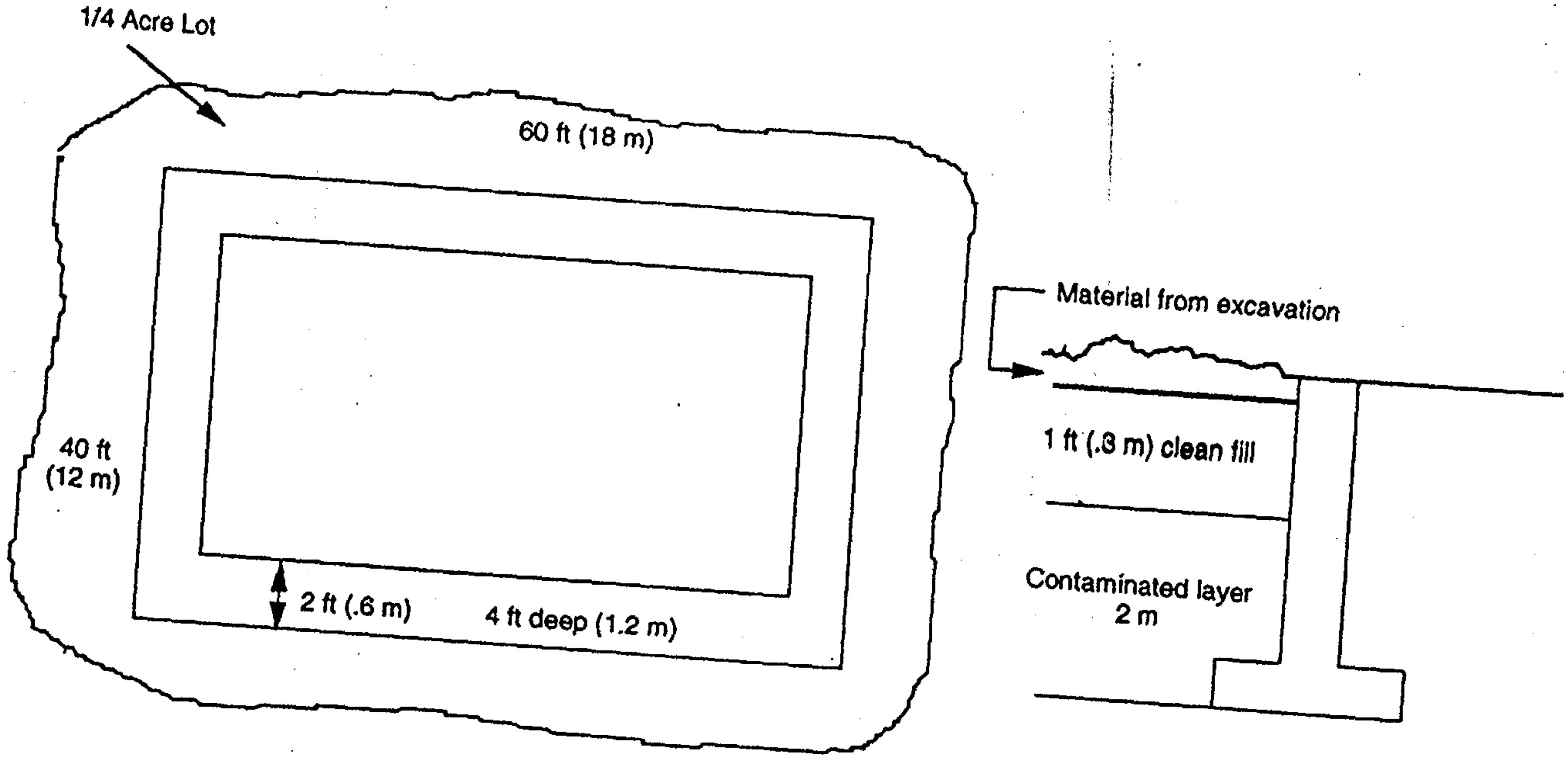
Table A-7. Estimated Dose and Risk from Residual Soil Contamination - Employee		
Employee Scenario	Effective Dose Equivalent (mrem/year)	Lifetime Excess Cancer Risk
Expected Conditions[a]		
Mean	2 (4)[c]	6×10^{-6} (1×10^{-5})[c]
RME	2 (4)[c]	2×10^{-5} (4×10^{-5})[c]
Minimum-Cover[b]		
Mean	8 (14)[c]	2×10^{-5} (4×10^{-5})[c]
RME	8 (15)[c]	8×10^{-5} (1×10^{-4})[c]

[a]Expected conditions: 0.3 m (1 ft) clean cover over residual contamination.
[b]Minimum-cover: 0.15 m (6 in.) clean soil over residual contamination.
[c]First value represents time=0; parenthetical value is maximum dose/risk over the period of analysis (t=1000 years), if different from time=0.

As shown in Table A-7, estimates of potential doses and excess cancer risks to workers at the properties containing residual contamination are well below the DOE's primary dose limit of 100 mrem/year in all cases, and within the EPA's target risk range. For the expected conditions, the cover depth of 0.3 m (1 ft) makes residual contaminants relatively unaccessible via most exposure pathways; at early times, external gamma radiation and radon emanation are predicted to be the dominant exposure pathways (~82% and ~18%, respectively), while the groundwater ingestion pathway is predicted to also become a significant contributor at distant times (~8%). Under the assumed minimum-cover conditions (i.e., 0.15 m clean soil cover over contaminated zone), external gamma exposure is the dominant exposure pathway (~95%). Again, mean and RME estimates of effective dose equivalent are not significantly different, but mean and RME risk estimates differ primarily due to the difference in exposure duration assumptions.

A.4.3 Intrusion

Potential dose and risk which might result from intrusion into the residual contaminated soil during construction activities at the affected properties was also evaluated. For the commercial/industrial properties, this analysis considered excavation of a perimeter foundation of assumed dimensions 12 m x 18 m x 1.2 m (40 ft x 60 ft x 4 ft), as depicted in Figure 3. Excavated soils were assumed to be spread on the ground surface surrounding the excavation site, with an average depth of approximately 0.05 m (2 in.) over an area of approximately 1000 m^2 (0.25 acre). Since the thickness of the contaminated zone at the commercial/industrial properties is large relative to the depth of excavation, the mixing with uncontaminated soils during excavation will be less than that for the residential properties; for the expected conditions of a 0.3 m (1 ft) cover over the residual contaminated soils, the 4-ft depth of excavation would



Perimeter volume

$2' \times 4' \times 200' = 1600\ ft^3$

1/4 acre = 10,890 ft^2

$$\frac{1{,}600\ ft^3}{10{,}890\ ft^2} = 0.147\ ft$$

= 1.76 inch thick layer to be placed on surface
Say 2 in (0.05 m) thick

FUS018M/081080

Figure 3. Intrusion Scenario for Commercial/Industrial Properties - Perimeter Foundation Excavation/Redistribution.

include the 1-ft cover layer and the top 3-ft of the contaminated zone. As discussed for the residential basement excavation analysis in Section A.3.3, it is likely that topsoil would be added to support vegetation, but the reduction in dose and risk provided by this clean cover material was not considered in this analysis.

Predicted dose rates and residual risks to an employee at this property are summarized in Table A-8. The predicted dose rate is well below the primary dose limit of 100 mrem/year, and the residual risk estimate is within the EPA's target risk range. External gamma exposure is the dominant exposure pathway (>90%) and the particulate inhalation and radon inhalation pathways provide smaller additional contributions to dose and risk. These estimates are considered to be highly conservative, due to the assumptions of spreading all excavated soils at the ground surface (as opposed to use as subsurface fill in some areas) and the assumed absence of a clean topsoil cover.

Table A-8. Estimated Dose and Risk from Commercial Foundation Excavation Scenario

Receptor Scenario	Effective Dose Equivalent (mrem/year)	Lifetime Excess Cancer Risk
Employee		
Mean	10	3×10^{-5}
RME	10	9×10^{-5}

A.5 Uncertainty Analysis

As noted above, and discussed at greater length in the Baseline Risk Assessment, the exposure assumptions used to predict these potential radiation doses are considered highly conservative. In addition to the parameters addressed in the Baseline Risk Assessment, the characteristics of the residual contaminated zone assumed for this analysis are considered to be very conservative - i.e., a subsurface layer 0.6 to 2 meters thick with soil contaminated at the upper bound of the subsurface residual concentration limit; in reality, such a thick layer of soil homogeneously contaminated at this level is highly unlikely, based on a review of site-specific borehole data and results of previous remedial actions at this and similar sites. Similarly, the assumed lateral extent of the contaminated zone is considered to be conservative; at most properties, residual contamination would be much more localized.

The residual radionuclide concentrations assumed for this analysis are considered to be particularly conservative. As noted in Section A.2, post-remediation characterization data for the 25 vicinity properties already remediated at the Maywood site found residual radionuclide concentrations below 5 pCi/g above background at most sampling locations, with an average of approximately 2 pCi/g above background for thorium-232. Furthermore, based on the available site characterization data, the mean and RME radionuclide concentrations assumed for the evaluation of baseline (pre-remediation) risks in the Baseline Risk Assessment (DOE 1993c) were lower than the proposed residual criteria for most properties (i.e., the site-wide upper 95% confidence level soil concentrations are estimated as 4 pCi/g for thorium-232, 0.9 pCi/g for radium-226, and 4 pCi/g for uranium-238). Thus, the source term considered in this analysis of residual risk is highly conservative, and actual dose rates and risks to current and future receptors are expected to be much lower. Similarly, the source term considered for the treated soils to be placed at the MISS, Stepan, and possibly adjacent properties as subsurface fill material is set at the upper bound of the acceptable residual radionuclide concentrations, and treatment to lower residual concentrations is anticipated. Despite this conservatism, doses are not predicted to exceed the 100 mrem/year limit, and lifetime excess cancer risks are estimated at the upper boundary of the target risk range.

The prediction of potential radiation dose and excess cancer risks at distant future times is highly uncertain. For this analysis, a time horizon of 1000 years has been considered, consistent with the provisions in 40 CFR 192 regulations for radium and thorium sites. For several of the exposure scenarios considered in this analysis, larger dose rates and risks may be predicted at future times beyond 1000 years. However, in all cases, the maximum predicted dose rates are below the primary dose limit of 100 mrem/year, and predicted excess cancer risks do not exceed the 10^{-4} level.

Additional verification of the protectiveness of the cleanup criteria for the Maywood site will be provided following completion of the remedial action. Post-remediation site characterization data will be collected by DOE's Independent Verification Contractor to confirm that the cleanup criteria have been achieved. These data will also be used to reevaluate dose rates and potential risks at the site to ensure that human health and the environment will be adequately protected.

For purposes of comparison, radiation exposure from natural sources of radioactivity results in an annual effective dose equivalent of approximately 300 mrem/year (NCRP 1987). The radiation dose associated with potential exposures to residual contaminants at the Maywood site is estimated to be significantly less than that from natural background radiation exposure.

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ATTACHMENT B

ALARA Analysis for Cleanup Criteria for the Maywood Site

(Revision 0 - September 28, 1993)

ALARA Analysis for Cleanup Criteria for the Maywood Site

The preferred alternative for the Maywood site is a phased action, where soils contaminated above the specified criteria would be excavated and the disposition of the excavated materials would differ for different phases of the project. During Phase I, contaminated soils from the residential vicinity properties and the Maywood Interim Storage Site (MISS) waste pile would be excavated and shipped off-site for commercial disposal. This action would be immediately followed by Phase II, which would consist of excavating contaminated soils at the remaining properties and treatment of the excavated soils using a physical separation treatment process. The concentrated residuals from the treatment process would be shipped off-site for commercial disposal, while the treated soils (i.e., with residual radionuclide concentrations below specified criteria) would be used as subsurface fill material at the MISS and Stepan properties (and possibly adjacent commercial properties, as necessary).

The cleanup criteria proposed by DOE in the "Proposed Plan for the Maywood Site" require excavation of soils with concentrations of thorium-232 (the principal contaminant at this site) and/or radium-226 greater than 5 pCi/g above background concentrations averaged over the surface 15-cm layer of soil, and 15 pCi/g above background averaged over any 15-cm layer below the surface layer, averaged over any area of 100 m^2. These criteria are specified as generic guidelines for residual radioactive material in soil in DOE Order 5400.5, as well as in the Uranium Mill Tailings Radiation Control Act regulations promulgated in 40 CFR 192. In accordance with requirements of DOE Order 5400.5, additional analyses have been conducted to optimize the cleanup criteria and ensure that radiation exposures associated with the Maywood site are as low as reasonably achievable (ALARA), taking into account technical, economic, and social considerations.

Table 1 presents a summary of the estimated costs and radiation doses associated with various cleanup criteria for the preferred alternative for the site, as well as for the No Action alternative. Estimates of individual dose following remediation are taken from the "Assessment for Residual Radioactive Contamination at the Maywood Site (Revision 2, August 23, 1993)", and represent the effective dose equivalent to the reasonable maximum exposure (RME) receptor under expected post-remediation conditions. Dose estimates for the 30 pCi/g and 5 pCi/g alternative cleanup criteria were computed using identical exposure assumptions, with the exception of the assumed residual soil concentration. Individual dose estimates for the No Action alternative are taken from the "Baseline Risk Assessment for the Maywood Site" (future-use RME receptors). Estimates of dose to the remedial action worker are taken from the "Feasibility Study-Environmental Impact Statement for the Maywood Site". In each case, conservative, reasonable maximum, assumptions were used to define the site-specific exposure conditions and the dose to potential receptors.

For each alternative considered, the collective dose was estimated by multiplying the individual dose estimates by the approximate number of persons subject to exposure at each property: for the 31 residential properties and 4 municipal park properties, future residential exposure was assumed, with an average household of 4 persons; for the 24 commercial/industrial properties, a worker exposure scenario was evaluated, assuming an average of 20 employees per property; and an average work force of 20 remedial action workers in the contaminated area during remediation was assumed. An integration period of 200 years was assumed for the collective dose estimates.

As indicated in Table 1, radiation exposures under baseline conditions at the Maywood site (pre-remediation) are estimated to yield an annual effective dose equivalent of 12 to 2800 mrem/year for potential receptors at specific property units (8 property units, and 3 additional subunits, are evaluated in the Baseline Risk Assessment) under reasonable maximum exposure conditions and future land use scenarios. Under expected conditions following remediation to the 15 pCi/g criterion, RME doses are estimated at approximately 1.8 mrem/year for residential properties and 4.1 mrem/year for commercial/industrial properties. (Residual dose estimates for residential properties are lower primarily because the extent of contamination is more limited than at some of the commercial/industrial properties, and occurs are greater depths below the ground surface; in addition, at the MISS and Stepan properties, and possibly some adjacent commercial/industrial properties, relatively large volumes of treated soils with low levels of residual radionuclides below treatment criteria, would be replaced on-site as subsurface fill material.) Under "minimum-cover" conditions, where soils with residual radionuclide concentrations of 15 pCi/g (thorium-232 + radium-226) are assumed to be covered by only 15 cm of clean soil, the RME dose is estimated at 22 mrem/year for residential properties and 15 mrem/year for commercial properties. Intrusion scenarios, involving excavation into the contaminated zone during construction activities, also have been evaluated, with estimated RME doses of 24 mrem/year for residential properties and 10 mrem/year for commercial/industrial properties. Additional discussion of exposure assumptions and parameters is provided in the "Assessment for Residual Radioactive Contamination at the Maywood Site (Revision 2, August 23, 1993)". Calculations for the alternative cleanup criteria of 5 pCi/g and 30 pCi/g for subsurface soils are conducted in an analogous manner, with the only change being the assumed residual radionuclide concentrations; in each case, for the purpose of this analysis, it is assumed that the concentration limit for replacement of treated soils is the same as the specified soil cleanup criterion.

Cost estimates for the No Action alternative and Phased Action with the 15 pCi/g cleanup criterion for subsurface soils are taken from the "Feasibility Study-Environmental Impact Statement for the Maywood Site" (Alternatives 1 and 6E in the FS-EIS, respectively). Cost estimates for the 30 pCi/g and 5 pCi/g subsurface soil criteria presented here assume that costs would scale linearly with changes in estimated waste volume. The increase in cost resulting from a change in the cleanup criterion for subsurface soils from 15 pCi/g to 5 pCi/g is estimated in the range $30-$120 million, as a result of an increase in waste volume of 20% to 80%. Unit cost for treatment of soils to the 5 pCi/g performance criterion is likely to exceed that for the 15 pCi/g criterion per unit waste volume, but this increased unit cost currently is not well defined; however, this effect may be offset by other cost elements (e.g., environmental monitoring, personnel training/monitoring, 5-year reviews) which may not increase significantly with increasing waste volumes. Therefore, the assumed linear relationship appears to be a reasonable assumption. Similarly, the cost estimate for remediation to a 30 pCi/g cleanup criterion is estimated to be approximately 56% of the cost for remediation to 15 pCi/g, or approximately $77 million. The $16 million cost estimate for the No-Action alternative results from assumed continuing environmental monitoring ($480,000/year) and 5-year remedy reviews ($200,000 each) for a period of 30 years; no continuing site maintenance or institutional controls are assumed.

Based on the estimates of cost and collective dose associated with each cleanup criterion as presented in Table 1, the approximate cost per person-rem avoided was computed, as presented in Table 2. Remediation of the site using a cleanup criterion of 30 pCi/g is estimated to result in a net reduction in collective dose relative to the No Action case by approximately 11,000 person-rem over a 200-year integration period (approximately 54 person-rem/year); the associated incremental cost is approximately $61 million (i.e, the $77 million estimated cost for this alternative minus the $16 million cost estimate for the No Action alternative), or approximately $5,500 per person-rem avoided. Further remediation to DOE's proposed cleanup criterion of 15 pCi/g is estimated to produce a dose reduction of approximately 440 person-rem over 200 years (2.2 person-rem/year), at an incremental cost of $61 million, or $140,000 per person-rem avoided. Further reduction to an alternative cleanup criterion of 5 pCi/g at all depths is estimated to produce an additional dose reduction of approximately 280 person-rem over the assumed 200-year period of integration (1.4 person-rem/year) at an additional cost of $30-120 million, or $110,000 to $430,000 per person-rem avoided. Table 2 also presents the cost per predicted reduction in excess cancer incidence, assuming a risk factor of 6×10^{-4} lifetime excess cancer risk (fatal + nonfatal cancers) per person-rem; resulting estimates of cost per excess cancer avoided exceed several million dollars.

Estimates of non-radiological risks associated with remediation of the Maywood site are presented in Table 3. These include accident risks to remedial action workers (i.e., risk of fatal accidents during excavation, construction, treatment, and material handling activities) and transportation risks (i.e., the risk of fatal accidents during transport of materials to and from the site). Transportation risks include risks associated with transport of waste from the site to a commercial disposal site by rail, and transportation of borrow soil from an off-site borrow area to the site; both waste volumes and borrow soil volumes are assumed to be directly proportional to the estimated soil volumes requiring excavation under each cleanup criterion. Non-radiological risks are estimated to increase with decreasing cleanup criteria, due to the increased volume of material requiring excavation, handling, and transportation for disposal; in each case, truck transportation of borrow soil to the site is estimated to be the predominant non-radiological risk, due to the relatively higher accident rates for road versus rail travel.

Based on this analysis, it is evident that the collective dose associated with the Maywood site is relatively low, and that the cost for reduction of this dose to lower levels is high. As a point of comparison, a typical criterion used by the nuclear industry as the upper limit for cost-effective dose reduction is approximately $1,000 per person-rem avoided. In this analysis, only remediation to a 30 pCi/g cleanup criterion approaches this measure of cost-effectiveness, whereas remediation to lower residual radionuclide concentrations is clearly outside this range. While the estimation of both individual and collective dose contains numerous uncertainties, an increase of two to three orders of magnitude in the dose estimates would be necessary to bring these estimates of cost per dose avoided below the typical benchmark. Thus, while remediation of subsurface soils to the 15 pCi/g criterion, as proposed by DOE, is required to comply with DOE Order 5400.5 generic guidelines, no further reduction in cleanup criteria appears to be justified based on benefit-cost considerations.

However, it is important to recognize that the proposed remedy also includes additional ALARA considerations during field implementation, such that the degree of remediation actually achieved is very likely to significantly exceed the specified guidelines. Due to the inherent uncertainties in field measurements to delineate the boundaries of contamination above the specified criteria and the imprecise nature of field excavation equipment, excavation of suspect contaminated soils continues until residual concentrations well below the target levels are achieved. Such practices are prudent due to the high costs for remobilization to remove additional soils at some later time. Given the large number of properties comprising the Maywood site and their different physical characteristics, decisions regarding cost-effective reductions in residual concentrations below the specified criteria can be made most effectively in the field during implementation of the remedy. The effectiveness of this approach is demonstrated by the post-remediation verification data collected for the 26 vicinity properties previously remediated at the Maywood site - i.e., although the cleanup criterion for subsurface soils was 15 pCi/g, measured concentrations of thorium-232 following remediation were below 5 pCi/g above background in over 95% of samples (i.e., in 1053 of 1105 soil samples collected, with an average thorium concentration of approximately 2 pCi/g above background), and radium-226 and uranium concentrations were generally at or near background levels.

In the context of DOE's ALARA policy, the predetermined cleanup criteria for a remedial action are considered as upper limits only, and the actual level of remediation attained may be significantly greater. DOE is committed to pursuing an aggressive ALARA program throughout the remediation of the Maywood site, which would include removal of soils contaminated below predetermined cleanup criteria in situations where incremental costs are reasonable and risks to remedial action personnel are low. The combination of the proposed cleanup criteria in concert with this active ALARA program throughout implementation of the remedial action provides a high level of protectiveness in the most cost-effective manner.

Table 1. Predicted post-remediation radiation dose.

Remedial Action Alternative & Cleanup Criteria	Cost[a] ($ Million)	Residual Dose		Remediation-Worker Dose	
		Individual (mrem/yr)	Collective (person-rem)[b]	Individual (mrem/yr)	Collective (person-rem)[b]
No Action	$16	12 - 2800	12,000	-	-
Phased Action 30 pCi/g	$77	3.6 (Res)[c] 8.2 (Com)[d]	880	100	18
Phased Action 15 pCi/g	$138	1.8 (Res)[c] 4.1 (Com)[d]	440	100	24
Phased Action 5 pCi/g	$168-258	0.6 (Res)[c] 1.4 (Com)[d]	160	100	30

[a]Detailed cost analysis is presented in the Feasibility Study for the No Action alternative and Phased Action with the 15 pCi/g (Alternative 6E) cleanup criterion for subsurface soils. Cost estimates for the 30 pCi/g and 5 pCi/g subsurface soil criteria assume that costs would scale linearly with changes in estimated waste volume: 20% to 80% increase in waste volume is estimated to result from changing the cleanup criterion for subsurface soils from 15 pCi/g to 5 pCi/g, whereas the estimated waste volume for the 30 pCi/g criterion is 56% of that for 15 pCi/g. The No-Action alternative cost results from assumed continuing environmental monitoring ($480,000/year) and 5-year remedy reviews ($200,000 each) for a period of 30 years; no continuing site maintenance or institutional controls are assumed.

[b]An integration period of 200 years is assumed in the estimates of collective dose from residual radioactivity exposures; in the estimates of collective dose to remediation workers, the implementation times for remedial action of 9, 12, and 15 years are assumed for the 30 pCi/g, 15 pCi/g, and 5 pCi/g cleanup criteria, respectively.

[c]Estimate for expected conditions following remediation at residential properties.

[d]Estimate for expected conditions following remediation at commercial/industrial properties.

Table 2. Estimated cost for dose/risk avoidance.

Cleanup Criteria (pCi/g)	Incremental Cost ($ Million)	Collective Dose Reduction (person-rem)	Cost per Dose Reduction ($ per person-rem)	Cost per Excess Cancer Avoided[a] ($ per cancer avoided)
No Action	$16	-	-	-
30 pCi/g	$61	11,000	$ 5,500	$ 9 Million
15 pCi/g	$61	440	$ 140,000	$230 Million
5 pCi/g	$30-120	280	$110,000 - 430,000	$180-720 Million

[a]Assumes 6 x 10^{-4} lifetime excess cancer incidence per person-rem.

Table 3. Estimated non-radiological risks from site remediation.

Remedial Action Alternative & Cleanup Criteria	Transportation Accident Risk[a] (fatalities)	Remediation Worker Accident Risk (fatalities)
No Action	-	-
Phased Action 30 pCi/g	0.004 rail 0.1 truck	0.005
Phased Action 15 pCi/g	0.007 rail 0.2 truck	0.009
Phased Action 5 pCi/g	0.009 - 0.01 rail 0.2 - 0.4 truck	0.01 - 0.02

[a]Transportation risks include risks associated with transport of waste from the site to a commercial disposal site by rail, and transportation of borrow soil from an off-site borrow area to the site. Both waste volumes and borrow soil volume requirements are assumed to be directly proportional to the estimates of soil volume requiring excavation under each cleanup criterion.