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RADIONUCLIDE CLEANUP GUIDELINE DERIVATION FOR ASHLAND 1, ASHLAND 2, AND SEAWAY

TONAWANDA, NEW YORK

SEPTEMBER 1997

U.S. Department of Energy
Oak Ridge Operations Office
Formerly Utilized Sites Remedial Action Program

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prepared by
U.S. Department of Energy, Oak Ridge Operations Office, Formerly Utilized Sites Remedial Action Program

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ACRONYMS AND ABBREVIATIONS

Ac	actinium
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
cm	centimeter(s)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
CFR	Code of Federal Regulations
DOE	Department of Energy
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
g	gram(s)
L	liter
m^2	square meter(s)
μ	micro
mg	milligram(s)
mrem	millirem(s)
pCi	picocuries
Pa	protactinium
Ra	radium
RI	Remedial Investigation
RME	reasonable maximum exposure
Rn	radon
TAGM	Technical Administrative Guidance Memorandum
Th	thorium
U	uranium
UCL_{95}	upper 95 percent confidence level
U. S.	United States
WL	working level
yr	year(s)

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EXECUTIVE SUMMARY

Background

This report describes the process used to develop site-specific cleanup guidelines for the Tonawanda site in Tonawanda, NY. This site is part of the U.S. Department of Energy's (DOE's) Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established under the authority of the Atomic Energy Act (AEA) to identify, evaluate, and if necessary, clean sites formerly associated with this nation's early atomic research program. As part of this program, site-specific cleanup guidelines were derived for the Tonawanda site using the following key assumptions developed through extensive stakeholder input.

- No onsite disposal cell will be constructed at the Tonawanda site.
- The final cleanup will be consistent with and permit full completion of the planned use of the properties as indicated in the Waterfront Region Master Plan for the Town of Tonawanda.
- Residual soil concentration guidelines will be developed based on planned land use of the Tonawanda site (primarily commercial/industrial), with consideration of Federal cleanup standards as well as New York State Department of Environmental Conservation (NYSDEC) guidelines.

Initially the guideline derivation evaluated the site on the basis of expected future land use (based on the Town of Tonawanda Waterfront Master Plan), and the expected remedial action strategy. At that time the proposed remedial action strategy involved excavation of the most contaminated soils, and then recontouring the site and mixing the remaining soils so that a relatively homogenous layer of soil containing less than 40 pCi/g Th-230 remained at the site. This strategy also employed use of a clean cover layer for supporting vegetation, and this cover layer was considered in the dose calculations for the industrial worker.

After review of the proposed cleanup guideline and remediation strategy by the New York Department of Environmental Conservation (NYDEC) and other stakeholders, concerns were expressed over both the concept of mixing or "blending" soils, and the use of cover in the dose calculations without some provision (such as institutional controls or land use restrictions) for ensuring that the cover remained in place. After consideration of these issues, DOE has proposed a modified remediation strategy that does not incorporate blending; the use of cover has also been eliminated from the dose calculations for the modified remediation strategy. This modified strategy utilizes the same cleanup guideline of 40 pCi/g for Th-230. However, unlike the previous proposal, the current remediation plan would involve excavation and offsite disposal of all soils containing Th-230 at 40 pCi/g or greater. The net result of such excavation is that the residual average Th-230 concentration after remedial action would be expected to be well below the 40 pCi/g cleanup criteria, and low enough so that all applicable dose constraints can be met without consideration of clean cover in the dose calculations. Also, unlike the previous strategy, no soil management system or blending

operation would be necessary to assure that the soils remaining at the site met the cleanup guideline. This revised remediation strategy involves removal of approximately twice the volume of soil as the previous remediation proposal.

This report summarizes the results of the dose calculations to support the remedial action decision-making at the Tonawanda site. It provides an assessment of doses under both the original proposed remediation approach (Approach 1), including consideration of cover, and under the current proposed remediation approach (Approach 2), without consideration of cover. Much of the original rationale for selection of 40 pCi/g Th-230 as the cleanup guideline is still valid even with the change in remediation strategy. In addition, under the new remediation strategy it is possible that localized areas of up to 40 pCi/g Th-230 could remain at the site (however these will not be widespread uniform areas as under Approach 1). Thus much of the original analysis for Approach 1 outlining doses associated with exposures to Th-230 at 40 pCi/g is still applicable. Additional analyses have been conducted to show what expected doses would be if all areas of 40 pCi/g Th-230 or greater were removed from the site. Rather than repeat all of the calculations performed for Approach 1, the analysis of Approach 2 builds on the Approach 1 results, and focuses on potential doses and risks associated with site conditions under the current proposed remediation plan.

The cleanup level of 40 pCi/g is based on limiting ingrowth of Ra-226 to no more than 15 pCi/g over the 1000 year modeling period. This limiting factor is independent of the remediation plan (i.e. it does not change if the remediation plan is changed). No matter what cleanup method is chosen, if 40 pCi/g of Th-230 is present in any area after remediation, then 15 pCi/g of Ra-226 will eventually result from the decay of Th-230 (over 1000 years). Since 40 pCi/g is the limiting value and it is not remedy dependent, this value was used as the starting point for the additional (remedy specific) dose and risk analysis used in support of the new remediation proposal.

Summary of Derivation Process and Results

The principal purpose of the Tonawanda cleanup guideline derivation process is to establish a cleanup guideline for Th-230, the primary radioactive constituent of concern (COC), such that when the site is cleaned up to this guideline, it will meet all of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements for current and proposed future land uses. A secondary purpose is to show that the cleanup guideline developed to meet CERCLA requirements also satisfies other important guidelines and considerations. The cleanup level needed is the limiting, or most restrictive, cleanup level that meets each of these considerations.

For the Tonawanda site properties considered for this analysis (Ashland 1, Ashland 2, and Seaway properties), the most restrictive criteria is a residual Th-230 concentration of 40 picocuries per gram (pCi/g). With a future Th-230 concentration of 40 pCi/g, all CERCLA risk and applicable or relevant and appropriate requirements (ARARs) criteria are satisfied. Conditions of New York (NY) State guidelines and proposed United States (U. S.) Department

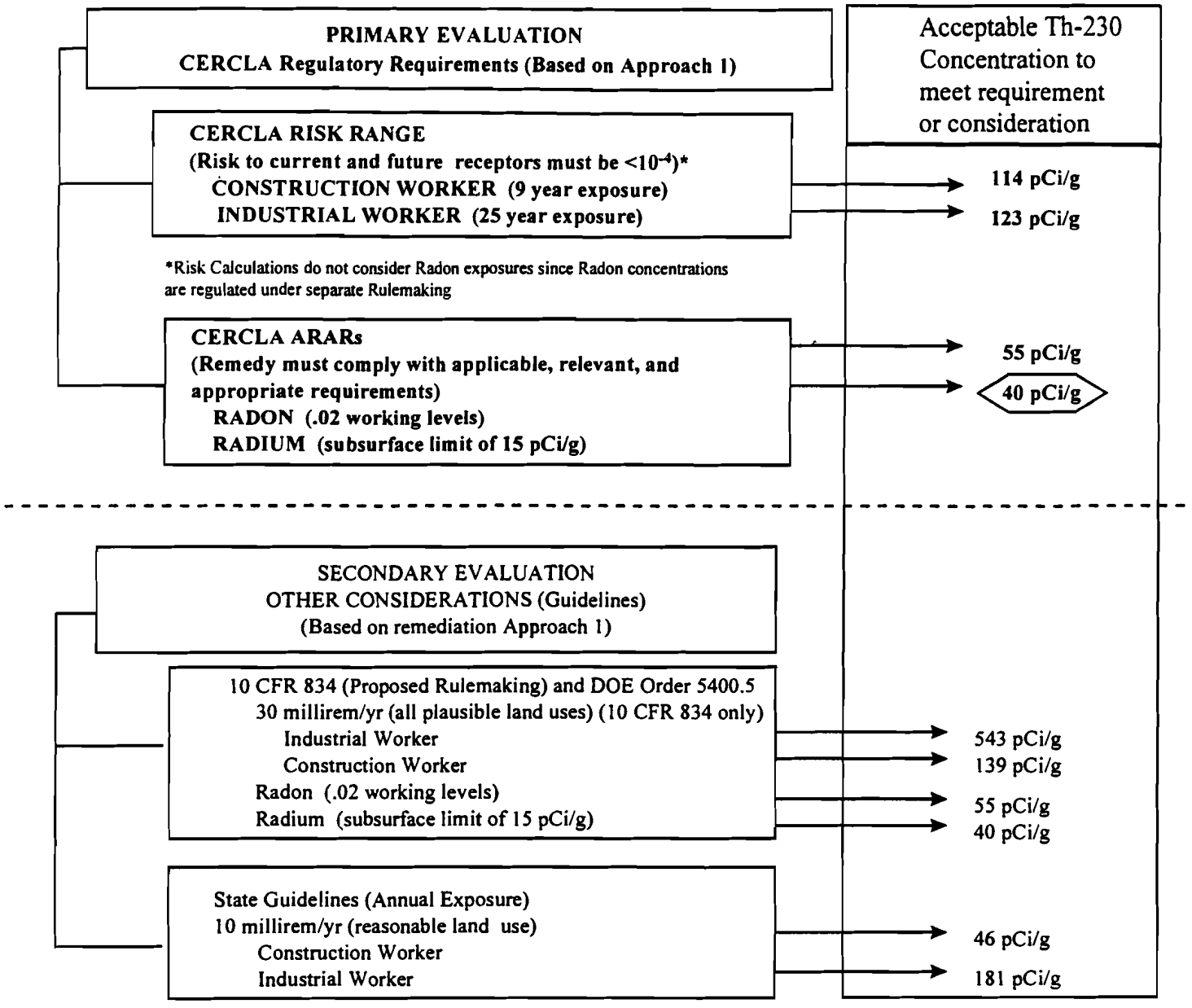
of Energy (DOE) rule-making, while not legally binding in their present form, are also satisfied by the 40 pCi/g criterion under the current remediation strategy (removal of all soils containing Th-230 at 40 pCi/g or greater).

The attached flow diagram (Figure 1) illustrates the process used to determine appropriate cleanup guidelines for the Ashland 1, Ashland 2, and Seaway properties. The primary consideration in the guideline derivation was to determine what the residual Th-230 concentration could be to meet the primary CERCLA requirements of protectiveness and compliance with ARARs. The U.S. Environmental Protection Agency (EPA) has defined an acceptable risk range of 10^{-6} to 10^{-4} (corresponding to cancer risks of one in 1 million to a few in ten thousand) as being protective for CERCLA cleanups. The upper bound of this range (10^{-4}) was used as the limit for the portion of the guideline derivation analysis which addressed CERCLA protectiveness requirements.

As shown in Figure 1, the residual Th-230 concentrations which correspond to 10^{-4} (taken here as 1.0×10^{-4}) for remediation Approach 1 (including consideration of cover) are 123 pCi/g for an industrial worker, and 114 pCi/g for a construction worker. These risk-based guideline concentrations are based on anticipated future industrial use exposure conditions. Risks associated with radon and groundwater ingestion are not considered in the guideline derivation process. Radon is specifically regulated by DOE and EPA (based on indoor air concentrations), and is considered separately as discussed below. Groundwater ingestion is not considered in this assessment since groundwater is not currently used as a drinking water source at the site, and is not likely to be used in the future due to the low quality and yield of the groundwater at the site. The industrial and construction worker scenarios are consistent with the proposed future use of this land as outlined in the Tonawanda Waterfront Master Plan, and include exposure durations of 25 years and 9 years, respectively.

The major regulation which must be considered to meet the CERCLA ARARs criteria for this site is Chapter 40 Code of Federal Regulations (CFR) Part 192 (*Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings*). While not directly applicable, this regulation contains standards that are relevant and appropriate for the radionuclides of concern at the Tonawanda site. These include a limit of 0.02 working levels (WL) for indoor radon concentrations (a working level is a unit of measure for alpha particle energy in air), and limits on surface and subsurface radium concentrations in soil. For properties being released without radiological restrictions, this regulation generally requires that Ra-226 concentrations must be limited to 5 pCi/g or less in the surface, and 15 pCi/g or less in the subsurface soils after remedial actions.

As shown in Figure 1, after remediation the residual Th-230 concentration must be limited to no more than 55 pCi/g to prevent indoor radon concentrations (under industrial conditions with cover) from reaching 0.02 WL. Without consideration of clean cover, the Th-230 concentration must be reduced to approximately 47 pCi/g. In addition, Th-230 concentrations must be further limited to no more than 40 pCi/g in order to keep future



Summary of Doses for Tonawanda Remediation Approaches

Receptor	Approach 1[a]	Approach 2[b]
Industrial Worker	2 mrem/yr	7 mrem/yr
Construction Worker	9 mrem/yr	2 mrem/yr

The limiting value of residual Th-230 that enables compliance with all CERCLA requirements is 40 pCi/g

a Remediation Approach 1 involves removal of the highest concentration soils, mixing remaining soils to obtain a sitewide average of 40 pCi/g Th-230. and covering with clean soil.

b Remediation Approach 2 involves removal of all soils containing 40 pCi/g or more of Th-230. Cover is not considered in the dose calculations for this approach.

Figure 1. Flow Diagram of the Tonawanda (Ashland 1, Ashland 2, and Seaway) Cleanup Guideline Derivation Process

subsurface soil Ra-226 concentrations to lower than 15 pCi/g (over the 1,000 year period considered in the modeling). Limiting concentrations of Ra-226 to less than 5 pCi/g in the surface soils (top 6 inch layer) is not expected to be an issue; as part of any remedial action, clean cover soil must be placed over the site to support vegetative growth. It is expected that site restoration activities will result in a foot or more of clean material over much of the site regardless of the final remedy design.

The secondary evaluation includes evaluation of recommended radiation dose guidelines that are not CERCLA requirements; for example, proposed rule-making or state guidelines. The Tonawanda guideline was evaluated for potential future exposures under construction, industrial, and residential land uses using the proposed DOE dose limit of 30 millirems per year (mrem/yr) [proposed 10 CFR 834 (DOE 1993a)]. Residential land use, while not considered likely for this site, was evaluated to determine the need for potential land use restrictions under DOE requirements. In addition, doses from this analysis can be compared to the NY State dose limit for reasonable land uses of 10 mrem/yr.

The results from the secondary evaluation of other considerations show that all supplemental guidelines will be satisfied using the most restrictive guideline determined under the CERCLA analyses (40 pCi/g Th-230). The proposed 10 CFR 834 (DOE 1993a) regulation, as well the existing DOE Order 5400.5 (DOE 1990), also specify limits on radon decay products in indoor air (0.02 WL) and radium concentrations in soil equivalent to those in 40 CFR 192.

Based on the analyses conducted to determine compliance with CERCLA (risk and ARARs), and secondary evaluation of other considerations, the most restrictive criteria is a residual Th-230 concentration of 40 pCi/g. This is the most limiting condition, in that this concentration satisfies all CERCLA risk and ARARs criteria. The final step in the guideline analysis was to estimate potential future doses and risks associated with land use after remediation. Because 40 pCi/g represents the most restrictive limit to satisfy the primary concern of compliance with CERCLA and meets all secondary evaluation criteria, doses and risks were assessed assuming remediation of the site using a cleanup guideline of 40 pCi/g. These dose evaluations were conducted both for the condition where 40 pCi/g Th-230 is present in a uniform layer across the entire site (Approach 1, the original remediation concept), and for the condition where all soil at or above 40 pCi/g is removed (Approach 2, the current remediation proposal).

As shown in Table 1, doses associated with a uniform site wide average residual Th-230 concentration of 40 pCi/g under expected land use conditions (including consideration of clean cover) are approximately 2 mrem/yr for an industrial worker, and 9 mrem/yr for a construction worker. Risks associated with these exposure scenarios include 3×10^{-5} for an industrial worker and 4×10^{-5} for a construction worker.

To assess the post remedial action conditions associated with the current remediation proposal, doses and risks were re-calculated using an estimate of the average Th-230

Table 1. Summary of Projected Doses and Risks Associated with Proposed Remediation Approaches for the Tonawanda Site

	Estimated Annual Dose to Potential Receptors (mrem/yr)	
Remedy	**Industrial Worker**	**Construction Worker**
Approach 1[a]	2	9
Approach 2[b]	7	2
	Estimated Lifetime Risk to Potential Receptors	
Remedy	**Industrial Worker**	**Construction Worker**
Approach 1[a]	$3x10^{-5}$	$4x10^{-5}$
Approach 2[b]	$1x10^{-4}$	$9x10^{-6}$

[a] Remediation Approach 1 involves removal of the highest concentration soils, mixing remaining soils to reach a site-wide average Th-230 concentration of 40 pCi/g, and then covering the site with 1 ft of clean cover. This cover is considered in the dose calculations for the industrial worker.
[b] Remediation Approach 2 involves removal of all soils containing 40 pCi/g or more of Th-230. Cover is not considered in the dose calculations for this approach.

concentration expected if all soils with Th-230 equal to or greater than 40 pCi/g were removed. The projected site wide average Th-230 concentration after removal of all soils containing 40 pCi/g Th-230 or more is approximately 12 pCi/g. This revised dose assessment utilizes this lower average Th-230 concentration, and does not incorporate the shielding benefits offered by clean cover. The details of this analysis (including the projection of new source term values) are presented in Appendix B. A summary of the dose and risk results is included in Table 1. These results show that with the reduced source concentrations, cover is not necessary to meet NY State TAGM guidance. For the expected land uses, projected doses are 7 mrem/yr to an industrial worker and 2 mrem/yr to a construction worker. Projected risks are 1×10^{-4} for an industrial worker and 9×10^{-6} for a construction worker.

In summary, use of a 40 pCi/g Th-230 cleanup guideline meets the CERCLA requirements to demonstrate protectiveness and comply with ARARs, and it meets proposed DOE criteria for release of sites without radiological restrictions. Doses associated with residual soils at the site are well below the DOE proposed limit of 30 mrem/yr (10 CFR 834). In addition, use of 40 pCi/g as a cleanup guideline (as currently proposed) will meet the NY State 10 mrem/yr TAGM (NYSDEC 1993) guideline for all land uses projected by the Tonawanda Waterfront Master Plan. Use of 40 pCi/g as a cleanup guideline under the current remediation proposal will allow DOE to release the Ashland 1, Ashland 2 and portions of the Seaway properties without land use restrictions, and will allow full implementation of the proposed Tonawanda Waterfront Master Plan under cleanup guidelines applicable to sites governed by NY State rules.

1. INTRODUCTION

The principal purpose of the Tonawanda cleanup guideline derivation process is to establish a cleanup guideline for thorium-230 (Th-230), the primary radioactive constituent of concern (COC), such that when the site is cleaned up to this guideline, it will meet all of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements for current and proposed future land uses. A secondary purpose is to show that the cleanup guideline developed to meet CERCLA requirements also satisfies other important guidelines and considerations. The cleanup level needed is the limiting, or most restrictive, cleanup level that meets each of these considerations. Thus the cleanup guideline evaluation was conducted in two phases, with the first phase consisting of the evaluation of primary CERCLA requirements, and the second phase consisting of evaluations of other considerations.

The primary consideration for the Tonawanda site cleanup guideline derivations is that the cleanup guidelines must meet the principal requirements of CERCLA. CERCLA requires that the cleanup remedy must be protective of human health and the environment, and that it must meet applicable or relevant and appropriate requirements (ARARs). The United States (U. S.) Environmental Protection Agency (EPA) has defined an acceptable risk range of 10^{-6} to 10^{-4} (corresponding to cancer risks of one in one million to a few in ten thousand) as being protective for CERCLA cleanups. The upper limit of 10^{-4} was used as the starting point for the guideline derivation analysis. The primary ARAR for this site is 40 CFR 192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings."

The secondary evaluation includes evaluation of recommended radiation dose guidelines that are not CERCLA requirements; for example, proposed rule-making or state guidelines. The Tonawanda guideline was evaluated for potential future exposures under construction, industrial, and residential land uses using the proposed U. S. Department of Energy (DOE) dose limit of 30 millirems per year (mrem/yr) (proposed 10 CFR 834). Residential land use, while not considered plausible for this site, was evaluated to determine the need for potential land use restrictions under DOE requirements. In addition, doses from this analysis can be compared to the New York (NY) State dose guideline for reasonable land uses of 10 mrem/yr. [It should be noted that while state regulations can be ARARs, the NY State 10 mrem/yr guideline is part of a Technical Administrative Guidance Memorandum (TAGM) (NYSDEC 1993) which is not a promulgated regulation, and is thus not eligible for consideration as an ARAR under CERCLA]. Similar dose evaluations are being performed for the remainder of the Seaway Landfill (areas A, B, and C) and the Town of Tonawanda Landfill to assure that performance objectives are met. (For the purposes of this assessment, Seaway Area D [adjacent to Ashland 1] is considered part of Ashland 1).

Since the Tonawanda site cleanup guideline effort was initiated, two proposals have been considered for remediation of the site. The first approach (Approach 1) involved determining what an acceptable cleanup guideline would be if the site was cleaned up in a way that resulted in a relatively uniform residual contaminant concentration in all soils across the site. This would have involved removal of the most highly contaminated soils, and then

mixing or "blending" marginally contaminated soils with clean site soils so that the resulting mixture contained a uniform level of Th-230, at the cleanup guideline of 40 pCi/g. Approach 1 also included placement of at least one foot of clean cover over the area and taking this cover into account in the dose assessment.

The second approach (Approach 2) involved establishing a cleanup guideline, and then removing all soils which contain Th-230 at or above that cleanup guideline. Approach 2 will result in an average site wide Th-230 concentration after remediation that is significantly less than the target cleanup guideline, and it will also result in removal of approximately twice as much soil as Approach 1. In addition, Approach 2 does not incorporate cover into the remedial action performance assessments (dose and risk calculations). Approach 2 is being actively considered by DOE for implementation at the site based on stakeholder input. Approach 1 (blending) is no longer being considered for implementation by DOE. However, it is important to note that while it is expected that much of the site will be far below the cleanup guideline concentration, it is possible that even with Approach 2, some localized areas of the site may contain Th-230 at the cleanup level after remediation. Thus many of the original calculations which consider the site as containing soils at the cleanup guideline are still shown in this report. This report is intended to address both the expected condition under Approach 2 (soils much less than the cleanup guideline), as well as the possible condition where some soils are at the cleanup guideline.

The following sections provide the detailed evaluations against CERCLA requirements (Section 2) and secondary considerations (Section 3) as discussed above. Section 2 includes a detailed discussion of the dose and risk assessment methods, including land use assumptions, exposure scenarios, and specific exposure parameters. Section 3 includes discussion of secondary evaluation criteria such as proposed regulations (10 CFR 834), and the dose criteria contained in NY State guidelines. A separate assessment of doses and risks associated with the new remediation proposal (Approach 2) is provided in Section 4. Section 5 discusses the uncertainties associated with this guideline derivation analysis, including information on the sensitivities of key parameters. Section 6 provides a summary of the results of this assessment with conclusions. These conclusions focus on the differences between the results of the dose assessments for each remediation approach (Approach 1 and Approach 2).

2. PRIMARY EVALUATION AGAINST CERCLA REQUIREMENTS

As discussed above, the primary basis for development of a cleanup guideline for the Ashland 1, Ashland 2, and Seaway properties is compliance with the "threshold" CERCLA requirements of protection of the public and environment, and compliance with ARARS. The following sections summarize the results from the development of guidelines which meet the CERCLA risk and ARARS requirements. As discussed previously, two remediation approaches have been considered for the Tonawanda site. The following summarizes the primary differences between these approaches.

1) Approach 1 involves calculation of doses with an assumed source term equal to the cleanup guideline uniformly spread across the site, with consideration of a clean cover layer. These are the conditions which were expected across the site under the original cleanup proposal. Approach 1 is retained because it represents possible conditions for isolated pockets of residual material under Approach 2.

2) Approach 2 involves calculation of doses with an assumed source term which is based on removal of all soils at or above the cleanup guideline. Thus the average concentration for residual soils used for this assessment is less than the actual cleanup guideline. The residual soil concentration (source term) used for the second assessment is based on removal of all samples equal to or greater than the expected cleanup guideline from the site database, and recalculating a site wide average concentration. The details of this process are outlined in Appendix B.

It is important to note that even under Approach 2 it is possible for some soils to be left at the site with Th-230 concentrations at or near the cleanup guideline (even though the site wide average should be well below the cleanup guideline). Thus the original calculations that were based on all soils containing Th-230 at the cleanup guideline are still an important "baseline" consideration for remediation decision making. Because the original calculations provide this baseline information, and to limit confusion, the following approach has been taken for this final guideline report:

- Original dose calculations and exposure assumptions have been left in the report to provide documentation of potential doses associated with possible remediation conditions (i.e. if an area is left with soils at the cleanup guideline and cover is then placed on such an area). Text which discusses the results for Approach 1 has been revised to point out that the results are based on the original approach.

- Additional dose and risk calculations have been performed to model conditions expected under the current remediation approach proposed by DOE (Approach 2). These calculations have been summarized in a new section of the report (Section 4) and in Appendix B.

2.1 RISK-BASED GUIDELINE DERIVATION

The primary basis for the risk-based cleanup guideline derivation is compliance with the CERCLA acceptable risk range of 10^{-4} to 10^{-6}. Because 10^{-4} represents the upper end of the acceptable risk range, cleanup guidelines were developed so that under proposed future land use, exposures to the cleanup guideline concentrations would result in an excess cancer risk of no more than 10^{-4}. The guideline derivation was conducted using EPA risk assessment guidance (EPA 1989) with site-specific exposure parameters as appropriate. The following

sections discuss the major components of the risk-based cleanup guideline derivation, including data evaluation, exposure assessment, and risk characterization.

2.1.1 Data Evaluation

2.1.1.1 Introduction and Background

The data set considered in this evaluation consists of results from numerous site investigations conducted at the site since 1978. These data are discussed in the Tonawanda Remedial Investigation (RI) Report (BNI 1992). To assess dose to future receptors, site data from the characterization efforts noted above were aggregated into a single data set for the Ashland 1, Ashland 2, and Seaway properties. This data set was used to develop a source term for the Tonawanda site.

Table 2 summarizes the current constituent concentrations for site soils. The table shows minimum, maximum, average, upper 95 percent confidence level (UCL_{95}) on the mean concentrations, background concentrations, and reasonable maximum exposure (RME) concentrations (UCL_{95} - background) for Ra-226, Th-230, Th-232, and U-238.

Table 2. Aggregated Site Data [picocuries per gram (pCi/g) (current conditions)]

Analyte	Minimum	Maximum	Average	UCL_{95}	Background	RME
Ra-226	0.38	750	6.08	8.59	1.1	7.49
Th-230	≅ 0.0	4,400	86.7	111	1.4	109.6
Th-232	0.11	27	1.40	1.51	1.2	0.31
U-238	1.00	1,500	20.8	27.2	3.1	24.1

2.1.1.2 Source Term

For the purposes of this analysis, soils containing residual radioactive materials are assumed to be present at the site in a homogenized layer approximately 40,000 square meters (m^2) in area and 2-m thick following completion of the remedial action. The 2-m layer of homogenized soils is assumed to contain a mixture of unconsolidated material (mostly clay with some sand, gravel, etc.) containing elevated concentrations of residual radioactive materials. Each of the radionuclides of concern is assumed to be uniformly distributed throughout the 2-m layer at the RME concentrations indicated in Table 2. Radioactive decay products of Ra-226, Th-232, and U-238 are assumed to be present at an equivalent concentration to the parent radionuclide. Uranium-235 is assumed to be present at 4.6 percent of the concentration of U-238 (based on assumption of natural uranium). However, the radionuclides protactinium-231 (Pa-231) and actinium-227 (Ac-227) are not assumed to be

present at equilibrium concentrations. Based on site-specific measurements and knowledge of the former processing operations at the Tonawanda site, these radionuclides are assumed to be present at concentrations equivalent to the concentration of Ra-226.

For calculations for Approach 1, the 2-m layer of soils containing residual radioactive materials at the site is assumed to be overlain by a 20-centimeter (cm) (8-inch) layer of clean topsoil. While it was expected that remediation under this approach would include 0.3-m (1 ft) of clean cover (one third from an off-site source and two thirds from on-site but containing no excess radioactivity), the guideline derivation only uses a conservative 20-cm (8-inch) layer. This clean topsoil layer would be required to sustain vegetative growth (e.g., a grass cover). The vegetative cover would provide erosion control and aesthetic benefits.

For calculations for Approach 2, no clean cover layer is considered. It is expected that at least one foot of clean topsoil will be placed over most of the site after remediation to support vegetative growth. For much of the site, restoration activities will involve placement of up to several feet of clean soil to bring the site to the proper grade and elevation. However, no credit is taken in the dose calculations either for the shielding provided by this layer of clean soil, or the effective dilution this clean soil will cause in the overall site wide average Th-230 concentration. The source term used for the dose calculations under Approach 2 was estimated simply by removal of data points from the site database which equal or exceed the proposed cleanup guideline, and then recalculating the site wide RME value. Table 3 provides a summary of the source term for Approach 2, and Appendix B provides a more detailed discussion on how this source term was developed.

Table 3. Source Term for Remediation Approach 2 (Removal of Soils containing Th-230 ≥ 40 pCi/g)

Analyte	Minimum	Maximum	Average	UCL_{95}	Background	RME
Ra-226	0.12	4.4	1.19	1.22	1.1	0.12
Th-230	≈0.00	39	11.80	12.40	1.4	11.00
Th-232	0.09	3.4	1.18	1.20	1.2	0.00
U-238	0.03	362	5.31	6.26	3.1	3.20

2.1.2 Exposure Assessment

Two potential exposure scenarios covering expected future land use alternatives were considered for the site. Each scenario assumes that at some time within 1,000 years following remediation the site may be released for productive reuse. The most likely future land use is considered to be commercial/industrial development (e.g., commercial offices or light industry); the Tonawanda Waterfront Master Plan calls for commercial/industrial land use for much of the current Ashland 1 and Ashland 2 areas. It is also expected that construction or utility

workers will be involved in onsite activities in the remediated area for more limited periods of time in direct contact with the soils containing residual radioactive materials.

For each exposure scenario (construction worker or industrial/commercial worker), parameter values were selected based on site-specific information, where available. In the absence of site-specific data, parameter values were selected to provide conservative, yet reasonable estimates of potential exposures. Parameter values used in previous analyses for the Tonawanda site, including the Baseline Risk Assessment (DOE 1993b), Feasibility Study (DOE 1993c), and uranium guideline derivation (Yu et. al 1988), were evaluated and used preferentially, where applicable. Standardized default parameter values recommended by EPA or other authorities were also used preferentially. A listing of all exposure parameters is presented in Appendix A.

The hypothetical commercial/industrial worker was assumed to work at the site in an office building or light industrial facility constructed at some future time. The worker was assumed to spend 8 hours per day onsite (7 hours indoors and 1 hour outdoors), 5 days per week, 50 weeks per year (i.e., a full-time working year) over an exposure duration of 25 years. The worker was assumed to inhale 8,400 m^3 of air per year (Yu et al. 1993a), with an average mass-loading of radioactive particulates of 30 micrograms (μg)/m^3. This mass loading is based on an assumed total dust loading of 100 $\mu g/m^3$, with a respirable fraction (corresponding to particles in the 1 to 10 μm range) of 30 percent. The worker was also assumed to ingest soil at a rate of 50 milligrams (mg)/day (EPA 1991) due to incidental hand-to-mouth contact. All water ingested or used by the worker was assumed to be provided from an offsite source not affected by site conditions (e.g., a municipal water supply). As discussed previously, for Approach 1 the site is assumed to be covered with 20 cm (8 inches) of clean soil. For Approach 2, no cover was considered, and the exposure point concentrations were based on reduced site wide average concentrations (as shown in Table 3) after removal of soils containing Th-230 equal to or greater than 40 pCi/g. No food products were assumed to be produced in the remediated area. Complete exposure pathways were assumed to include direct gamma exposure, inhalation of resuspended soil particulates, and soil ingestion; inhalation of radon and its decay products is considered as a separate constraint in the following section.

The hypothetical construction worker was assumed to participate in excavation and construction activities in the remediated area which involve excavation through the clean surface soils and direct contact with the soils containing residual radioactive materials (e.g., underground utility construction or maintenance, building foundation construction or repair, etc.). The hypothetical construction worker was assumed to spend 8 hours per day, 5 days per week, 8 weeks per year (i.e., a conservative period for performing utility work or constructing building foundations), for nine years. Most other exposure parameters were assumed to be equivalent to those of the commercial/industrial worker. Exceptions include the incidental soil ingestion rate of 480 mg/working day (EPA 1991) and a particulate loading of 60 $\mu g/m^3$ of soil-related material in ambient air (200 $\mu g/m^3$ with 30 percent in the respirable range), which were assumed to account for the increased soil contact in this scenario. Complete exposure

pathways were assumed to include direct gamma exposure, inhalation of resuspended soil particulates, and soil ingestion.

The hypothetical commercial/industrial worker scenario may also double for a worst-case indoor construction worker scenario. Even though some exposure parameter values may be slightly different for a construction worker (e.g., higher inhalation and soil ingestion rates), the primary pathway for indoor exposure is external gamma radiation. Because dose and risk from exposure to external gamma radiation is dependent on the length of time exposed and not on soil ingestion and inhalation rates, the indoor construction worker would have a maximum dose equal to the commercial/industrial worker's dose. Lifetime risk would be lower for the construction worker because he would likely be onsite for much less than 25 years. In fact, the indoor construction worker would likely be onsite for less than one full work year and yearly dose and risk rates would likely be less than those for the commercial/industrial worker. It is conceivable that an indoor construction worker could cut through a concrete floor and be exposed to underlying soils. In this case the dose and risk would be directly comparable to the outdoor construction worker's dose and risk, even though the duration of exposure would likely be much less than 8 weeks.

2.1.3 Risk Characterization

2.1.3.1 Methods

Risk estimates for each scenario were computed using the RESRAD computer code (Yu et. al 1993b), Version 5.61, with risk factors taken from the EPA's Health Effects Assessment Summary Tables (HEAST). Radiation risks to each hypothetical receptor were modeled over a period of 1,000 years. For each scenario, the residual radioactive materials were assumed to be present initially at the RME concentrations indicated in Table 2. Radioactive decay and ingrowth were considered to determine the year in which the maximum risk to each receptor would be predicted to occur. The risk from that year is then assigned to the hypothetical receptor as the most conservative risk estimate.

For each scenario, the maximum risk to the receptor was then compared to the 10^{-4} CERCLA risk limit. If the maximum radiation risk to a given receptor is predicted to exceed 10^{-4}, then the concentrations of residual radioactive materials in soil must be reduced (e.g., via removal of soils containing the highest concentrations). If the maximum dose is predicted to be below 10^{-4} for that receptor, then no concentration reduction would be required to satisfy the risk constraint for that scenario. The amount of reduction in the source term that would be required in each scenario can be estimated using the ratio of the maximum risk predicted for that scenario to the 10^{-4} CERCLA risk limit. These ratios, which are presented in Table 4 for Approach 1 and the exposure scenarios considered here, were then used to derive the concentration limits for each radionuclide of concern.

Table 4. Risk Comparison for Site Receptors

Risks[a]	Industrial	Construction
Estimated (maximum)	8.9×10^{-5}	9.6×10^{-5}
Limit	10^{-4}	10^{-4}
Risk Fraction[b]	0.89	0.96

[a] Assuming projected conditions
[b] Risk fraction = Estimate/Limit (i.e., this is the fraction that risks, and thus concentrations, must be reduced (or can be increased) by to meet the 10^{-4} limit)

2.1.3.2 Risk-Based Cleanup Guideline Results

For both exposure scenarios described in Section 2.1.2, the RESRAD computer code was used to predict potential radiation risks over a period of 1,000 years following remediation. In each case, the maximum risk was predicted to occur at 1,000 years following remediation. Risks were predicted to increase with time over the period of analysis, due primarily to the ingrowth of Ra-226 from Th-230. Under all scenarios, the dominant exposure pathway was estimated to be direct gamma irradiation, primarily from Ra-226 and its decay products.

Table 5 lists the maximum allowable concentration of each radionuclide of concern under Approach 1 for each exposure scenario, in order to satisfy the 10^{-4} risk constraint. These concentration limits were derived by dividing the RME concentration of each radionuclide in the original source term (Table 2) by the "Risk Fraction" value listed in Table 4 for that scenario. Selection of the most restrictive concentration values (i.e., those for the construction worker scenario) would assure that post-remediation conditions satisfy the 10^{-4} risk constraint for intended future land use scenarios.

Table 5. Guideline Concentrations
(based on 10^{-4} risk constraint and original remediation approach)

Radionuclide	Limiting Concentration (pCi/g) for Source Term Radionuclides[a]	
	Industrial	Construction
Pa-231	8.38	7.80
Ac-227	8.38	7.80
Pb-210	8.38	7.80
Ra-226	8.38	7.80
Ra-228	0.35	0.32
Th-228	0.35	0.32
Th-230	123	114
Th-232	0.35	0.32
U-234	27.0	25.1
U-235	1.24	1.16
U-238	27.0	25.1

[a] Note: The concentrations shown above represent the concentrations of radionuclides present at the site, in equivalent proportion to the initial site source term mixture which could be left, after remedial actions, and result in 10^{-4} risk under assumed land uses. All concentrations are above ambient background concentrations.

2.2 ARARs COMPARISON

Section 2.1 presented a derivation of potential guidelines for remediation of residual radioactive materials at the Tonawanda site to limit radiation risk to intended future receptors to 10^{-4}. In this section, guidelines are derived independently to satisfy ARARs which apply to the Tonawanda site.

2.2.1 Radon Decay Product Concentration Limits

Ra-226 in soil undergoes radioactive decay to produce Radon-222 (Rn-222), a noble gas, which may migrate into overlying buildings or structures, potentially leading to above-background concentrations of Rn-222 and its radioactive decay products in indoor air. Both DOE directives (DOE Order 5400.5) and EPA regulations (40 CFR 192) limit concentrations of the radioactive decay products of Rn-222 in indoor air within any habitable building to an annual average of 0.02 Working Level (WL) (including background), where reasonably achievable; in any case, the radon decay product concentration (including background) must not exceed 0.03 WL. The 0.02 WL limit equates to a radon air concentration of approximately 4 pCi/liter (L), the EPA guideline for radon in indoor air, assuming that radon decay products are present at 50 percent equilibrium conditions (i.e., typical equilibrium conditions in indoor air).

The RESRAD computer code was used to evaluate potential concentrations of radon and its radioactive decay products in indoor air within a hypothetical building that might be constructed above the soils containing residual radioactive materials. The estimated site-specific concentrations of radionuclides in the residual soils were taken from the industrial scenario values in Table 5 (the construction worker scenario is assumed to include only outdoor exposure). Reasonably conservative parameter values, as listed in Appendix A, were used to describe the characteristics of the hypothetical building and model the concentrations of radon decay products at various times following completion of the remedial action. The results from the radon modeling indicate that indoor radon concentrations will be limited to less than 0.02 WL throughout the 1,000 year modeling period with a residual Th-230 concentration of 55 pCi/g under remediation Approach 1 (with one foot of cover), and 47 pCi/g under remediation Approach 2 (reduced source term with no cover).

This estimate considers a hypothetical building with dimensions and characteristics typical of small commercial or residential structures that might be constructed on the site at some future time. The depth of clean fill material for Approach 1 is assumed to be only 0.2 m beneath the hypothetical building; for conditions where a greater thickness of clean fill material is present, the attenuation of radon diffusing toward the surface will increase, resulting in a reduced flux of radon gas and reduced concentrations of radon and its decay products in indoor air. For calculations under Approach 2, no clean cover is assumed to be present beneath the building.

Other sensitive parameters include the building dimensions and ventilation rates. (Soil moisture content also has been identified as a significant parameter, but is not explicitly included in the RESRAD analysis.) The hypothetical building was assumed to occupy an area of 100 m^2 over the residual radioactive materials; the average room height is assumed to be 2.5-m (8 feet). A ventilation rate of 1 air exchange per hour is assumed, based on typical building construction practices, and construction is assumed to occur on a 0.15-m concrete slab at the ground surface. These assumptions are intended to provide reasonably conservative estimates of potential radon concentrations. Actual concentrations of radon and its decay products in indoor air would be dependent on the specific building characteristics, soil moisture content, and other factors, and may be more accurately determined by direct measurements within the completed structure.

2.2.2 Radium-226 Concentration Limits

EPA regulations (40 CFR 192) also limit concentrations of Ra-226 in soil to 5 pCi/g above background in the surface 0.15-cm layer of soil and 15 pCi/g above background in any subsequent 0.15-cm layer, in each case averaged over an area of 100 m^2. These same limits are included in DOE's proposed regulations, under 10 CFR 834. Since concentrations of Th-230 in soil at the Ashland and Seaway properties of the Tonawanda site exceed concentrations of Ra-226, the Ra-226 concentrations may increase over time as a result of radioactive decay. As Th-230 decays (with a half-life of approximately 77,000 years) it

produces Ra-226. The concentration of Ra-226 at any time (t) in the 1,000 year exposure period may be calculated as:

$$\text{Ra-226}(t) = \text{Ra-226}(t=0)\ e^{-\lambda t} + \text{Th-230}(t=0)\ (1-e^{-\lambda t})$$

where,

Ra-226(t)	=	concentration of Ra-226 at time t (pCi/g),
Ra-226(t=0)	=	initial (time = 0) concentration of Ra-226 in pCi/g,
Th-230(t=0)	=	initial (time = 0) concentration of Th-230 in pCi/g,
λ	=	decay constant for Ra-226 = $4.33 \times 10^{-4}\ yr^{-1}$, and
t	=	time (years).

Under conditions where no Ra-226 is present in the initial soil, and assuming no depletion of the source term by erosional or leaching processes, the concentration of Th-230 that will not exceed the 15 pCi/g limit for Ra-226 within 1,000 years is approximately 43 pCi/g. Table 3 indicates that the residual concentration of Ra-226 in onsite soils following remediation is estimated to be approximately 0.07 that of Th-230; under these conditions, the concentration of Th-230 that will not exceed the 15 pCi/g limit for Ra-226 within 1,000 years is approximately 38 pCi/g, again neglecting any losses due to leaching processes. The RESRAD computer code also incorporates estimates of the depletion of the initial radionuclide concentrations by leaching. If Ra-226 is assumed to be present initially, and loss of the source term radionuclides by leaching is assumed, the Th-230 concentration limit to satisfy the 15 pCi/g constraint for Ra-226 within the 1,000-year period of analysis (accounting for both leaching and radioactive decay processes) is approximately 39 pCi/g. Considering the lack of leaching data for the Tonawanda site and the approximate radium and thorium concentration ratios, 40 pCi/g (the average of 43, 38, and 39 pCi/g) is considered the best estimate of the site-specific Th-230 concentration that would result in a 1,000 year Ra-226 concentration of 15 pCi/g.

It is important to note that the results calculated above for Ra-226 ingrowth from Th-230 are independent of the remedy. That is, these results are the same for both remediation Approach 1 and Approach 2.

3. SECONDARY EVALUATION OF OTHER CONSIDERATIONS

The secondary evaluation includes evaluation of recommended radiation dose guidelines that are not CERCLA requirements; for example, proposed DOE rule-making or state guidelines. The Tonawanda guideline was evaluated for potential future exposures under construction, industrial, and residential land uses using the proposed DOE dose limit of 30 mrem/yr (proposed 10 CFR 834). Residential land use, while not considered realistic for this site, was evaluated to determine the need for potential land use restrictions under DOE regulations. In addition, doses from this analysis can be compared to the NY State dose

guideline for reasonable land uses of 10 mrem/yr. (It should be noted that while state regulations can be ARARs, the NY State 10 mrem/yr guideline is part of TAGM which is not a promulgated regulation, and is thus not an ARAR to be considered under CERCLA).

As indicated above, potential residential development of the remediated site at some future time was considered as part of the secondary evaluation. The hypothetical resident was assumed to spend approximately 111 hours per week onsite[1] (108 hours indoors, 3 hours outdoors) (EPA 1991), 50 weeks per year, for an exposure duration of 30 years (EPA 1990). The resident was assumed to inhale 20 m^3 of air per day (EPA 1991), containing a dust loading of 30 $\mu g/m^3$ of soil-related particulates. The resident was also assumed to ingest an average of 100 mg/day of soil as a result of incidental hand-to-mouth contact (EPA 1991). No onsite production of meat, milk, or fish was assumed due to the urban nature of the site. Factors that affect indoor radon are considered identical for the industrial and residential structures.

Table 6 provides a summary of the dose-based cleanup guidelines derived as part of the analysis of secondary considerations under the original remediation approach (Approach 1). The results from the dose analysis conducted as part of the secondary evaluation, show that the NY State 10 mrem/yr guideline can be met with a residual Th-230 concentration of 46 pCi/g for a construction worker exposure, and 181 pCi/g for an industrial worker exposure if cover is considered. In addition to dose limits, the proposed 10 CFR 834 regulation, as well as the existing DOE Order 5400.5, also specify limits on radon decay products in indoor air (0.02 WL) and radium concentrations in soil equivalent to those in 40 CFR 192. As shown in Table 6, the results from the secondary evaluation of other considerations show that supplemental criteria will be satisfied using the most restrictive guideline (40 pCi/g Th-230) determined under the CERCLA analyses for Approach 1.

4. ASSESSMENT OF REVISED REMEDIAL ACTION APPROACH

As previously discussed, DOE has revised the proposed remediation approach for the Tonawanda site based on comments from impacted stakeholders and NY State regulators. Based on previous analyses under the original proposed remediation approach, a cleanup guideline of 40 pCi/g Th-230 appeared to be reasonable for the Tonawanda site. This concentration was the most limiting (lowest) value based on analysis of several criteria as described in Sections 2 and 3. It is important to note that this value comes about based on limiting Ra-226 ingrowth in subsurface soils to 15 pCi/g over the 1000 year period of evaluation. This ingrowth of Ra-226 is independent of any remediation approach - it is the same for both Approach 1 and 2. Given that the most limiting value from the analysis of the initial approach is 40 pCi/g Th-230, and that this limit is not dependent on the remediation approach, it seems appropriate to test this limit under conditions that would be expected under the new remediation approach. Thus rather than repeat all of the previous evaluations under

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The values used for indoor and outdoor exposure fractions are based on the weighted mean hours per week indoors (107.6 hr), and outdoors (3.07 hr) as discussed on page 5-27 of the Exposure Factors handbook. These values are mean hours per week weighted to reflect time use on weekdays and weekend days combined.

Table 6. Summary of Tonawanda Cleanup Guidelines for Ashland 1, Ashland 2, and Seaway Derived from Secondary Considerations

SECONDARY EVALUATION OTHER CONSIDERATIONS (Guidelines)	Acceptable Th-230 concentration to meet consideration
Proposed 10 CFR 834 30 mrem/yr (all plausible land uses)	
INDUSTRIAL WORKER	543 pCi/g
CONSTRUCTION WORKER	139 pCi/g
10 CFR 834 (Proposed rulemaking and DOE Order 5400.5)	
RADON (.02 WL)	55 pCi/g
RADIUM (subsurface limit of 15 pCi/g)	40 pCi/g
State Guidelines (Annual Exposure) 10 mrem/yr (reasonable land use)	
CONSTRUCTION WORKER	46 pCi/g
INDUSTRIAL WORKER	181 pCi/g

[a] Dose calculations do not consider radon exposures, since radon concentrations are regulated under separate rulemaking.

Approach 1 for Approach 2, this section summarizes the results of the dose and risk assessments conducted under remediation Approach 2, with an assumed cleanup guideline of 40 pCi/g Th-230.

To assess potential doses and risks associated with Approach 2, the post remedial action conditions were modeled using the existing database. To simulate removal of all soils containing Th-230 at or above 40 pCi/g, data points in the site database which contained 40 pCi/g Th-230 or greater were removed from the database. If deep buried pockets of contamination exceeding 40 pCi/g were present, then the data for samples above these deep areas were also removed, since this soil would be removed to dig up the deeper material. A new database was thus constructed which contained only data with Th-230 less than 40 pCi/g. This new database is the model for the site after remedial actions. New average and RME values were calculated using the new database, and the dose and risk calculations previously discussed were performed using these new RME concentrations. This process is described in more detail in Appendix B. Table 1 provides a summary of the dose and risk results based on the new RME values after remediation.

As shown in Table 1, doses for the expected land use conditions are estimated as 7 mrem/yr for an industrial worker and 2 mrem/yr for a construction worker under Approach 2. As part of the supplemental evaluation for Approach 2, an additional evaluation was conducted for a second construction worker. This evaluation modeled exposures to this worker regrading the site for construction of buildings (i.e., a pan operator). The estimated dose to the pan operator construction worker is 6 mrem/yr. Details on the exposure conditions for this evaluation are provided in Appendix B. Risks associated with Approach 2 are 1×10^{-4} for the industrial worker and 9×10^{-6} for a construction worker.

5. UNCERTAINTIES

5.1 PARAMETER ASSUMPTIONS

Exposure parameters were selected to provide a conservative, yet reasonable, estimate of potential radiological dose and risk to each receptor. Site-specific measurements and data were used, where available, to describe site conditions as accurately as possible. Where site-specific data were not available, parameter values were chosen to provide reasonably conservative estimates of dose and risk, with preferential use of parameter values from previous site analyses (e.g., Feasibility Study, Baseline Risk Assessment) or standard default values recommended by EPA or other authorities. In other cases, parameter values (e.g., distribution coefficients for most radionuclides) were determined from a survey of the scientific literature. Pertinent references for parameter values are provided in Appendix A. Exposure scenarios and parameter values have been consistently chosen to provide conservative, yet reasonable, estimates of potential radiation risk, in accordance with DOE's policy to reduce potential radiation exposures as low as reasonably achievable (ALARA).

5.2 LIMITATIONS ON AVAILABLE DATA

The primary radionuclide of concern in Tonawanda soils is Th-230. However, early analyses [e.g., three Oak Ridge National Laboratory (ORNL) investigations in 1978 (ORNL 1978a, ORNL 1978b, and ORNL 1978c); two Ford, Bacon, and Davis of Utah, Incorporated investigations in 1981 (FBDU 1981a and FBDU 1981b); and portions of the BNI investigations reported in the Remedial Investigation Report (BNI 1992)] did not include this radionuclide. A review of the database indicated that many samples which exclude Th-230 analysis contain relatively elevated concentrations of Ra-226. It is likely that the Th-230 concentrations in these samples were also elevated, but this was left undetermined. Samples which were analyzed for Ra-226 but not for Th-230 were excluded from this analysis based on the following reasoning:

- The relationship between Ra-226 and Th-230 concentrations is significant because Ra-226 is a primary contributor to dose.

- A review of the site analytical data reveals that Th-230 is typically present at 10 to 14 times the Ra-226 concentration for samples where both results are available (see Table 2).

- The Th-230 to Ra-226 ratio drops to less than 10:1 when all Ra-226 results (with or without an associated Th-230 result) are included, i.e., inclusion of these data leads to an increased RME concentration estimate for Ra-226 without a commensurate increase in the Th-230 RME concentration estimate. Inclusion of these samples in calculating the source term statistics would bias the Th-230 to Ra-226 ratio and artificially alter the relative contributions of Ra-226 and Th-230 to risk. These data have, therefore, been excluded to ensure conservative source term estimates.

Even though the source term used in the guideline derivation is considered the most appropriate given the available data, two additional methods were considered. The first method involved calculating a new source term (and resulting doses and cleanup guideline) using every data point in the Tonawanda database, including all Ra-226 results which do not have a corresponding Th-230 result. Under the second method, a regression analysis was used to calculate the Th-230 value for each Ra-226 result where Th-230 had not been analyzed. The resulting source term was then used to re-calculate doses and proposed cleanup guidelines. The 10^{-4} risk level for the industrial worker was used as a basis for comparing the results from these two methods with the original cleanup guideline.

Under the first method, the 10^{-4} risk level changed from 123 pCi/g to 115 pCi/g for Th-230. Under the second method (regression analysis), the proposed cleanup guideline changed from 123 pCi/g to 126 pCi/g. In summary, neither method substantially changed the results from the original calculation. Using the first method, risk and dose-based cleanup guidelines slightly decrease. Using the second method, risk and dose-based cleanup guidelines slightly increase. However, under each method, the limiting value of 40 pCi/g based on controlling Ra-226 ingrowth to 15 pCi/g at 1,000 years remains essentially the same (with a range of 36 to 43 pCi/g of Th-230 depending on the initial post remedial action Ra-226 concentration assumed).

5.3 WEIGHTED AVERAGE ASSUMPTIONS

An additional uncertainty in the sample data relates to the volumetric distribution of the residual radioactive materials. Each data point is given equal weight in calculating the concentration statistics, although each data point does not necessarily represent a fixed volume of soil nor are sampling locations uniformly distributed throughout the site. Since sample locations are typically biased toward locations of increased direct gamma activity, the sample statistics are likely to over-estimate the actual radionuclide concentrations in site soils.

5.4 IMPACTED ZONE THICKNESS ASSUMPTIONS

The residual radioactive materials remaining onsite following the completion of remedial action are assumed to be uniformly distributed throughout a 2-m thick layer of soil across the site area. Actual site conditions are expected to be much more irregular, such that the thickness of this residual soil layer may range from several feet to a few inches. Similarly, the radionuclide concentrations are not likely to be truly homogeneous throughout the site. The 2-meter homogeneous layer assumed for this analysis was ultimately selected because it is likely an overestimate of conditions after remedial actions, and it is the default used in the RESRAD code for screening dose assessments. It was considered appropriate to use a conservative 2 m-thickness (which may overestimate dose) until a more defensible value is calculated as part of the remedial design. This value is not intended to be used as an accurate description of post-remedial action depth conditions (e.g., by use in a volume calculation).

5.5 GROUNDWATER ASSUMPTIONS

Groundwater is not considered in this guideline derivation as a plausible exposure pathway. This is because groundwater sampling in the region has demonstrated 1) yields insufficient for use as drinking water, and 2) high levels of sulfates and carbonates resulting in poor water quality (Adler 1997). Consumers are also most likely to get water from a municipal supplier. The use of groundwater is, therefore, highly unlikely and not considered in this derivation.

5.6 DISTRIBUTION COEFFICIENTS

With the exception of the uranium K_d, which was measured, all K_d values are taken from literature sources as summarized in Table 32.1 of the Data Collection handbook to Support Modeling the Impacts of Radioactive Material in Soil (Yu et al. 1993a). This table provides average K_d estimates for sand, loam, clay, and organic soil types. Because glacial till is more like clay than loam, sand, or organic material; the clay K_d was used for the calculations.

As a test of the sensitivity of the K_d parameter, dose calculations were performed using K_d values for sand. This causes the radioactive material to leach from the soil more rapidly. The exposure scenarios for the Tonawanda site are controlled primarily by the external gamma radiation pathway. Exposures from this pathway are actually reduced as material leaches from the surface soils to subsurface soils. Thus, use of the sand K_d values resulted in lower doses (and higher cleanup guidelines) than the clay K_d values.

Selection of the average clay K_d values for the dose calculations was based on the following factors:

- Soil types at Tonawanda (primarily glacial till and clay based on Figures 3-26 and 3-27 in the RI Report) are most closely matched by the default clay K_d (rather than sand, loam, or organic material).

- The analysis using sand K_d values showed lower doses than the analysis using clay K_d values.

- Historical site data show that materials are not leaching significantly from the site, which is consistent with K_d values based on clay. This is also consistent with data from other FUSRAP sites which show that radium, uranium, and thorium are not highly mobile under most environmental conditions.

6. SUMMARY AND RECOMMENDATIONS

Sections 2 and 3 present estimates of the maximum acceptable concentrations of residual radioactive materials in soils at the Tonawanda site to satisfy CERCLA requirements (protectiveness and compliance with ARARs) and other considerations. For purposes of this discussion, the residual radionuclide concentrations are presented for Th-230, the predominant radionuclide at these properties; other radionuclides of concern would be limited to concentrations proportional to their relative abundance in the current site soils. The calculated residual concentration limits for Th-230 include the following considerations:

- The maximum Th-230 soil concentration to satisfy the 10^{-4} risk constraint (including consideration of the risk contribution from all other source term radionuclides) for intended future land use scenarios at this site (including consideration of cover for industrial and residential exposures) is approximately 114 pCi/g. Concentration limits for each of the scenarios evaluated include 123 pCi/g for a commercial/industrial worker and 114 pCi/g for a construction worker.

- Thorium-230 concentration limits below approximately 55 pCi/g (with cover) and 47 pCi/g (without cover) are estimated to satisfy the additional consideration to maintain concentrations of radon decay products to 0.02 WL in indoor air within a hypothetical commercial or residential building that might be constructed over the remediated soil.

- Thorium-230 concentrations limits between approximately 38 and 43 pCi/g would satisfy the additional consideration to limit future soil concentrations of Ra-226 to levels below 15 pCi/g in subsurface soils (regardless of the remediation approach). This range is dependent on the amount of Ra-226 present initially, and the amount of leaching assumed.

Based on the analyses conducted to determine compliance with CERCLA (risk and ARARs), and supplemental evaluation of other considerations, the most restrictive criteria is a residual Th-230 concentration of 40 pCi/g. This is the most limiting condition, in that this

concentration satisfies all CERCLA risk and ARARs criteria. The final step in the guideline analysis was to estimate potential future doses associated after remediation. Because 40 pCi/g represents the limit to satisfy the primary concern of compliance with CERCLA, and meets all supplemental evaluation criteria, doses were assessed assuming remediation of the site using a cleanup guideline of 40 pCi/g, under two proposed remediation approaches.

Doses associated with a residual Th-230 concentration of 40 pCi/g under Approach 1 (including consideration of cover for industrial and residential exposures) are approximately 2 mrem/yr for an industrial worker, and 9 mrem/yr for a construction worker. Under very unlikely urban residential land use conditions, the estimated annual dose is 13 mrem/yr. Under Approach 2 (removal of all soils containing 40 pCi/g or more Th-230), projected doses to the likely exposure groups are 7 mrem/yr to an industrial worker, and 2 mrem/yr to a construction worker. Under both approaches, no cover was assumed to be present for the construction worker scenario. Projected dose to a future resident under Approach 2 is 20 mrem/yr.

These doses are well below the DOE proposed limit of 30 mrem/yr under all plausible land use conditions (proposed 10 CFR 834). In addition, use of 40 pCi/g as a cleanup guideline will meet the NY State 10 mrem/yr TAGM guideline for land uses projected by the Tonawanda Waterfront Master Plan.

In summary, use of a 40 pCi/g Th-230 cleanup guideline meets the CERCLA requirements to demonstrate protectiveness and comply with ARARs, and it meets proposed DOE criteria for release of sites without radiological restrictions. Use of 40 pCi/g as a cleanup guideline under Approach 2 will allow DOE to release the Ashland 1, Ashland 2, and Seaway properties without land use restrictions, and will allow full implementation of the proposed Tonawanda Waterfront Master Plan under cleanup guidelines applicable to sites governed by NY State rules.

7. REFERENCES

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APPENDIX A

EXPOSURE PARAMETERS

Ashland/Seaway Industrial Worker Parameters for Approaches 1 and 2

RESRAD Parameter	Value	Units	Reference/Comments
Area of Impacted Zone	40,000	m2	1988 ANL Uranium Guideline Derivation for Ashland 1 and 2
Thickness of Impacted Zone	2	m	RESRAD default
Radiation Dose Limit	30	mrem/yr	10 CFR 834 dose lit to a member of the public from a single source (100 mrem/yr is the limit for all sources).
Cover Depth	0.203 (0.0)	m	The remedial design in Approach 1 calls for a 12 inch cover (8 inches from clean on-site sources and 4 inches from an off-site source). To be conservative, this derivation considers only the 8 inch (0.203 m) portion of the clean cover. The cover was removed (depth = 0.0 m) for Approach 2.
Density of Impacted Zone	1.5	g/m3	RESRAD Default
Impacted Zone Erosion Rate	0.0	m/yr	The industrial site's cover is assumed to be concrete or asphalt which will have minimal erosion.
Impacted Zone Total Porosity	0.45	-	1993 Tonawanda BRA
Impacted Zone Effective Porosity	0.2	-	RESRAD default
Impacted Zone Hydraulic Conductivity	123	m/yr	1993 Tonawanda BRA
Evapotranspiration Coefficient	0.46	-	1993 Tonawanda BRA
Precipitation	1.23	m/yr	1993 Tonawanda BRA
Runoff Coefficient	0.25	-	1993 Tonawanda BRA
Distribution Coefficients	-	cm3/g	Values adopted for clay (primary impacted zone soil type): 2,400 for actinium, 2,700 for protactinium, 550 for lead, 9,100 for radium, and 5,800 for thorium (Sheppard and Thibault 1990). The uranium coefficient is 10 based on measured data from the RI (BNI 1992).
Inhalation Rate	8,400	m3/yr	RESRAD default
Mass Loading for Inhalation	0.00003	g/m3	NRC 1992: 100 micrograms of dust per cubic meter of air for ambient concentrations. Mass loading is based on a total mass loading of 100 micrograms of dust per cubic meter of air for ambient conditions (NRC 1992). The total mass loading is modified using a respirable fraction of 30%. The 30% fraction is based on Paustenbach 1989 which indicates that approximately 30% of the ambient dust falls in the range of < 10 micrometers in diameter and corresponds roughly to the range of applicability for the ICRP lung model (0.2 to 10 micrometers) (ICRP 1979).
Exposure Duration	25	yr	EPA's 1990 Exposure Factors Handbook - reasonable upper bound for residence time applied to industrial worker
Shielding Factor, Inhalation	0.4	0-1	RESRAD default
Shielding Factor, External Gamma	0.7	0-1	RESRAD default
Fraction of Time Spent Indoors	0.2	0-1	1993 Tonawanda BRA - 7 hours per day for 250 days per year
Fraction of Time Spent Outdoors	0.03	0-1	1993 Tonawanda BRA - 1 hour per day for 250 days per year
Soil Ingestion Rate	18.25	g/yr	EPA 1991 (RAGS , Volume 1: Human Health Evaluation Manual, Supplemental Guidance) - 50 milligrams per day for adult
Drinking Water Intake	0.0	L/yr	Assumes worker uses municipal water supply
Bldg Foundation Material Thickness	0.15	m	RESRAD default
Bldg Air Exchange Rate	1.0	1/hour	Average rate for single family detached house (Mueller Associates, Inc. 1986, "Indoor Air Quality Environmental Information Handbook: Radon"). Industrial rate likely higher
Bldg Room Height	2.5	m	RESRAD default
Building Depth Below Ground Surface	0	m	Assumes slab on grade

Ashland/Seaway Construction Worker Parameters for Approaches 1 and 2

RESRAD Parameter	Value	Units	Reference/Comments
Area of Impacted Zone	40,000	m2	1988 ANL Uranium Guideline Derivation for Ashland 1 and 2
Thickness of Impacted Zone	2	m	RESRAD default
Radiation Dose Limit	30	mrem/yr	10 CFR 834 dose limit to a member of the public from a single source (100 mrem/yr is the limit for all sources).
Cover Depth	0	m	Worker is assumed to dig through the vegetative layer in Approach 1. No cover was assumed for Approach 2.
Density of Impacted Zone	1.5	g/m3	RESRAD Default
Impacted Zone Erosion Rate	0.0	m/yr	The subsurface material in this scenario is exposed only during construction activities and is not subject to erosion over a period of years.
Impacted Zone Total Porosity	0.45	-	1993 Tonawanda BRA
Impacted Zone Effective Porosity	0.2	-	RESRAD default
Impacted Zone Hydraulic Conductivity	123	m/yr	1993 Tonawanda BRA
Evapotranspiration Coefficient	0.46	-	1993 Tonawanda BRA
Precipitation	1.23	m/yr	1993 Tonawanda BRA
Runoff Coefficient	0.25	-	1993 Tonawanda BRA
Distribution Coefficients	-	cm3/g	Values adopted for clay (primary impacted zone soil type): 2,400 for actinium, 2,700 for protactinium, 550 for lead, 9,100 for radium, and 5,800 for thorium (Sheppard and Thibault 1990). The uranium coefficient is 10 based on data from the RI (BNI 1992).
Inhalation Rate	12,300	m3/yr	(Yu et al. et al 1993) Data Collection Handbook value for typical outdoor activities including a mixture of high, moderate and low activity levels.
Mass Loading for Inhalation	0.00006	g/m3	(Gilbert 1983): 200 micrograms of dust per cubic meter of air considering short periods of high mass loading. The total mass loading is modified using a respirable fraction of 30%. The 30% fraction is based on Paustenbach 1989 which indicated that approximately 30% of the ambient dust falls in the range of < 10 micrometers in diameter and corresponds roughly to the range of applicability for the ICRP lung model (0.2 to 10 micrometers) (ICRP 1979).
Exposure Duration	9	yr	Assuming the worker is involved with construction, maintenance or utility activities over a 9 year period [based on a median residency (EPA 1990)].
Fraction of Time Spent Indoors	0.0	0-1	No indoor activities
Fraction of Time Spent Outdoors	0.037	0-1	Assumes 8 hours per day, 5 days per week for 8 weeks per year. It takes less than 4 days to build the foundation for a 10,000 square ft building using a 4 man crew: 3,350 sq ft per day to pour (10,000 sq ft / 3350 sq ft/day = 3.0 day) and 600 linear ft per day to set forms (400 linear ft / 600 linear ft/day = 0.67 day) equating to < 4 days. (Means Heavy Construction Cost Data, 10th Annual Edition 1996. 8 weeks or 40 days is ten times the expected occupancy for this type of construction work.)
Soil Ingestion Rate	175.2	g/yr	480 mg per day for construction activities (ANL's 1993 Data Collection Handbook)
Drinking Water Intake	0.0	L/yr	Assumes the worker uses municipal water supply

Ashland/Seaway Resident Parameters for Approaches 1 and 2

RESRAD Parameter	Value	Units	Reference/Comments
Area of Impacted Zone	40,000	m2	1988 ANL Uranium Guideline Derivation for Ashland 1 and 2
Thickness of Impacted Zone	2	m	RESRAD default
Radiation Dose Limit	30	mrem/yr	10 CFR 834 dose lit to a member of the public from a single source (100 mrem/yr is the limit for all sources).
Cover Depth	0.203 (0.0)	m	The remedial design in Approach 1 calls for a 12 inch cover (8 inches from clean on-site sources and 4 inches from an off-site source). To be conservative, this derivation considers only the 8 inch (0.203 m) portion of the clean cover. The cover was removed (depth = 0.0 m) for Approach 2.
Density of Impacted Zone	1.5	g/m3	RESRAD Default
Impacted Zone Erosion Rate	0.00006	m/yr	ANL's 1993 Data Collection Handbook for non-farm/garden scenario
Impacted Zone Total Porosity	0.45	-	1993 Tonawanda BRA
Impacted Zone Effective Porosity	0.2	-	RESRAD default
Impacted Zone Hydraulic Conductivity	123	m/yr	1993 Tonawanda BRA
Evapotranspiration Coefficient	0.46	-	1993 Tonawanda BRA
Precipitation	1.23	m/yr	1993 Tonawanda BRA
Runoff Coefficient	0.25	-	1993 Tonawanda BRA
Distribution Coefficients	-	cm3/g	Values adopted for clay (primary impacted zone soil type): 2,400 for actinium, 2,700 for protactinium, 550 for lead, 9,100 for radium, and 5,800 for thorium (Sheppard and Thibault 1990). The uranium coefficient is 10 based on data from the RI (BNI 1992).
Inhalation Rate	7,300	m3/yr	EPA's 1990 Exposure Factors Handbook - average adult inhalation rate = 20 cubic meters per day = 7,300 cubic meters per year
Mass Loading for Inhalation	0.00003	g/m3	NRC 1992: 100 micrograms of dust per cubic meter of air for ambient concentrations. Mass loading is based on a total mass loading of 100 micrograms of dust per cubic meter of air for ambient conditions (NRC 1992). The total mass loading is modified using a respirable fraction of 30%. The 30% fraction is based on Paustenbach 1989 which indicates that approximately 30% of the ambient dust falls in the range of < 10 micrometers in diameter and corresponds roughly to the range of applicability for the ICRP lung model (0.2 to 10 micrometers) (ICRP 1979).
Exposure Duration	30	yr	EPA's 1990 Exposure Factors Handbook - reasonable upper bound for residence time
Shielding Factor, Inhalation	0.4	0-1	RESRAD default and value typically used by ANL for residential farmer scenario
Shielding Factor, External Gamma	0.7	0-1	RESRAD default and value typically used by ANL for residential farmer scenario
Fraction of Time Spent Indoors	0.62	0-1	EPA Exposure factor handbook value based on 108 hrs per week assuming 50 weeks per year
Fraction of Time Spent Outdoors	0.02	0-1	EPA Exposure factor handbook value based on 3 hrs per week assuming 50 weeks per year
Soil Ingestion Rate	36.5	g/yr	Assumes 100 mg per day (EPA's 1990 Exposure Factors Handbook)
Drinking Water Intake	0	L/yr	Assumes the resident uses municipal water supply
Bldg Foundation Material Thickness	0.15	m	RESRAD default
Bldg Air Exchange Rate	1.0	1/hour	Average rate for single family detached house (Mueller Associates, Inc. 1986, "Indoor Air Quality Environmental Information Handbook: Radon")
Bldg Room Height	2.5	m	RESRAD default
Building Depth Below Ground Surface	0	m	Assumes slab on grade

APPENDIX B

SOURCE TERM MODEL FOR REMOVING SOIL WITH TH-230 ≥ 40 pCi/g (REMEDIATION APPROACH 2)

Introduction

Results from the Ashland 1, Ashland 2, and Seaway guideline derivation are based on scaling down current RME radionuclide concentrations until dose and/or concentration guidelines are satisfied. To model this approach, the ratio of concentrations (i.e., Th-230:Ra-226) is assumed to remain constant through the scaling process and the constituents of concern (COCs) are assumed to be homogeneously distributed in the soil. In reality, however, the COCs are distributed inhomogeneously and ratios vary from natural abundance (i.e., 1:1 for Th-230: Ra-226) to many times the normal value. There are two important considerations when using the scaling down approach:

1. Scaling down to Th-230 = 40 pCi/g results in a much different Th:230:Ra-226 ratio than would a straight removal of localized Th-230 greater than 40 pCi/g; and
2. To get the final average Th-230 concentration of 40 pCi/g in the guideline derivation, Th-230 concentration several times 40 pCi/g could be left in place in some areas.

Alternatively, removing all Th-230 greater than 40 pCi/g would result in a final average concentration significantly lower than 40 pCi/g with a Th-230:Ra-226 ratio that approaches 1. The purpose of the following discussion is to detail the latter case (remove all Th-230 greater than 40 pCi/g) and provide results of a radiological assessment using this method.

Method

Exposure Scenarios

An industrial worker, a construction worker, and a resident are included in the assessment assuming exposure parameters identical to those in the guideline derivation. A fourth scenario (a pan operator) is added to this assessment to model an individual who levels the site soils prior to the construction of buildings. The pan operator is assumed to be present 140 eight-hour days on site during one year. He has an inhalation rate of 8,400 m^3/yr and a soil ingestion rate of 36.5 g/yr. A detailed table of pan operator exposure parameters is attached. Exposure parameter tables for the other scenarios are included in the guideline derivation. No cover and eight-inch cover alternatives are considered.

Source Term

The Tonawanda site database contains site analytical data and can be queried to give statistical summaries. For this assessment, a statistical summary is provided using a query with the following requirements:

1. Consider only results from the Ashland 1, Ashland 2,and Seaway properties using linear regression, where necessary, to fill in missing Th-230 data (explained below);
2. Remove from consideration all data from any sample with Th-230 $\geq$ 40 pCi/g;

3. Also remove all data from any sample at a shallower depth than the deepest sample exceeding 40 pCi/g (to mimic excavation); and
4. Provide UCL_{95} concentrations from the remaining data set to be used in the assessment.

Query results are listed in Table B-1, noting the Th-230:Ra-226 ratio of 12.4 pCi/g to 1.22 pCi/g. In this report "complete" data refers to the set of samples which all contain measured values for Ra-226, Th-230, and U-238. If the "complete" data set were used, as with the guideline derivation, and all results with Th-230 greater than or equal to 40 pCi/g were removed, the Th-230:Ra-226 ratio would be approximately 4.8 pCi/g to 1.3 pCi/g. The difference in the two methods stems from how elevated concentrations are considered. As noted earlier, by removing elevated soil concentrations, the Th-230:Ra-226 ratio should approach the background ratio of 1:1. This is evident in the "complete" data set where the relative distribution or ratio is still impacted by moderately elevated residue concentrations, but to a lesser extent. The regression approach is more conservative because the regression is performed on the total data set and the Th-230: Ra-226 ratio is biased by highly elevated results where disequilibrium is pronounced. In summary, the Th-230:Ra-226 regression ratio used in this assessment is a conservative estimate of anticipated site conditions [i.e., it results in a larger source term estimate for Th-230 (12.4 pCi/g) than the alternative method (4.8 pCi/g)].

Table B-2 lists reasonable maximum exposure (RME) concentrations (UCL_{95} minus background) for primary COCs and other relevant radionuclides and decay products. Also given for comparison in Table B-2 are the final guideline derivation concentrations assuming the final Th-230 concentration equals 40 pCi/g. As shown in Table B-2, and as previously discussed, the final concentrations vary significantly from the guideline derivation source term.

Results

Results are listed in Table B-3 and indicate that doses and risks are reduced a factor of approximately 4 when comparing a removal of all Th-230 greater than 40 pCi/g (Approach 2) to leaving a site wide average Th-230 concentration of 40 pCi/g (Approach 1). These results are reasonable considering the RME for Th-230 has been reduced from 40 pCi/g to 11 pCi/g.

Table B-1. Database Summary Table for Soils with Th-230 < 40 pCi/g

Analyte	No. Samples above MDA[a]	Minimum (pCi/g)	Maximum (pCi/g)	Average (pCi/g)	UCL_{95} (pCi/g)
Ra-226	671	0.12	4.4	1.19	1.22
Th-230	718	0.0	39	11.8	12.4
Th-232	482	0.09	3.4	1.18	1.20
U-238	288	0.03	362	5.31	6.26

[a] Minimum detectable activity

Table B-2. RME Concentrations for Soils with Th-230 < 40 pCi/g

Analyte	Database value (pCi/g)	Background[a] (pCi/g)	Approach 2 RME[b] (pCi/g)	Approach 1 RME[c] (pCi/g)
Ac-227			0.12	2.7
Pa-231			0.12	2.7
Pb-210			0.12	2.7
Ra-226	1.22	1.1	0.12	2.7
Ra-228			0.0	0.11
Th-228			0.0	0.11
Th-230	12.4	1.4	11	40
Th-232	1.20	1.2	0.0	0.11
U-234			3.2	8.8
U-235			0.15	0.41
U-238	6.26	3.1	3.2	8.8

[a] Source = Remedial Investigation for the Tonawanda Site (BNI 1992).
[b] Multipliers define the relationship between a radionuclide and a parent (as with Pb-210 and Ra-226), a natural abundance (as with U-238 and U-235), or site specific relations (as with Pa-231 and Ra-226). For Example, it is assumed that the U-235 concentration is 4.6 percent the U-238 concentration.
[c] For the original remediation approach (Approach 1) source term, the baseline values are scaled down to make Th-230 = 40 pCi/g (the guideline concentration).

Table B-3. Dose and Risk Results Comparison

	Estimated Yearly Dose to Potential Receptors (mrem/yr)			
No Cover Alternatives	**Industrial**	**Construction**	**Pan Operator**	**Resident**
Guideline (Th-230 = 40)	31	8.6	29	86
Remove Th-230 > 40	7.3	1.9	6.3	20
8" Cover Alternatives	**Industrial**	**Construction[a]**	**Pan Operator[a]**	**Resident**
Guideline (Th-230 = 40)	2.2	8.6	29	13
Remove Th-230 > 40	0.54	1.9	6.3	3.1
	Estimated Lifetime Risk to Potential Receptors			
No Cover Alternatives	**Industrial**	**Construction**	**Pan Operator**	**Resident**
Guideline (Th-230 = 40)	4.E-04	4.E-05	1.E-05	1.E-03
Remove Th-230 > 40	1.E-04	9.E-06	3.E-06	3.E-04
8" Cover Alternatives	**Industrial**	**Construction[a]**	**Pan Operator[a]**	**Resident**
Guideline (Th-230 = 40)	3.E-05	4.E-05	1.E-05	2.E-04
Remove Th-230 > 40	8.E-06	9.E-06	3.E-06	6.E-05

[a] The construction worker and pan operator are assumed to dig through cover material. A cover was, therefore, not considered resulting in identical doses and risks as in the no cover alternative.

Ashland/Seaway Pan Operator

RESRAD Parameter	Value	Units	Reference/Comments
Area of Impacted Zone	40,000	m2	1988 ANL Uranium Guideline Derivation for Ashland 1 and 2
Thickness of Impacted Zone	2	m	RESRAD default
Radiation Dose Limit	30	mrem/yr	10 CFR 834 dose limt to a member of the public from a single source (100 mrem/yr is the limit for all sources).
Cover Depth	0	m	Worker is assumed to dig through the 15 cm vegitative layer
Density of Impacted Zone	1.5	g/m3	RESRAD Default
Impacted Zone Erosion Rate	0.0	m/yr	The subsurface material in this scenario is exposed only during construction activites and is not subject to erosion over a period of years.
Impacted Zone Total Porosity	0.45	-	1993 Tonawanda BRA
Impacted Zone Effective Porosity	0.2	-	RESRAD default
Impacted Zone Hydraulic Conductivity	123	m/yr	1993 Tonawanda BRA
Evapotranspiration Coefficient	0.46	-	1993 Tonawanda BRA
Precipitation	1.23	m/yr	1993 Tonawanda BRA
Runoff Coefficient	0.25	-	1993 Tonawanda BRA
Distribution Coefficients	-	cm3/g	Values adopted for clay (primary impacted zone soil type): 2,400 for actinium, 2,700 for protactinium, 550 for lead, 9,100 for radium, and 5,800 for thorium (Sheppard and Thibault 1990). The uranium coefficient is 10 based on data from the RI (BNI 1992).
Inhalation Rate	8,400	m3/yr	(Yu et al. et al 1993) Data Collection Handbook value for normal breathing plus short periods at a higher rate. The pan operator is not expected to routinely and strenuously exert himself while on site.
Mass Loading for Inhalation	0.00018	g/m3	(Oztunali et al. 1981): 600 micrograms of dust per cubic meter of air for construction activities. The total mass loading is modified using a respirable fraction of 30%. The 30% fraction is based on Paustenbach 1989 which indicated that approximately 30% of the ambient dust falls in the range of < 10 micrometers in diameter and corresponds roughly to the range of applicability for the ICRP lung model (0.2 to 10 micrometers) (ICRP 1979).
Exposure Duration	1	yr	Assuming the pan operator does not have to rescrape the same surface over multiple years.
Fraction of Time Spent Indoors	0.0	0-1	No indoor activities
Fraction of Time Spent Outdoors	0.128	0-1	(Means 1997 Heavy Construction Cost Data) Assuming a large scraper or pan is used to take a 4 ft (1.33 yd) layer off the surface of the 22 acre (106480 sq. yards) site. Soil removal rate = 1030 cubic yards per 8-hour day. Total volume removed = 106480x1.33 = 142,000 cubic yards. 142,000 cy/1030cy/day = 140 days. Fraction then is (140*8)/(365*24) = 0.128.
Soil Ingestion Rate	36.5	g/yr	100 mg per day for typical ingestion rates (RAGS Human Health Evaluation Manual, Part A) assuming the operator spends time on site during construction activites but not necessarilly come into direct contact with the ground surface.
Drinking Water Intake	0.0	L/yr	Assumes the worker uses municiple water supply