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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
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Terms

ALARA	as low as reasonably achievable
CA	Composite Analysis
DAS	Disposal Authorization Statement
HSRAM	Hanford Site Risk Assessment Methodology
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	low-level waste
MEI	maximally exposed individual
PNNL	Pacific Northwest National Laboratory
TEDE	Total Effective Dose Equivalent
UTF	unit transport factor

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1 Introduction

The U.S. Department of Energy (DOE) in DOE O 435.1 Chg. 1, *Radioactive Waste Management*, requires the preparation and maintenance of a composite analysis (CA). The primary purpose of the CA is to provide a reasonable expectation that the primary public dose limit is not likely to be exceeded by multiple source terms that may significantly interact with plumes originating at a low-level waste disposal facility. The CA is used to facilitate planning and land use decisions that help assure disposal facility authorization will not result in long-term compliance problems; or, to determine management alternatives, corrective actions or assessment needs, if potential problems are identified.

A CA is not prepared to demonstrate current compliance; rather, its purpose is to model potential future exposure events. In other words, a CA is a DOE planning tool, used to provide a reasonable expectation that DOE public radiation protection requirements will be met over the long-term after the DOE site achieves its projected end state; and, the CA is a prerequisite to acquire and maintain an operational Disposal Authorization Statement (DAS).

CAs are closely linked with performance assessments for specific disposal facilities, which DOE uses to demonstrate that there is a reasonable expectation that the performance objectives will be met for a given facility. CAs may be documented in a companion report to the performance assessment, or integrated in the same report with a PA. At the Hanford Site, with numerous separate disposal facilities and tank farms, the CA has been developed and maintained as a separate document that includes all facilities contributing to dose at a specific boundary for supporting performance assessments for several low-level waste disposal facilities at the Hanford Site.

The CA also establish the inventories and evaluate the exposure and dose impact from activities under the Tank Waste Remediation System (TWRS) and tank closures programs. DOE has been proceeding with plans to permanently immobilize and dispose the low-level portion of the wastes (in single- and double shell tanks) onsite in near surface disposal facilities. The performance assessments for these activities and facilities provided insight for the designs and operations, and evaluated the compliance to the DOE standards.

The currently maintained CA for the Hanford Site is documented in PNNL-11800, *Composite Analysis for Low Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, and the subsequent addendum, PNNL-11800-Addendum-1, *Addendum to Composite Analysis for Low Level Waste Disposal in the 200 Area Plateau of the Hanford Site*. The annual summary report for this CA for fiscal year 2015 reached the determination that an update to the Hanford Site CA is necessary based on information reviewed for fiscal year 2015 as well as information presented in prior annual status reports. DOE has initiated work to develop a revised CA followed a phased approach with planning, scoping, and analysis phases. The scoping phase will culminate in the development of a detailed technical approach for preparing the revised CA. This technical approach description document presents the approach for the atmospheric pathway as one facet of the overall technical approach. This is a companion document to a series of other technical approach description documents for various facets of the revised CA.

2 Regulatory Basis

DOE M 435.1-1, *Radioactive Waste Management Manual*, requires that, “For disposal facilities that received waste after September 26, 1988, a site-specific radiological composite analysis shall be prepared and maintained that accounts for all sources of radioactive material that may be left at the DOE site and may interact with the low-level waste disposal facility, contributing to the dose projected to a hypothetical member of the public from the existing or future disposal facilities. Performance measures shall be consistent with DOE requirements for protection of the public and environment and evaluated for a 1,000-year period following disposal facility closure."

Under DOE M 435.1-1, DOE activities may not cause doses to members of the public from all exposure pathways, except for doses from radon isotopes and radon decay products, to exceed 100 mrem in a year. In addition, the as-low-as-reasonably-achievable (ALARA) process must be implemented for all DOE activities that cause public dose.

2.1 Composite Analysis Measures

As indicated in the above requirement, the CA evaluates the all-pathways dose to a hypothetical future member of the public from all sources considered in the analysis. Table 1 provides a summary of the performance measures and corresponding points of compliance for a CA. As shown in the table, two performance measures are considered – a dose limit and a dose constraint.

Table 1. Performance Measures and Points of Compliance for Composite Analyses

Component	Measure	Point of Compliance
All Pathways	DOE primary dose limit of 100 mrem in a year (DOE M 435.1-1)	The point of highest projected dose at or beyond, the projected boundary of land controlled by DOE. A more conservative (nearer the low-level waste disposal facility) boundary should be selected if land-use plans are uncertain.
All Pathways	Composite Analysis dose constraint(1) of 30 mrem in a year	The point of highest projected dose at, or beyond, the projected boundary of land controlled by DOE. A more conservative (nearer the low-level waste disposal facility) boundary should be selected if land-use plans are uncertain.

(1) The primary dose limit for radiological protection of the public from all sources and all pathways is 100 mrem in a year. However, a dose constraint of 30 mrem in a year is established for the composite analysis to ensure that the sources analyzed do not use an extraordinary portion of the primary dose limit. If the results of the composite analysis exceed the primary dose limit, mitigating actions must be taken before the dose limit is exceeded; if the results do not exceed the primary dose limit but do exceed the dose constraint, mitigating actions should be considered, but may not actually be taken.

2.1.1 Dose Limit

The primary dose limit for radiological protection of the public from all sources and all pathways is 100 mrem/yr. Note that the primary limit excludes dose received by patients from medical sources of radiation and by volunteers in medical research programs; dose received from background radiation; and dose received from occupational exposure under NRC or Agreement State license or to general employees regulated under 10 CFR Part 835.

2.1.2 Dose Constraints

A dose constraint of 30 mrem/yr is established for the CA to ensure that the sources analyzed do not use an extraordinary portion of the primary dose limit. If the results of the CA exceed the primary dose limit, mitigating actions must be taken before the dose limit is exceeded; if the results do not exceed the primary dose limit but do exceed the dose constraint, mitigating actions should be considered, but may not actually be taken.

The Draft Technical Standard (planned for release at the end of CY 2016) lists an additional constraint for the CA in Section 2.2.1 Performance Measures. "Furthermore, if the CA dose exceeds 25 mrem/yr TEDE for DOE sources, potential interacting non-DOE sources (excluding dose from radon and its decay products, medical exposures, background radiation, and occupational exposures) that could significantly contribute to doses at a receptor also shall be considered. Additionally, any other performance measures deemed pertinent to the CA due to any site-specific institutional relationships, agreements, or commitments shall be identified." For the Hanford Site, this means that the US Ecology disposal facility releases would be figured into the CA, should dose exceed 25 mrem/yr.

In applying these performance measures, it is appropriate to assume that DOE will control the land on which low-level waste (LLW) is disposed and any surrounding land until the land can be safely released pursuant to DOE G 430.1-8 (7-16-2015), or transferred to another authorized party. Therefore, the analyses performed for the CA (i.e., the calculations performed to generate a result for comparison with a performance measure) should be prepared consistent with site plans for future land use and control. This will affect the selection of the assumed point of future public access and exposure used in the analyses. As plans for future land use or control are revised, they should be tested, prior to implementation, through the composite analysis maintenance program to ensure that changes in land-use plans are not likely to compromise the performance of the LLW disposal facilities. For the revised Hanford CA, land use plans developed in the following documents were used to determine the appropriate boundary or boundaries for the modeling:

- DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*;
- The subsequent ROD (64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)");
- The 2008 supplement analysis (DOE/EIS-0222-SA-01, *Supplement Analysis: Hanford Comprehensive Land Use Plan Environmental Impact Statement*);
- The subsequent ROD (73 FR 188, "Amended Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement"); and
- The 2015 supplement analysis (DOE/EIS-0222-SA-02, *Supplement Analysis of the Hanford Comprehensive Land-Use Plan Environmental Impact Statement*).

3 Exposure Pathways

Pacific Northwest National Laboratory (PNNL-16115, *Updated User Instructions for the Systems Assessment Capability, Rev. 1, Computer Codes Volume 1: Inventory, Release, and Transport Modules*) worked to develop a very robust modeling capability to use for preparing a revised CA and to support other site-wide modeling needs for the Hanford Site during the period 2000 – 2005 (PNNL-). This effort was suspended in 2006, and further work on the revised CA deferred, while the Tank Closure & Waste

Management Environmental Impact Statement (TC&WM EIS) (DOE/EIS-0391, *Final Tank Closure & Waste Management Environmental Impact Statement*) was developed and issued.

The three previous site-wide modeling analyses (the initial CA of 1998, the uncompleted CA of 2006, and the TC&WM EIS issued in 2012) all relied on a general approach that modeled the site from the 1940s forward – starting from a clean environment and simulating the release and migration in the environment in the past and continuing into the future. Under this approach, as facilities were retired from service, their emissions were assumed to eventually stop; as another facility were started, those emissions were then added as the analysis progressed through time. The conceptual exposure pathways considered in the previous modeling work are depicted in Figure 1.

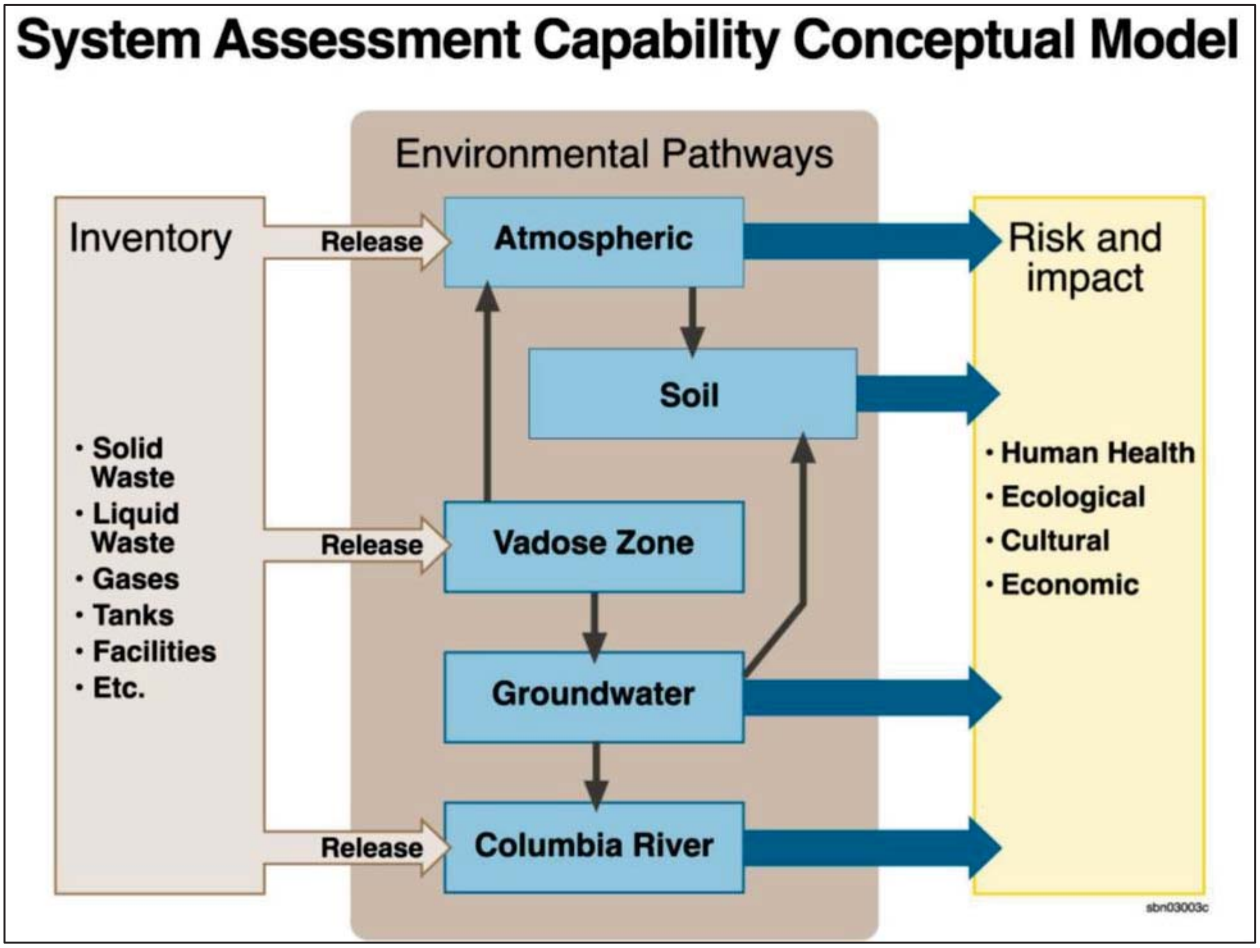

Figure 1. System Assessment Capability Conceptual Model, after PNNL-11800

For the present work to update the CA, the preferred approach to modeling was determined during the Hanford Site Revised Composite Analysis Key Aspects Scoping Workshop conducted in May 2016. The selected preferred approach would not calculate dose in the river, but consider a boundary closer to the proposed Inner Area boundary or Core Zone boundary from the most Comprehensive Land Use Plan, as amended including the 2015 supplement analysis (DOE/EIS-0222-SA-02). Therefore, the surface-water transport module (depicted as the Columbia River in Figure 1) would not be required. The rationale behind this preference is that if doses calculated closer to the Inner Area are compliant, then doses calculated at or in the Columbia River would be correspondingly lower. This would primarily be the result of dilution in the saturated zone, or time delays allowing for radionuclide decay as the contaminants transport in the unconfined aquifer over the approximately 20- to 30-mile distance to the river.

Further, the preferred approach would start the analyses at the date that the entire site is closed, now estimated at 2070 or possibly later [the exact date for the start of the 1000-year performance period for the revised Hanford Site Composite Analysis is currently under consideration by the Low-Level Waste Disposal Facility Federal Review Group (LFRG)]. By starting the CA performance period later (2070 or beyond), many of the operating facilities that are currently generating air emissions will be closed. This includes, for example, the pump and treat facilities, the Waste Treatment Plant, and any future supplemental treatment technologies, should they be utilized. This serves to simplify the CA greatly with regard to air-pathway dose calculations, should these be determined necessary to include in the quantitative analysis.

The ability to omit a potential pathway, such as the air pathway, from detailed evaluation, must be justified and approved. While tentative approval to exclude the air pathway from the quantitative evaluation was obtained during the Key Aspects Workshop, regulations do require that all sources that contribute to dose be identified. However, the LFRG (who perform the review of the CA for DOE Headquarters), specifies the following for the analysis: “Sources selected should include all sources that could make a significant contribution to potential future doses associated with the LLW disposal facility.” One way to assess significance is by screening the sources based on their contribution to dose. In the previous CA (PNNL-11800), the value of “significant” was determined to be all sources contributing to 99% of the total dose. If one awaits site closure, then the sources contributing to the air pathway become very diminished and limited. These will be dominated primarily by the disposed production graphite-reactor core contributions of carbon-14 and generally fall orders of magnitude below the PA air dose criteria of 10 mrem/yr.

4 Methodology

The methodology employed for the development of a technical approach for the air pathway is to evaluate prior and developing performance assessments and prior site-wide evaluations results for the air pathway to determine significance to the total radiological dose reported. This review will provide the basis for determining:

1) Does the atmospheric pathway evaluation in the initial CA requires recalculation for the updated CA?

2) Are the results of prior and developing analyses sufficient to recommend considering the air pathway as insignificant to the total radiological dose (in comparison to the groundwater pathway), and can it therefore be removed from the full quantitative evaluation for the updated CA?

4.1 Screening of Insignificant Radionuclides and Exposure Pathways

During the initial scoping exercise in May 2016 (CP-60649), the expressed preference was to exclude quantitative modeling of the air pathway if adequate justification can be provided. However, if there are significant questions regarding a particular source, the choice to eliminate the air pathway could also be made on a case-by-case basis.

In its *Consolidated Decommissioning Guidance* (NUREG-1757, NRC 2006), the U.S. Nuclear Regulatory Commission provided guidance on conditions under which radionuclides or exposure pathways may be considered insignificant, and may be eliminated from further consideration. The dose criteria in 10 CFR

Part 20, Subpart E, apply to the total dose from residual radioactivity. Thus, NRC requested that demonstrations of compliance should generally address the dose from all radionuclides and all exposure pathways. However, NRC recognized that "there may be large uncertainties associated with survey data and with dose assessment results. In a risk-informed, performance-based paradigm, NRC staff has determined it is reasonable that radionuclides or pathways that are insignificant contributors to dose may be eliminated from further detailed consideration".

Furthermore, NRC considered "radionuclides and exposure pathways that contribute no greater than 10% of the dose criteria to be insignificant contributors". Because the dose criteria are performance criteria, this 10% limit for insignificant contributors is an aggregate limitation only. That is, the sum of the dose contributions from all radionuclides and pathways considered insignificant should be no greater than 10% of the dose criteria.

NRC further suggested that once the radionuclides or exposure pathways are determined insignificant, then

(a) The dose from the insignificant radionuclides and pathways must be accounted for in demonstrating compliance, but

(b) The insignificant radionuclides and pathways may be eliminated from further detailed evaluations.

Based on the NRC guidance and the review of the initial CA and related documents, it is recommended that the following steps should be implemented to determine whether the elimination of a detailed quantitative modeling of the air pathway for the current CA is warranted:

1. Review dose reported and significance of air pathway dose reported in prior studies, including Hanford Site Performance Assessments, the initial CA, the incomplete 2006 CA, and the TC&WM EIS. (Section 5).
2. Investigate and recover the details of methodologies, inputs, and outputs of the air transport modeling in the initial CA (Section 6) to:
    a. Verify their validities based on the current regulatory guidance.
    b. Investigate and recover the details of methodologies, equations, inputs, and outputs of the exposure and dose modeling in the initial CA, and verify their validities based on the current regulatory guidance.
    c. Validate the exposure dose results for atmospheric pathway in the initial CA.
3. Perform screening analysis to determine the inclusion or exclusion of a detailed quantitative modeling and evaluation of atmospheric pathway in the current CA.

5 Air Pathway Dose and Significance for Prior Assessments

This section provides a review of air pathway dose reported and significance of the air pathway dose in prior studies, namely the Hanford Site Performance Assessments, the initial CA, the incomplete 2006 CA, and the TC&WM EIS.

5.1 Air Pathway Dose for Hanford Site Performance Assessments

The methodology utilized in this approach is to compare air pathway doses obtained from previous facility-specific performance assessments, or from preliminary calculation files performed for scoping for performance assessments currently in development. Several performance assessments have been conducted for Hanford Site LLW disposal facilities that describe doses and contaminants of concern in the air exposure pathway. During the first 1,000 years after closure – before contaminants released from LLW disposal facilities will reach the groundwater –the primary dose received is often from the air pathway. However, these doses are extremely small and fall far below the allowed air pathway dose of 10 mrem/yr. Table 2 is a compilation of calculated air pathway doses received by a maximally exposed individual (MEI) for several previous performance assessments. None of these doses would be significant when evaluated against the 100 mrem/yr or 30 mrem/yr standards.

Table 2. Air Pathway Dose for Hanford Site Performance Assessments

Facility	Reference	Calculated Dose from Air pathway
Integrated Disposal Facility – 2001 PA	DOE/ORP-2000-24, *Hanford Immobilized Low Activity Waste Performance Assessment: 2001 Version*	0.006 mrem/yr
Integrated Disposal Facility – 2016 PA (preliminary results)	RPP-CALC-61014 Rev.0 Draft *Atmospheric Pathway Dose Calculation for the Integrated Disposal Facility Performance Assessment* (1)	Three orders of magnitude below 10 mrem/yr standard
Environmental Restoration Disposal Facility	WCH-520, *Performance Assessment for the Environmental Restoration Disposal Facility, Hanford Site, Washington*	3×10^{-4} mrem/yr
LLBG 218-E-12B; includes defueled U.S. Navy reactor compartments	WHC-SD-WM-TI-730, 1996, *Performance Assessment for the Disposal of Low Level Waste in the 200 East Area Burial Grounds*	"nil"
LLBG 218-W-Cat 1 Facility	WHC-EP-0645, *Performance Assessment for the Disposal of Low Level Waste in the 200 West Area Burial Grounds*	1.1×10^{-6} mrem/yr
LLBG 218-W-Cat 3 Facilities	WHC-EP-0645, *Performance Assessment for the Disposal of Low Level Waste in the 200 West Area Burial Grounds*	0.012 mrem/yr
Waste Management Area C preliminary results – 2015	RPP-ENV-58782 Revision A Draft, *Performance Assessment of Waste Management Area C, Hanford Site, Washington* (1)	Three orders of magnitude below 10 mrem/yr standard

(1) Information is from preliminary drafts of performance assessments currently in progress, and information is taken as indicative of expected results but are subject to change.

5.2 Air Pathway Dose in Prior Composite Analysis Calculations

The updated CA will replace the initial CA (PNNL-11800; PNNL-11800-Addendum-1). A CA update was in progress in 2006 when work was stopped; consideration of the scope of that analysis with respect to the air pathway is noted although published results are not available for review.

5.2.1 Initial 1998 Composite Analysis

The evaluation of the atmospheric pathway in the initial CA (PNNL-11800) was performed for a single suite of sources and only considered potential releases from graphite cores of production reactors. This assumption was made based on a review of previously completed analyses (PNNL-11800) It was assumed in this analysis that these graphite cores will be disposed in a hypothetical burial ground in the 200 West Area, with potential long-term exposure to individuals living in the vicinity of atmospheric releases resulting from degradation of these production reactors. Radionuclides released to the atmosphere from these production reactors were transported downwind in the analysis from the hypothetical solid waste burial ground.

5.2.2 The Composite Analysis Conducted in 2006

In contrast, the Composite Analysis tasks performed in 2006 included full quantitative evaluation of the atmospheric pathway. The RATCHET atmospheric transport model (PNWD-2224-HEDR, *Regional Atmospheric Transport Code for Hanford Emission Tracking (RATCHET);* PNNL-16115) was incorporated in the modeling framework.

A major module within the System Assessment Capability (SAC) Systems (PNNL-16071), RATCHET calculates the release rates of contaminants to the air and deposition rates of airborne contaminants to the soil. RATCHET is a Lagrangian trajectory, Gaussian-puff atmospheric dispersion model that includes deposition and depletion. Gaussian models are used to describe the atmospheric dispersion of radioactive and chemical effluents from nuclear facilities. A Lagrangian trajectory, Gaussian puff model is used where temporal or spatial variations in meteorological conditions or depletion of the plume due to dry deposition may be significant (PNNL-16071).

The RATCHET2 code was originally developed for the Hanford Environmental Dose Reconstruction (HEDR) Project. For HEDR, it used hourly meteorological and iodine-131 release data to estimate daily exposures (time-integrated concentrations) and surface contamination over an area of approximately 195,000 km^2 (75,000 mi^2) in eastern Washington, eastern Oregon, and northern Idaho. For SAC, RATCHET2 has been modified to estimate normalized annual exposures and surface contamination over an area of approximately 9,100 km^2 (3,500 mi^2) that includes the Hanford Site and adjacent land. Meteorological data for the SAC calculations consist of hourly surface observations made at 28 stations from 1983 through 2002. These data, which include wind direction and speed, temperature, precipitation, and atmospheric stability indicator, were used to derive the spatially and temporally varying meteorological fields needed by RATCHET2. Ground-level and elevated release points can be placed at appropriate locations on the Hanford Site, and exposures and surface contaminations were estimated at more than 2,100 locations on a 41 x 53 Cartesian grid that had 2 x2 km (1.2 x 1.2 mi) spacing (PNNL-16071).

In the implementation in 2006 CA, the model represented transport of atmospheric sources from the production reactor blocks (as in the initial CA) and from gas-phase partitioning of volatile contaminants in the vadose zone at all waste sites as well. The preliminary results of this complex analysis indicated the air pathway was not significant, but those results were not published before work was stopped on the 2006 CA, so no further information can be derived from that analysis.

5.3 Air Pathway Dose in the Tank Closure and Waste Management Environmental Impact Statement

The TC&WM EIS only evaluated the air pathway for short-term consequences. Those results are reviewed below for context. No long-term consequences

5.3.1 Air Pathway in the Long-Term Consequences Evaluation

The TC&WM EIS did not present an analysis of the atmospheric pathway for long-term consequences. The remainder of this discussion reviews, for completeness, air pathway evaluation for short-term consequences presented in DOE/EIS-0391.

5.3.2 Air Pathway in the Short-Term Consequences Evaluation

For the short-term consequences analysis, the TC&WM EIS (Appendix P, Ecological Resources and Risk Analysis), radionuclide flux through a cap for a landfill or cover over waste sites was not calculated. Rather, as is stated below in Section P.2.1.3 of the TC&WM EIS, a conservative estimate for the air pathway was used, by calculating deposition rates due to operation of the WTP and from D&D (FFTF) and closure of facilities. The TC&WM EIS analysis assumed that contaminants were re-suspended and that the deposition lasted over the lifetime of the facility. In the excerpt below, the EIS states (in Section P.2.1.3) that all scenarios were below the cut off levels and that because direct exposure was so small, any indirect exposures to the ecosystems would be minor.

> **Except from Section P.2.1.3 of the TC&WM EIS - Predicted Soil and Air Concentrations:**
>
> The cumulative surface-soil and maximum air concentrations under Tank Closure Alternatives 1 through 6C; FFTF Decommissioning Alternatives 1, 2, and 3 (Hanford and Idaho Options); and Waste Management Alternatives 1, 2, and 3 were calculated from the modeled air deposition rates resulting from site and WTP operations (see Appendix G). The onsite soil concentrations were calculated from the maximum-modeled air deposition rates. The modeled soil concentrations assumed persistence of existing soil contamination and accumulation of deposited contamination over the duration of the operations period. The surface-soil concentrations were calculated assuming that the amount of material deposited on the soil surface over the operations period would be mixed throughout the upper 1 centimeter (0.39 inches) of soil. The deposition flux per unit area (grams per square meter per year or curies per square meter per year) was multiplied by the duration of operations (years) and divided by the mass of soil per unit area (grams per square meter) to estimate the concentration (grams of contaminant per gram of soil or curies per gram), and these results were converted to milligrams per kilogram or picocuries per gram. The instantaneous air concentration (milligrams per cubic meter or picocuries per cubic meter) was estimated as the annual average deposition flux (milligrams per second or picocuries per second) divided by the unitized flux rate (cubic meters per second). The conservative estimates of surface-soil concentrations for radionuclides were used for both above- and below-ground external exposures.
>
> Air concentrations at the ground surface resulting from re-suspension of soil were calculated for each location for which soil concentrations were predicted. Modeled air concentrations of radionuclides were used to calculate external exposure to terrestrial ecological resources. Soil and air concentrations were used as the source term in the exposure model described in P.2.1.4.
>
> Exposure to radioactive COPCs from air emissions under all alternatives was below the l-rad-per-day benchmark for soil-dwelling invertebrates and plants and the 0.l-rad-per-day benchmark for terrestrial wildlife receptors (i.e., Woodhouse’ s toad, mule deer, mourning dove, Great Basin

> pocket mouse, western meadowlark, coyote, and burrowing owl). Estimated hazards for the representative species indicated that no adverse effects are expected for offsite terrestrial receptors from exposure to radioactive COPCs from air emissions. Because the direct impacts of air exposure are expected to be small, any associated, potential indirect impacts on the ecosystem would be correspondingly minor.

The short-term impacts from the TC&WM EIS were calculated by making conservative assumptions during the operational phase of the Hanford Site. Therefore, it can be presumed that after operations cease, even smaller doses would be realized, thus lending support to the position that air pathways dose can be excluded from quantitative evaluation in the revised CA.

The TC&WM EIS states:

> "The radiological impacts on the public due to the FFTF Decommissioning alternatives and options are presented in Table K–57 for the population, in Table K–58 for an MEI, and in Table K–59 for an onsite MEI at Hanford. Impacts of FFTF Decommissioning Alternatives 2 and 3 would include the impacts of facility disposition, disposition of RH-SCs, and disposition of bulk sodium. Based on the calculated collective population dose, no LCFs are expected as a result of any of the alternatives or options; all calculated LCF values are much less than 1. The incremental risk of an LCF to an MEI would be extremely small in all cases; the largest risk over the life of the project would be about 2×10^{-10}, or less than 1 in a billion."

TC&WM EIS Tables K58 and K59 are reproduced below as Table 3 and Table 4, respectively for reference.

Table 3. FFTF Decommissioning Alternatives – Impacts on the Maximally Exposed Individual during Normal Operations (After DOE/EIS-0391 (2012), Table K-58)

	Life of Project		Year(s) of Maximum Impact			
Radionuclides	**Dose (Millirem)**	**Lifetime Risk of an LCF**	**Dose (millirem per year)**	**Risk of an LCF**	**Direction**	**Distance (Kilometers)**
Alternative 1, No Action[a]						
Hydrogen-3 (tritium)	6.7×10^{-4}		6.7×10^{-6}		SE	9.1
Cesium-137	2.8×10^{-5}		2.8×10^{-7}			
Plutonium-239	9.6×10^{-4}		9.6×10^{-6}			
Total	$\mathbf{1.7\times10^{-3}}$	$\mathbf{1\times10^{-9}}$	$\mathbf{1.7\times10^{-5}}$	$\mathbf{1\times10^{-11}}$		
Alternative 3, Facility Disposition						
Cesium-137	5.8×10^{-8}	3×10^{-14}	5.8×10^{-8}	3×10^{-14}	SE	9.1
Alternative 3, Facility Disposition						
-	-	-	-	-	-	-
Alternatives 2 or 3, Disposition of Remote-Handled Special Components – Hanford Option						

Table 3. FFTF Decommissioning Alternatives – Impacts on the Maximally Exposed Individual during Normal Operations (After DOE/EIS-0391 (2012), Table K-58)

	Life of Project		Year(s) of Maximum Impact			
Radionuclides	**Dose (Millirem)**	**Lifetime Risk of an LCF**	**Dose (millirem per year)**	**Risk of an LCF**	**Direction**	**Distance (Kilometers)**
Sodium - 22	4.3×10^{-6}		3.5×10^{-6}		ENE	18.2
Cesium-137	5.3×10^{-6}		4.4×10^{-6}			
Total	$\mathbf{9.6\times10^{-6}}$	$\mathbf{6\times10^{-12}}$	$\mathbf{7.8\times10^{-6}}$	$\mathbf{5\times10^{-12}}$		
Alternative 2 or 3, Disposition of Remote-Handled Components – Idaho Option						
Sodium - 22	2.3×10^{-4}		1.0×10^{-4}		S	13.4
Cesium-137	3.7×10^{-6}		2.5×10^{-6}			
Total	$\mathbf{6.7\times10^{-6}}$	$\mathbf{4\times10^{-12}}$	$\mathbf{4.4\times10^{-6}}$	$\mathbf{3\times10^{-12}}$		
Alternative 2 or 3, Disposition of Bulk Sodium – Hanford Reuse Option						
Tritium	2.3×10^{-4}		1.0×10^{-4}		SE	9.1
Sodium - 22	7.6×10^{-4}		3.5×10^{-4}			
Cesium-137	2.8×10^{-5}		1.3×10^{-5}			
Uranium	1.0×10^{-7}		4.7×10^{-8}			
Total	$\mathbf{1.0\times10^{-3}}$	**6×10-10**	$\mathbf{4.6\times10^{-4}}$	$\mathbf{3\times10^{-10}}$		
Alternative 2 or 3, Disposition of Bulk Sodium – Idaho Reuse Option						
Tritium	1.7×10^{-4}		8.4×10^{-5}		SSE	5.2
Sodium - 22	5.5×10^{-4}		2.7×10^{-4}			
Cesium-137	2.0×10^{-5}		1.0×10^{-5}			
Uranium	7.6×10^{-8}		3.8×10^{-8}			
Total	$\mathbf{7.4\times10^{-4}}$	$\mathbf{4\times10^{-10}}$	$\mathbf{3.7\times10^{-4}}$	$\mathbf{2\times10^{-10}}$		

[a] The life-of-project dose would not be received by one individual person due to the duration of this alternative (100 years). The dose and lifetime risk of an LCF from 70 years of exposure at the average annual dose rate would be 1.2 x 10-3 millirem with a corresponding lifetime risk of an LCF of 7×10^{-10}.

Note: To convert kilometers to miles, multiply by 0.6214.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; Idaho=Idaho National Laboratory; LCF=latent cancer fatality.

Table 4. FFTF Decommissioning Alternatives – Impacts on the Hanford Onsite Maximally Exposed Individual during Normal Operations (after DOE/EIS-0391, Table K-59)

	Life of Project		Year(s) of Maximum Impact		
Radionuclides	**Dose (millirem)**	**Lifetime Risk of an LCF**	**Dose (millirem per year)**	**Risk of an LCF**	**Location**
Alternative 1, No Action(a)					
Hydrogen-3 (tritium)	1.2×10^{-8}		1.2×10^{-10}		CGS
Cesium-137	4.9×10^{-6}		4.9×10^{-8}		
Plutonium-239	1.1×10^{-3}		1.1×10^{-5}		
Total	$\mathbf{1.1\times10^{-3}}$	$\mathbf{6\times10^{-10}}$	$\mathbf{1.1\times10^{-5}}$	$\mathbf{6\times10^{-12}}$	
Alternative 2, Facility Disposition					
Cesium-137	1.0×10^{-8}	6×10^{-15}	1.0×10^{-8}	6×10^{-15}	CGS
Alternative 3, Facility Disposition					
-	-	-	-	-	-
Alternative 2 or 3, Disposition of Remote-Handled Special Components – Hanford Option					
Sodium-22	2.3×10^{-5}		1.5×10^{-5}		US Ecology
Cesium-137	3.9×10^{-6}		2.6×10^{-6}		
Total	$\mathbf{2.7\times10^{-5}}$	$\mathbf{2\times10^{-11}}$	$\mathbf{1.8\times10^{-5}}$	$\mathbf{1\times10^{-11}}$	
Alternative 2 or 3, Disposition of Bulk Sodium – Hanford Reuse Option					
Tritium	4.1×10^{-9}		1.9×10^{-9}		LIGO
Sodium-22	9.7×10^{-4}		4.4×10^{-4}		
Cesium-137	5.0×10^{-6}		2.3×10^{-6}		
Uranium	1.1×10^{-7}		4.8×10^{-8}		
Total	$\mathbf{9.8\times10}$	$\mathbf{6\times10^{-10}}$	$\mathbf{4.4\times10^{-4}}$	$\mathbf{3\times10^{-10}}$	

(a) The life-of-project dose would not be received by one individual person due to the duration of this alternative (100 years). The dose and lifetime risk of an LCF from 40 years of exposure at the average annual dose rate would be 4.2×10^{-4} millirem, with a corresponding lifetime risk of an LCF of 3×10^{-10}.

Key: CGS=Columbia Generating Station; FFTF=Fast Flux Test Facility; Hanford=Hanford Site; LCF=latent cancer fatality; LIGO=Laser Interferometer Gravitational-Wave Observatory; US Ecology=US Ecology Commercial Low-Level Radioactive Waste Disposal Site.

The remainder of this discussion will review the air pathway evaluation presented in the initial CA. The purpose of this review is to evaluate the modeling results and basis to determine if the calculation basis remains valid and, if so, whether the dose result can be considered an insignificant contributor to total radiological dose for the purposes of the updated CA.

6 Details of Methodologies, Inputs, and Outputs of the Air Transport Modeling in the Initial Composite Analysis

In this section, the details of methodologies, inputs, and outputs of the air transport modeling in the initial CA are investigated to:

a) Verify their validities based on the current regulatory guidance.

b) Investigate the details of methodologies, equations, inputs, and outputs of the exposure and dose modeling in the initial CA, and verify their validities based on the current regulatory guidance.

c) Validate the exposure dose results for atmospheric pathway in the initial CA.

6.1 Initial Composite Analysis Source Release Rates for Carbon-14 and Tritium

The source release rates for C-14 and tritium were developed from the 2050 inventories for the hypothetical burial site in the northwestern part of the 200 West Area for the atmospheric modeling in the original CA. Since no method was developed to partition the gas verses the liquid phase for C-14 and tritium as they were released from the eight graphite reactor cores, the 2050 inventories of C-14 and tritium were assumed to be released to both air and vadose zone pathways. Therefore, they were accounted for twice in the original CA

The estimated release rates of C-14 and tritium used in the initial CA were based on the methods and results presented in the *Draft Environmental Impact Statement - Decommissioning of Eight Surplus Production Reactors at the Hanford Site* (DOE/EIS-0119D, 1989). Using the following equation,

$$R_s\left(\frac{1}{day}\right) = 565(1 + 100e^{-0.08t})e^{-6440/T}$$

where,

- t is the time in days after wetting of the graphite
- T is the ambient temperature in degree K.

The maximum potential release rate for C-14 from water-saturated cores was calculated as 4 mCi per day per reactor or 1.5 Ci per year per reactor. The maximum total release rate for the eight reactor cores was 12 Ci per year. For tritium, the calculated total maximum release rate was 0.0073 Ci per year in 2050, the time when it was assumed that the cores would be placed in their hypothetical disposal area (DOE 1989, PNNL 1998).

6.1.1 Initial Composite Analysis Assumptions of the Atmospheric Transport Model

The key assumptions made for the development of the atmospheric transport model used in the initial CA are listed in PNNL-11800 (Section 4.1.5, Table 4.12). The assumptions included:

- The graphite reactor cores source was the only significant contributor to the dose via the atmospheric pathway;
- The entire fraction of inventory predicted to have been released from the reactor cores would enter the atmosphere; and

- Atmospheric emissions were to occur uniformly over an area source of 100 m by 600 m.

6.1.2 Initial Composite Analysis Atmospheric Model Implementation

In the initial CA, unit transport factors (UTFs) were calculated for the postulated release originating within the exclusive waste management area. The atmospheric transport of gaseous radionuclides was evaluated with the *Multimedia Environmental Pollutant Analysis System* (MEPAS) code. PNL-10395, *Multimedia environmental pollutant assessment system (MEPAS) Application Guidance, Guidelines for Evaluating MEPAS Input Parameters for Version 3.1,* and PNNL-11080, *The Multimedia Environmental Pollutant Assessment System (MEPAS): Atmospheric Pathway Formulations*, describe the MEPAS code. The MEPAS code is based on the sector-averaged Gaussian model, which is the method recommended for dose calculations performed for releases from Hanford Site facilities (PNL-3777 Rev. 2, *Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters*).

The UTFs provide estimates of air concentration and deposition rate to soil as a function of distance and direction from each source area. The UTFs were normalized to an annual release of 1 pCi of each radionuclide and provided air concentration estimates in units of pCi/m^3 and deposition rates in units of $pCi/m^2/yr$.

Within the initial CA, atmospheric transport away from the eight surplus reactor cores, which were hypothetically located at burial site in the northwestern part of the 200 West Area, was treated as a radial transport directed away from the center of the source area. Because the source of emission was characterized as a distributed source based on either the actual size of the reactor cores or the size of the burial ground cover under which the reactors cores would be placed, the peak values for the concentration and dose rate estimated at the actual source location center were not meaningful resulting from the radial nature to the fall off. Also, the model predictions for the points inside the 600-m by 100-m source area should be ignored since they were within the source boundary.

It should be noted that although the input parameter values and the associated discussions for the Unit Dose Factors were presented in Appendix F of the initial CA report (PNNL-11800), the details for the methods, equations, and input parameter values for the sector-averaged Gaussian modeling as well as for the implemented MEPAS were not presented in the initial CA. The detail information is critical for verifying the validity of the results from the initial atmospheric transport modeling and determining the technical approach for the updated CA.

Recommended atmospheric data from PNL-3777 (Rev. 2) were used to perform the atmospheric transport calculations. It is noted here that the contents related to this statement could not be verified in PNNL-11800. Moreover, general discussions about atmospheric releases, atmospheric transport characteristics, and meteorological data requirements were also presented in PNL-3777, Rev. 2. The environmental settings for the transport calculations used for the initial CA were described by Holdren et al. (1995).

Further search for MEPAS input details from other documents (e.g., PNL-10550) yielded little useful information.

6.1.3 Initial Composite Analysis Exposure and Dose Results for the Atmospheric Releases

The radiological dose impact of the atmospheric releases of C-14 and tritium was evaluated along with other radionuclides and chemicals of concerns in the original CA, and the exposure scenarios used were those defined for the Hanford Site Risk Assessment Methodology (HSRAM). The exposure doses were predicated with the unit dose factors (UDFs) and the source release rates. The UTFs were evaluated for each exposure scenario and environmental media appropriate to the individual exposure scenarios. The environmental media considered included ground water, air, and soil contaminated by atmospheric deposition. Based on the 2050 inventories, Carbon-14 and tritium were analyzed for vapor phase migration upward and then lateral transport in the atmosphere, and the calculated atmospheric releases yielded a contribution of approximately 0.4 mrem in a year to the all pathway dose (PNNL-11800). This dose was the result of soil contamination that included the continuous buildup of contamination in surface soils because of atmospheric deposition over the entire 1000-year period following the Hanford Site closure. It was determined that the maximum contribution from the soil-atmospheric pathway occurred on the western edge of the 200 West Area.

In comparison, the maximum dose for the agriculture scenario, which exhibited the highest dose among all the evaluated exposure scenarios, was less than 6 mrem in a year during the regulatory period of the 1000 years following the Hanford Site closure for all the lands outside the buffer zone. Therefore, the atmospheric pathway contributed less than 7% to the maximum dose for the agriculture scenario.

The details of the exposure and dose calculations, such as methodologies, exposure and dose equations, and input parameters were presented in Appendix F of the initial CA report (PNNL-11800). Initial evaluation of input parameter values showed that further investigation and comparison with EPA guidance and other regulatory documents are warranted. The investigation of this detail information is necessary for confirming the exposure and dose calculation results from the initial CA, and for performing the screening analysis to determine the inclusion or exclusion of a detail quantitative modeling of atmospheric pathway in the current CA.

The following table summarizes the components, methods, models, and results for the atmospheric pathway evaluation in the initial CA:

Table 5. Summary of Atmospheric Pathway Evaluation in the Initial Composite Analysis

Component	Result
Source of Radionuclide Releases	Eight graphite reactor cores (assumed disposed in a 200 West Area burial ground in 2050)
Area of Source	600 × 100 m
Radionuclide for Study	Carbon-14, Tritium
Year of Emission Inventory	2050
Source Release Rate	
Carbon-14	12 Ci per year
Tritium	0.0073 Ci per year
Atmospheric Transport Model	UTF, MEPAS
Technical Details	Not presented
Exposure and Dose Model	UDF, HSRAM
Transport Media	Soil (air deposition), Air, Groundwater
Exposure Pathway (Agriculture Scenario)	Ingestion, External, Dermal Contact, Suspension-Inhalation, Biota-Dairy, Biota-Meat, Biota-Game, Biota-Fruit, Biota-Vegetable

Table 5. Summary of Atmospheric Pathway Evaluation in the Initial Composite Analysis

Component	Result
Technical Details	Not presented
Dose Result-Atmospheric Pathway	0.4 mrem in a year
Maximum Dose-Agriculture Scenario	6 mrem per year
Atmospheric Pathway Contribution to Agriculture Scenario Dose	7%

The initial CA showed that exposure from atmospheric releases from the production reactor graphic cores to be an insignificant contributor to the total dose outside of the buffer zone during the 1,000 years following site closure.

Because release of all but about 10 mi^2 of land area is planned after remediation under CERCLA RODs is completed, these areas will be expected to contribute insignificant impacts to an overall CA.

7 Screening Analysis

Through the review of the initial Composite Analysis, as discussed in Section 6, it is found that many details of methodologies, equations, inputs, and outputs for the atmospheric transport modeling and exposure and dose modeling in the initial CA cannot be verified, so, the dose result for the atmospheric pathway can not be validated based on the current regulatory guidance.

It is recommended that in the analysis phase of the updated CA

1) An independent modeling and calculation based on the current regulatory documents should be conducted.

2) If the independent modeling and calculation validate the results of the initial CA atmospheric pathway evaluation and support a finding of non-significance of the air pathway (relative to the groundwater pathway), then the level of presentation and discussion of the atmospheric pathway in the updated CA should be evaluated and determined.

8 Quality Assurance and Quality Control

If quantitative evaluation of the air pathway is determined necessary for the updated CA, then the quality assurance/quality control requirements specified in the project management plan (PRC-MP-EP-53107, *Hanford Composite Analysis Project Management Plan*). That plan identifies all relevant quality assurance and quality control requirements, and imposes additional project-specific requirements for the CA update project.

9 Conclusions

Small and/or insignificant sources may be eliminated in the update of the CA. Further, all doses from the air pathway calculated to date by many credible analyses have concluded that the air pathway does not significantly contribute to the all pathways dose to an MEI within a 1,000-year period following disposal or closure of the site. This would indicate that the significance of the source terms related to the air pathway and in fact, the air pathway portion of the CA, could be abstracted or simplified, pending further evaluation and approval.

To reach the decision of simplification, it is necessary to investigate the initial CA and recover more details for the atmospheric transport modeling and exposure and dose modeling, validate and confirm the calculated dose for the atmospheric pathway, and then perform an independent validation modeling and analysis following the NRC guidance. If the independent modeling and calculation validate the results for the initial CA atmospheric pathway evaluation and support a finding of non-significance of the air pathway (relative to the groundwater pathway), then the level of presentation and discussion of the atmospheric pathway in the updated CA should be evaluated and determined.

10 References

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