HOW TO DETERMINE SITE-WIDE RISKS IN COMPLEX MULTI UNIT CERCLA ACTIVITIES

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ABSTRACT

Typically, a complex site such as Fernald is broken up into manageable operating units. The purpose of smaller units is to combine similar types of materials or wastes into groups where they can be more easily managed. While baseline risks are evaluated in the RI and future risks for a set of alternatives in the FS for each operating unit, overall site-wide risks must be considered to determine if the cumulative impact of all of the units meets risk requirements. To meet this need the concept of a Comprehensive Response Action Risk Evaluation (CRARE) was developed for the Fernald remediation process. The CRARE calculates the impact after remediation of all of the operating units on receptors both on and off the site.

In developing the Consent Agreement between USEPA and DOE, a key issue became the concern that after all of the operating units had been remediated that the sum of the risks would be unacceptable. While each unit would meet the risk acceptance criteria, cumulative impact would be unacceptable. Further, it may be less expensive to reduce risks from one operable unit than another. Although each unit must meet individual risk acceptance criteria, additional reductions may be necessary in some units to reduce the cumulative risk.

The Consent Agreement requires that each Feasibility Study (FS) provide a CRARE which is updated with the new information contained in each new FS. A CRARE has been completed for the first FS to be sent to USEPA. CRAREs will be completed for three other units before the end of 1994.

The purpose of the paper will be to provide the policy framework that was followed in developing the CRARE, the details of how the separate units were brought together for evaluation, findings and results, and lessons learned.

The document has already had its desired effect in helping to focus on the risk "drivers". Through this valuable input, current FSs are better able to address those source terms, pathways, etc. which are most important from a site perspective. The CRARE provides the assurance that when the last operating unit is remediated the residual risk will be at an acceptable level and additional cleanup will be unnecessary.

Every site with multiple operating units must find a way to look at site wide risks to insure that protectiveness requirements are met, the CRARE provides a unique model for meeting this need.

INTRODUCTION

The Comprehensive Response Action Risk Evaluation (CRARE) analyzes the potential cumulative, residual, human health risks projected to remain at the Fernald site following implementation of the remedial action. Its purpose is to make sure that when the individual operable units are remediated, the cumulative risk from the site as a whole is within acceptable levels. Each sequential FS for the five operable units will include a CRARE unless there is no change in cumulative site risk. The first CRARE has been completed, which addresses final remedial action for two operable units; the second iteration is under way.

The CRARE uses the preferred alternative from the proposed plan or, if not completed, the leading remedial alternatives (LRAs) (presently considered the most likely alternative) as defined in the Site-Wide Characterization Report. Because the CRAREs are based only on the information available at the time they are prepared, all but the final CRARE are considered *preliminary* evaluations of final residual risk. One of the most important uses of the early CRAREs is to identify areas and factors which contribute the greatest risk and thus provide focus and direction to future data collection and analysis and response actions considered for the remaining operable units.

FEMP Site History

Formerly known as the Feed Materials Production Center, the Fernald Environmental Management Project (FEMP) is a contractor-operated federal facility where pure uranium metals were produced for the U.S. Department of Energy (DOE) from 1951 to 1989. After production ceased, plant resources were focused on a cleanup program. In 1991, the FEMP was officially closed as a federal production facility and the site focused on environmental studies and cleanup activities. The FEMP site is located on 425 hectares (1050 acres) in a rural area of Hamilton and Butler counties, approximately 29 kilometers (18 miles) northwest of downtown Cincinnati, Ohio.

CRARE Objectives

The objective of the CRARE is to estimate, from a site-wide perspective, the long-term residual risk remaining after the FEMP has been remediated. This objective and other supporting objectives are depicted in Fig. 1. The figure also presents the iterative nature of the CRARE.

The CRARE is an informational document rather than a decision document. It provides information on site-wide risks that will be essential in determining remediation levels during the Record of Decision (ROD) process for each operable unit.

The CRARE

- Quantifies operable-unit-specific contributions to site-wide potential public health concerns, which include both potential carcinogenic (radiological and chemical) and noncarcinogenic effects.
- Provides information to address modifications of site-wide preliminary remedial goals (PRGs), based

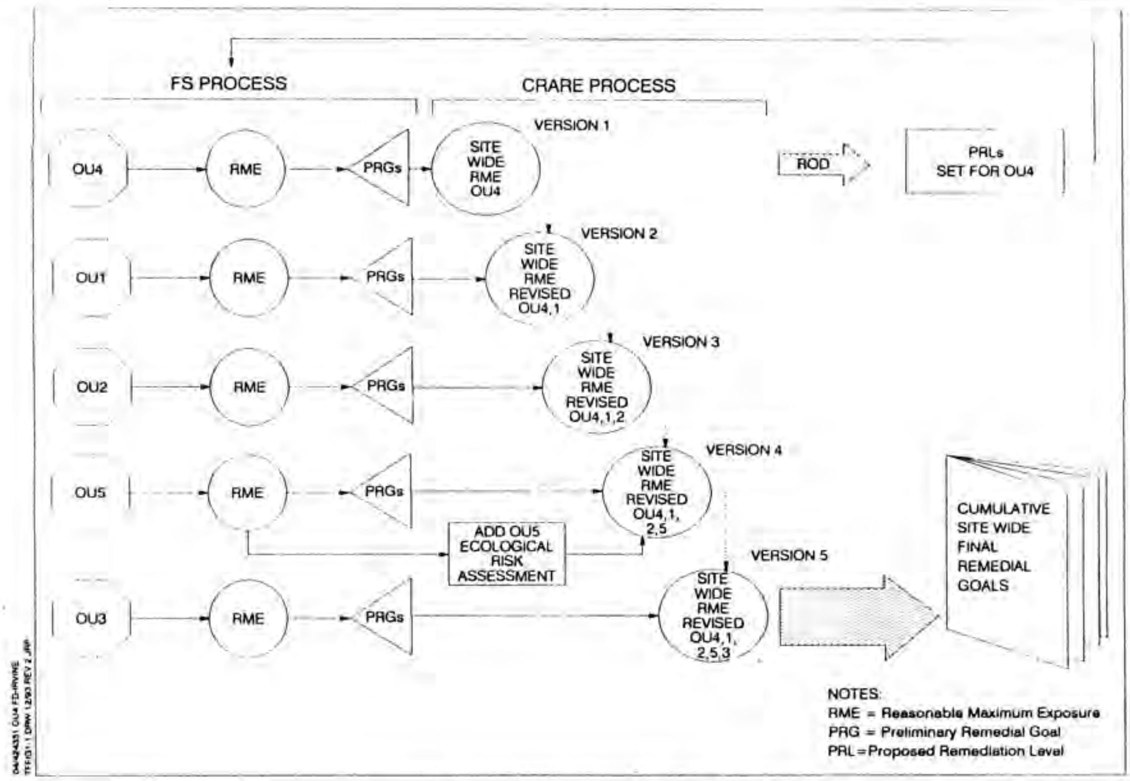

Fig. 1. Iterative nature of the CRARE.

on associated carcinogenic and noncarcinogenic effects to human receptors.

- Incorporates operable-unit-specific information from the Operable Unit 4 FS risk assessment (the first operable unit risk assessment completed) and sets the protocol for future operable unit considerations.

Operable Units

The FEMP was divided into five operable units under the original 1990 Consent Agreement, and the units were redefined under the Amended Consent Agreements. Figure 2 shows the FEMP site as a whole. The five operable units definitions are presented below:

- **Operable Unit 1:**

  Waste Pits 1 through 6, the Clearwell, Burn Pit, berms, liners, and associated contaminated soil within the operable unit boundary. Waste Pits 3 and 5 and the Clearwell also contain water, including perched water.

- **Operable Unit 2:**

  The Active and Inactive Flyash Piles, South Field, Lime Sludge Ponds, Solid Waste Landfill, berms, liners, and associated contaminated soil and perched water within the operable unit boundary.

- **Operable Unit 3:**

  The former Production Area and associated facilities and equipment including all structures, equipment, utilities, drums, tanks, solid waste, waste product, thorium, effluent lines, K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feed stocks, and the coal pile.

- **Operable Unit 4:**

  Silos 1, 2, 3, and 4, berms, decant tank system, radon treatment system, and associated contaminated soil and perched water within the operable unit boundary.

- **Operable Unit 5:**

  Perched and regional groundwater, surface water, and soil not associated with other operable units (e.g., hot spots not previously identified). Also, soil beneath Operable Unit 3.

CRARE Site-Wide Conceptual Model

The CRARE examines specific time periods after the remediation of all operable units is complete and is not intended to provide information on current risks. A key component of the CRARE is the CRARE Site-Wide Conceptual Model, which examines current and future land uses for the periods immediately and up to 1,000 years after all remedial actions are complete. The model depicts the final combination of FS remedial alternatives to ensure that the FEMP achieves a residual risk that protects human health and the environment on a site-wide basis.

Figure 3 provides an overview of the conceptual model for the five operable units from remedial action to remediated site conditions. For each operable unit, the conceptual model depicts the LRAs anticipated for implementation. After site-wide remediation is complete, it is assumed that all existing structures would be removed. As shown in the figure, the remaining features and containment sources at the FEMP would be:

- Permanent disposal facilities known as vaults
- Capped areas
- Areas where treated soil has been placed

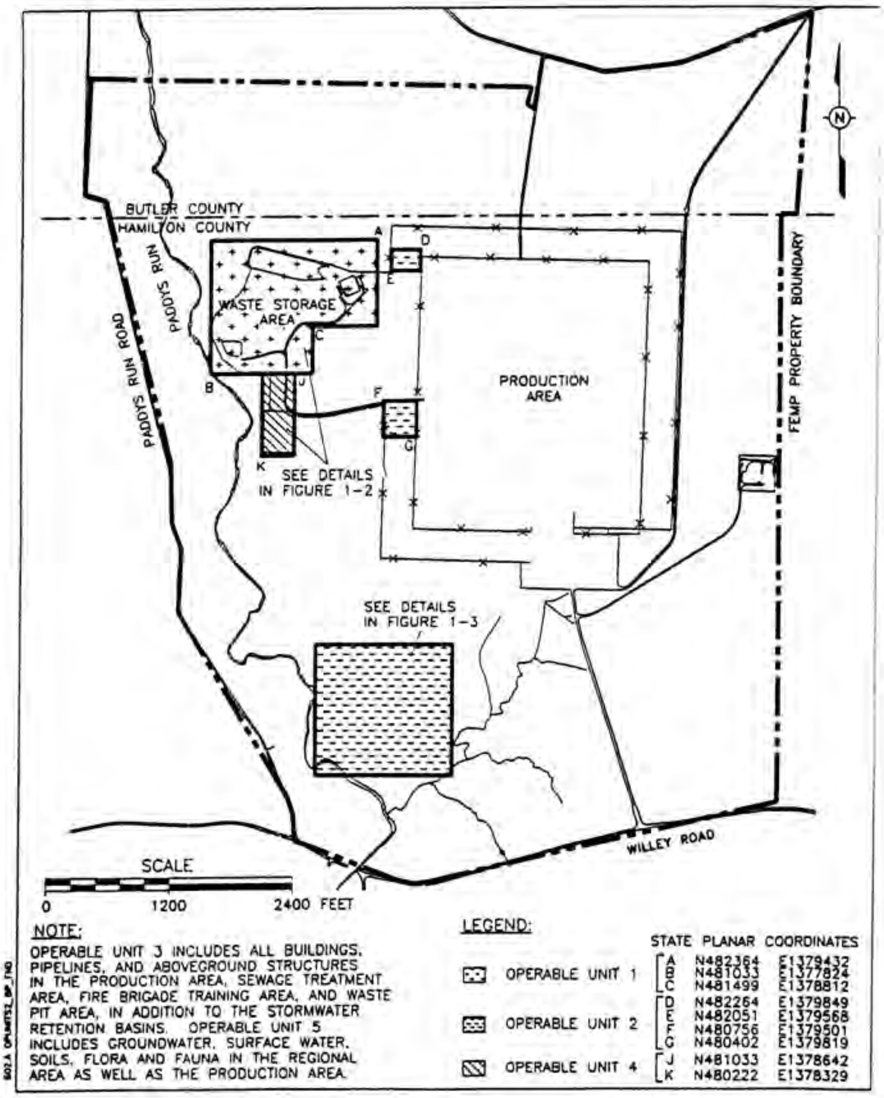

Fig. 2. RI/FS operable units.

- Remaining contaminated media, which has been remediated to acceptable levels.

The CRARE Site-Wide Conceptual Model graphically represents the sources, release mechanisms, transport-media, and risk pathways for various human receptors under the current and future land use scenarios of the five operable units. The Current Land Use scenario assumes DOE ownership, access control, and maintenance of the FEMP and associated remedial structures for 70 years starting immediately after all remedial actions are complete. The only remaining treatment facility active on the site at the start of the 70 years should be the wastewater treatment plant in Operable Unit 5.

Two Future Land Use scenarios describe the FEMP for up to 1,000 years after all remedial actions are complete. Future Land Use With Federal Ownership assumes continued government ownership and land use restrictions; Future Land Use Without Federal Ownership assumes occupation by a resident farmer and limited access controls in the form of a perimeter fence with no *trespassing/no hunting* signs. Both future land use scenarios assume no access control, maintenance, or treatment operations. Contaminant fate and transport have been modeled for 1,000 years to provide optimum risk information necessary to make critical decisions related to land use, institutional controls, and final disposal.

Figure 4 presents the Future Land Use With Continued Federal Ownership scenario and displays the risks and exposure pathways to three types of human receptors. The figure represents each exposure pathway by which radioactive or chemical contaminants of concern (COCs) migrate from their sources to human receptors on and off the FEMP. The pathways to be considered include soil ingestion, direct radiation, inhalation, exposure to all native vegetation, farm crops, invertebrate fish and wildlife, farm animals, milk, and subsequent human uptake.

As each operable unit is examined individually, the pathway model, (Table I and Fig. 4) will become site/Operable Unit-specific, improving the ability to predict future situations for the entire site.

CRARE PROGRAMMATIC APPROACH

Initial conditions for the CRARE are determined from the result of treatment and disposal alternatives described in the Site-Wide Characterization Report (SWCR) and updated in each FS. Modeling is used to determine future concentrations,

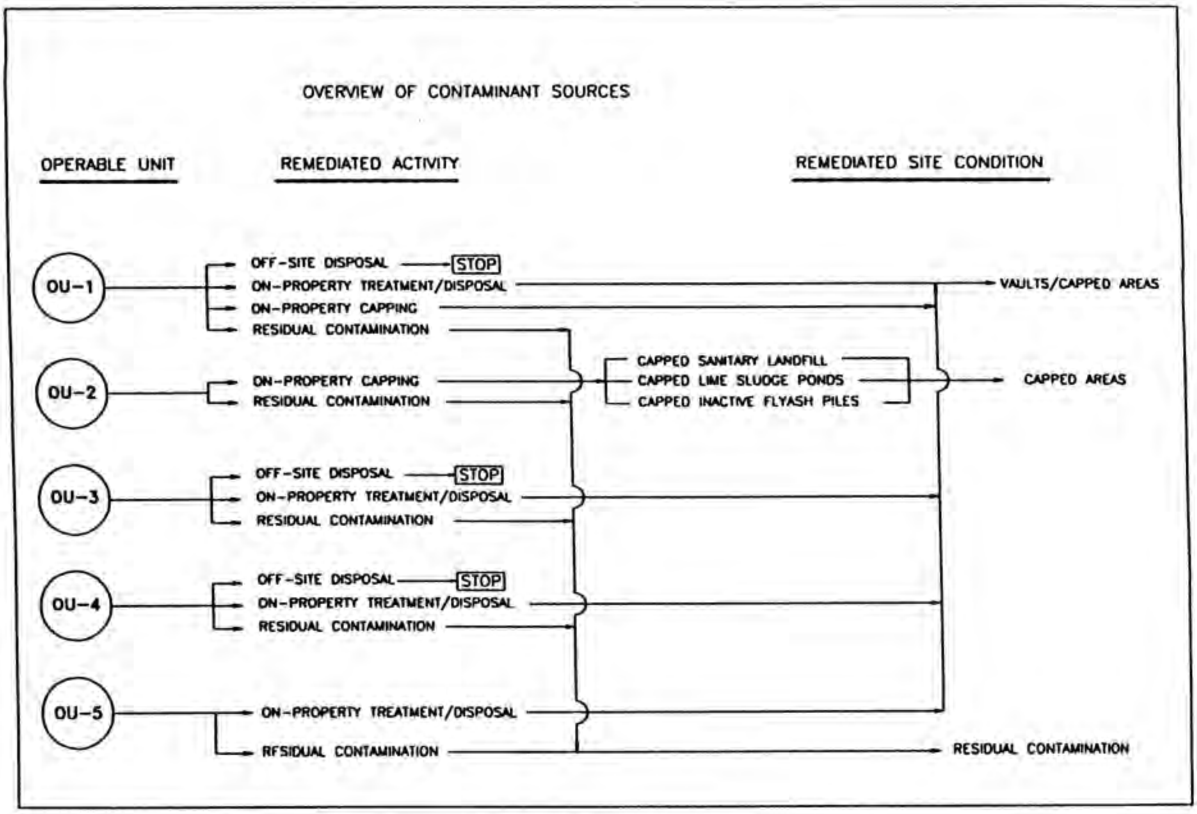

Fig. 3. Overview of contaminant sources operable Units 1 through 5.

TABLE I
CRARE SCenarios and Receptors

Scenario	Time Frame	RME Receptor
Current Land Use	For 70 years after remedial actions are complete	Groundskeeper Trespassing child Off-property resident farmer Adult Youth Child
Future Land Use With Federal Ownership	Up to 1,000 years after remedial actions are complete	Expanded treaspasser Off-property resident farmer Adult Youth Child
Future Land Use Without Federal Ownership	Up to 1,000 years after remedial actions are complete	On-property resident farmer Adult Youth Child Off-property resident farmer Adult Youth Child

The receptors are the same for each operable unit-specific risk assessment. By using standard receptors, the cumulative risks for all operable unit CRAREs are consistent and comparable.

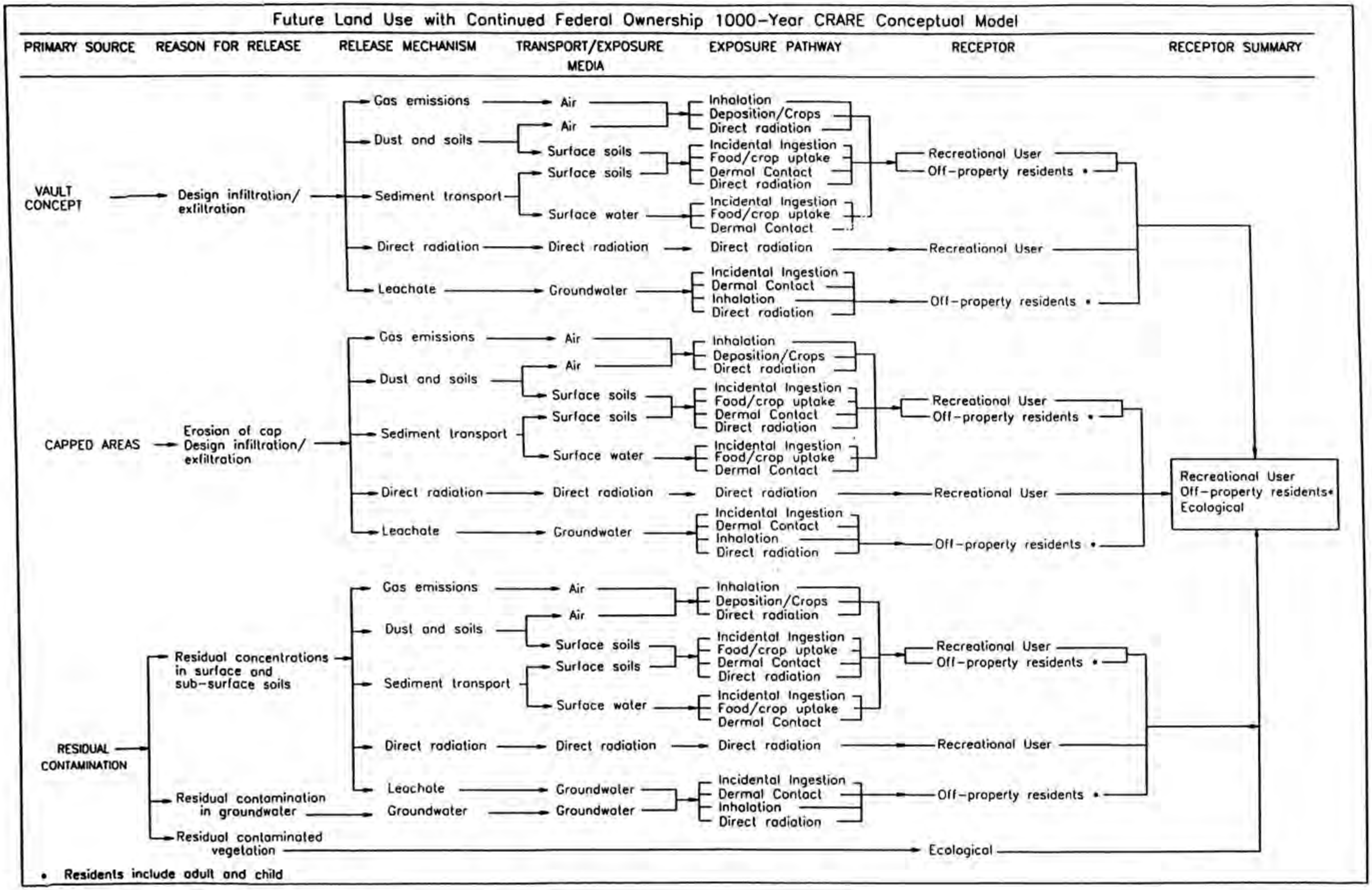

Fig. 4. Site conceptual model 1000 years.

and exposures, and risks to receptors are calculated under various land use scenarios for the preferred alternative.

Groundwater fate and transport modeling was used as part of the CRARE methodology to predict future groundwater concentrations resulting from migrations from residual soil contamination and the on-site disposal facilities. Future ambient air concentrations are predicted from air pathway transport modeling of soil and disposal area sources. Direct exposure (via food pathways) from soils and water are modeled using projected soil and water contaminant concentrations. All of the transport modeling is based on site physical conditions, topography, and projected impacts from engineering evaluations of the remedial alternatives.

Assumptions

Assumptions concerning future site conditions, the completeness of data, future facility management, demographics, materials containment, and risk assessment methods have been addressed. Specific assumptions of the first CRARE (first iteration) are:

- Volatile organic compounds (VOCs) have been effectively removed to a level no longer warranting air dispersion modeling after remedial action is complete.
- The CRARE Site-Wide Conceptual Model describes site conditions immediately after and for a period up to 1,000 years after remediation.
- Site soil would be remediated for uranium-238 to an activity level not exceeding 60 pCi/g (based on the expanded trespasser receptor). The value of 60 pCi/g was selected as a target cleanup level based on information provided in the Site-Wide Characterization Report and may change in subsequent iterations.
- The contaminated surface soil would be remediated to the PRGs for all COCs.
- For the Current Land Use scenario, maintenance would be performed on the facility and storage areas for 70 years after remediation.
- The government would own the FEMP for up to 1,000 years under the Future Land Use With Federal Ownership scenario, and therefore, will control land use to prohibit residences, farms, or any land use, although frequent trespassing could occur.
- Under the Future Land Use Without Federal Ownership scenario, the FEMP would revert to private ownership and would become a resident or farmer immediately after the remediation is complete.
- For the CRARE, the off-site resident farmer is at the point of maximum exposure -on the fence line - for both air and groundwater COC modeling.
- All material left on-property, not including soils left in place, would be contained in permanent on-property vaults or in capped areas for the duration of the 1,000 year evaluation period.
- Soils would either be washed, capped, or removed to meet Proposed Remedial Levels (PRLs).
- Containment structures would be effective in preventing direct contact with disposed materials for a period of at least 1,000 years but may leak and seep.
- The surface caps would use a RCRA-type cap design supplemented with erosion protection that would last 1,000 years.
- Inputs from individual source areas can be summed to obtain site-wide inputs to receiving streams.

Leading Remedial Alternatives Used for 1st Iteration

This section summarizes the LRAs for each operable unit.

Operable Unit 1

The LRA for Operable Unit 1 involves removing and treating waste material from Waste Pits 1 through 6, the Burn Pit, the Clearwell, and associated contaminated soil to achieve risk-based PRGs. Treated wastes would be disposed of in the on-property vaults. The excavated area would be filled with compacted soil. Remaining waste and contaminated soil in the unit would be stabilized and covered with a closure cap. The excavated material would be treated and placed within the on-property vault.

Operable Unit 2

The LRA for Operable Unit 2 includes localized excavations to remove and treat impacted media, and capping the waste units with a RCRA-type cap with appropriate radon emission controls. The waste units would be regraded and runoff/run-on controls employed. Direct contact with the waste and transport of waste would be prevented.

Operable Unit 3

For the Operable Unit 3 LRA, contaminated material would be removed, treated and/or decontaminated, and disposed of to reduce the potential for contaminant migration. Decontamination and treatment residue would require further treatment and disposal. Contaminated material would be disposed of in the vaults while clean material would be free-released for reuse or recycling.

Operable Unit 4

The preferred alternative (obtained through detailed analysis) for Operable Unit 4 includes removing the waste stored in Silos 1, 2, and 3, stabilizing it via vitrification, and removing it to an off-property disposal facility. Contaminated soil and construction material from the silo berms, subsoil, and decant tank would be removed to the extent necessary to achieve risk-based proposed final remediation levels.

Operable Unit 5

Under the LRA for Operable Unit 5, contaminated groundwater would be extracted, treated at an on-property facility, and discharged to the Great Miami River through the newly constructed effluent line. Treatment residuals would be disposed of on property in a vault. The LRA also involves excavating contaminated sediment and soil necessary to meet risk-based PRLs, transporting the contaminated material to an on-property location for treatment using soil-washing, and returning the treated material as backfill. The soil-washing fluids would be recycled and the removed contaminants stabilized and disposed of in on-property vaults. This material would then be transferred to Operable Units 3 and 5 for subsequent treatment and disposal.

When FEMP remediation is complete, the only structures remaining on the site will be the containment structures, the

RCRA-type caps, and the water treatment facility. Waste from Operable Units 1, 3, and 5 would be disposed of in the on-property containment structures which would have leachate collection systems. In the Current Land Use scenario, the maintenance of these collection systems was assumed to continue for 70 years after remediation and to include the repair of leaks and the periodic removal and disposal of leachate. In the two Future Land Use scenarios, it was assumed that no maintenance would be performed for up to 1,000 years.

At the end of the remediation period, all remediated soil is assumed to be at the PRGs of the respective contaminants, and the residual soil is assumed to retain its current level of concentration and/or activity. The current characterization information suggests that uranium and radium will be the drivers for surface soil remediation.

Receptors

Air contaminant concentrations were modeled using a receptor grid, a system of fenceline receptors, and several discrete receptors. The receptor grid consisted of 900 receptor points covering the site and extending approximately 1,200 meters (4,000 feet) beyond the FEMP fenceline in each direction. The grid was used to develop airborne concentration isopleths for the FEMP and surrounding area. The maximum on-property impact location was determined from modeled results at the receptor grid points. The on-property residential, expanded trespasser, and occupational worker exposures were developed from the grid point concentration values.

The fenceline receptor system consisted of 36 receptor points located around the FEMP at the fenceline. The maximum off-property impact location was determined from modeled results at these receptor points. The off-property residential exposure was developed from this maximum impact location (the nearest off-property resident is assumed to be at the maximum off-property impact location).

CONTAMINANTS OF CONCERN

The principal radioactive constituents found in environmental media at the FEMP are uranium, radium, thorium, and their progeny. Principal hazardous waste constituents include heavy metals, chlorinated and non-chlorinated solvents, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). The contribution to risk areas of the nonradioactive constituents are typically smaller than those of the radioactive constituents.

COC Selection Process

It was assumed that constituents evaluated in the CRARE are all COCs, since COC selection has occurred as part of the RI and FS. The CRARE is a postremediation time frame document. As such, total COC concentrations would be reduced to reflect the screening in both the RI and FS. Furthermore, some contaminants will be removed, treated, or contained such that exposure to humans and the environment is precluded. For this CRARE, the new site-wide list was screened three times to eliminate contaminants that pose little to no risk to postremediation receptors:

1. Initial screening: Eliminate laboratory artifacts, nutrients, and contaminants with off-site sources.
2. Second screening: Eliminate contaminants with vapor pressures above 10 millimeters (0.4 inches) of mercury at 20°C (68°F).
3. Third screening: Eliminate contaminants that will degrade sufficiently, based on their organic degradation rates in soil over time, or will be removed from the groundwater by pump and treat operations.

EXPOSURE SCENARIOS

In general, each exposure scenario is made up of the same components: a source of contaminants, the transport of contaminants from the source through various environmental media, receptors in the local environment, and a route or mechanism of exposure for those receptors. During development of the exposure scenarios, the environmental setting of the FEMP years after the completion of remediation was considered.

Characterization of Exposure Setting

The characterization of the exposure setting relied on the definition of the operable units, the actions proposed in the LRAs, and the existing characterization information from the RIs to establish the nature of changes caused by each remedial action to each operable unit. The source areas of contamination considered for each operable unit were the existing contaminated areas plus new areas associated with the on-property disposal facilities. Material moved off property during remediation was not considered in the compilation of risks.

Locations of Reasonable Maximum Exposure

Receptor locations were selected based on the graphical representation of modeled air, soil, and water COC concentrations from remediated conditions. In keeping with the philosophy of evaluating the Reasonable Maximum Exposure (RME) individual, the locations of highest on- and off-property exposures were assessed.

The RME locations were determined by first locating areas on and off the FEMP property which would have the highest exposure point concentration. Time-weighted exposure concentrations at these areas, along with U.S. Environmental Protection Agency-approved exposure parameters were then considered to define exposure pathways and to quantify the potential contaminate intake by the receptor.

The resulting intakes by potential receptors at various locations were then evaluated, and the location producing the highest intake was designated as the RME location. In the case of multiple pathways and contaminants, risks and hazard values were also considered in the selection of the RME location.

Due to the multiple sources of COCs, the different patterns of COC fate and transport in the environment, and the variety of COC release mechanisms at the FEMP, a complex matrix of interdependent effects was found to exist among COCs, exposure pathways, and the resulting exposure concentrations. Consequently, the selection of the site-wide RME locations required careful comparison of dispersion concentrations and estimated risk values.

In this CRARE, five hypothetical receptors were selected for the Current Land Use scenario. Each receptor represents a unique population and exposure scenario and as a whole, they cover a wide range of exposures for potentially impacted human receptors. The five receptors are:

1. Groundskeeper
2. Trespassing child
3. Off-property resident farmer adult

4. Off-property resident farmer youth
5. Off-property resident farmer child

For the Future Land Use With Federal Ownership *scenario*, *four* receptors were selected:

1. Expanded trespasser
2. Off-property resident farmer adult
3. Off-property resident farmer youth
4. Off-property resident farmer child

For the Future Land Use Without Federal Ownership scenario, six receptors were selected:

1. On-property resident farmer adult
2. On-property resident farmer youth
3. On-property resident farmer child
4. Off-property resident farmer adult
5. Off-property resident farmer youth
6. Off-property resident farmer child

RESULTS/CONCLUSIONS

The estimated risks from the FEMP summarized in Table II which presents a 52-year adult exposure combined with the child (six years) and youth (12 years) to produce a 70 year calculated lifetime cancer risk.

TABLE II
Summary Of ILCR and HI for All Receptors, All Scenarios
Current Land Use

RME Receptor	ILCR	HI
Groundskeeper	4.7×10^{-4}	4.2×10^{-1}
Trespassing Child	2.0×10^{-5}	7.8×10^{-2}
Off-Property Resident Farmer		
Adult[a]	1.0×10^{-4}	1.1×10^{0}
Youth	1.9×10^{-5}	1.8×10^{0}
Child	7.5×10^{-5}	3.1×10^{0}
Lifetime	1.7×10^{-4}	NA
Current Land Use		
RME Receptor	ILCR	HI
Groundskeeper	4.7×10^{-4}	4.2×10^{-1}
Trespassing Child	2.0×10^{-5}	7.8×10^{-2}
Off-Property Resident Farmer		
Adult[a]	1.0×10^{-4}	1.1×10^{0}
Youth	1.9×10^{-5}	1.8×10^{0}
Child	7.5×10^{-5}	3.1×10^{0}
Lifetime	1.7×10^{-4}	NA
Future Land Use With Federal Ownership		
RME Receptor	ILCR	HI
Expanded Trespasser	2.7×10^{-5}	1.2×10^{-1}
Off-Property Resident Farmer		
Adult[a]	9.0×10^{-5}	1.1×10^{0}
Youth	1.6×10^{-5}	1.8×10^{0}
Child	6.6×10^{-6}	3.1×10^{0}
Lifetime	8.9×10^{-5}	NA
Future Land Use Without Federal Ownership		
RME Receptor	ILCR	HI
On-Property Resident Farmer		
Adulta	1.1×10^{-2}	6.4×10^{1}
Youth	2.3×10^{-3}	1.0×10^{2}
Child	3.6×10^{-3}	2.46×10^{2}
Lifetime	1.4 x 10-2	8.9×10^{-5}
Off-Property Resident Farmer		NA
Adult[a]	9.0×10^{-5}	1.1×10^{0}
Youth	1.6×10^{-5}	1.8×10^{0}
Child	6.6×10^{-6}	3.1×10^{0}
Lifetime	8.9×10^{-5}	NA

[a] The resident farmer adult ILCR values are based on a 70-year exposure period. To obtain the total lifetime risk, the adult values were multiplied by 52/70 before adding to the youth and child risks.
NA = Not applicable or not available

TABLE III
Operable Unit Contributions to Risk
Contributions to Radiological Risk: Air/Radiation Exposure

	Contribution (%)				
RME Receptor	OU1	OU2	OU3	OU4	OU5
Expanded Trespasser	<0.01	<0.01	<0.01	<0.01	1.92 98.08
Off-Site Resident	<0.01	<0.01	<0.01	0.73	99.27
On-Site Resident	<0.01	<0.01	<0.01	0.54	99.46
Contributions to Radiological and Chemical Risk: COC Mass Loading in Ground/Surface Water					
	Contribution (%)				
RME Receptor	OU1	OU2	OU3	OU4	OU5
COC Mass/Total Mass (mg/l)	<0.01	<0.01	<0.01	3.60	96.40
Contributions to Carcinogenic Risk: Ingestion of and Dermal Contact with Soil					
	Contribution (%)				
RME Receptor	OU1	OU2	OU3	OU4	OU5
Expanded Trespasser	<0.01	<0.01	<0.01	1.93	98.07
On-Site Resident	<0.01	<0.01	<0.01	1.93	98.07

Operable Unit Contributions to Risk

Table III presents the contributions to total risk by the various operable units and by the transport pathways of air, ground/surface water, and soil. The partitioning was performed by calculating the relative portions of FEMP remediated materials remaining on site.

Operable Unit 5 contamination is associated with almost all of the residual risk after FEMP remediation. Under the Current Land Use scenario, approximately 99 percent of radionuclide emissions are from Operable Unit 5 (the former Production Area soils and the remaining FEMP surface soil). The soil beneath the former Production Area accounts for approximately 60 percent of the off-property resident farmer risk. It also accounts for 35 percent of the on-property groundskeeper and trespasser risk associated with direct inhalation of radionuclides.

Under the two Future Land Use scenarios, atmospheric emissions from Operable Unit 5 result in the largest contributions to inhalation pathway cancer risks. Over 99 percent of the total radionuclide emissions are from Operable Unit 5 areas, indicating that this operable unit is the major contributor to the inhalation pathway risks. The soil beneath the former Production Area accounts for approximately 75 percent of the on-property resident farmer cancer risk, 60 percent of the off-property resident farmer risk, and 35 percent of the expanded trespasser's cancer risk associated with direct inhalation of radionuclides.

Current groundwater modeling predicts that the highest cancer risk in this pathway will be associated with contaminants leaching from the soil, which will be addressed by Operable Unit 5. An important consideration is that the accuracy of the groundwater modeling depends on the representativeness of the geochemical and vadose zone transport modeling. These processes are affected by many parameters, some of which vary by orders of magnitude across the site.

Future CRARE Considerations

The CRARE has effectively identified site-wide sources of greatest risk and has identified the assumptions used in determining site risk that warrant careful consideration. Specifically, the following issues must be effectively managed: 1) soil remediation levels, 2) effectiveness of on-site disposal facilities, 3) groundwater modeling assumptions, and 4) land use.