

5. RISK EVALUATION AND DERIVATION OF CERCLA-DERIVED WASTE DISPOSAL CRITERIA

This chapter presents the methods and models used for the human health and ecological risk evaluations and, using the fate and transport modeling results, completes these evaluations. This chapter also presents the CERCLA-derived waste disposal criteria and contaminant inventory limits and the methods used to derive them.

5.1 HUMAN HEALTH

This section presents the risk evaluations for the most sensitive receptor (i.e., the groundwater user) and for the other human receptors selected for quantitative analysis in Chap. 3. This section concludes with the listing of preliminary CERCLA-derived waste disposal criteria that are protective of all reasonable human receptors evaluated. Final CERCLA-derived waste disposal criteria and contaminant inventory limits for the C-746-U Landfill that are protective of both human health and ecological receptors are derived later in this chapter.

5.1.1 Risk Evaluation of the Most Sensitive Receptor

As discussed in Chap. 4, forward fate and transport modeling utilizing concentrations derived for CERCLA-derived waste acceptable for placement in the C-746-U Landfill were used to estimate contaminant concentrations in media that may be contacted by human health and ecological receptors at three exposure points. These points of exposure, the medium contacted, and the potential human receptors quantitatively evaluated are presented in Table 5.1.

Table 5.1. Points of exposure, media, and receptors considered when selecting the most sensitive receptor

Point of Exposure	Medium Contacted	Potential Receptor
Groundwater drawn from well completed in RGA at the DOE property boundary	Groundwater	Groundwater user and rural resident
Groundwater drawn from well completed in RGA at the Ohio River	Groundwater	Groundwater user and rural resident
Springs at the Ohio River	Groundwater	Recreational user and industrial worker

DOE = U.S. Department of Energy.
RGA = Regional Gravel Aquifer.

As discussed in Chap. 3, the selected most sensitive receptor is the groundwater user utilizing water drawn from a well completed in the RGA at the DOE property boundary. This receptor was selected for two primary reasons. First, the acceptable concentrations for contaminants in water for this receptor are lower and more restrictive than those for other receptors. Second, among the groundwater users, this receptor is at the point closest to the source of contamination.

To complete the evaluation, contaminant concentrations estimated by fate and transport modeling over all periods of landfill performance (i.e., over 10,000 years) were compared to the risk-, hazard-, and dose-based, no-action screening levels for groundwater taken from the PGDP human health risk methods document (DOE 2001b; please see Table 5.2, footnotes a and b for additional information regarding the no-action screening levels). These comparisons were then used to calculate chemical-specific risk, hazard, and dose estimates as a function of time. The chemical-specific risk, hazard, and dose values were then summed to derive total risk, hazard, and dose values at each point in time.

The equations used to calculate the chemical-specific risk, hazard, and dose estimates at each time are as follows:

$$\frac{C_{W \text{ No Action}}}{C_{W \text{ Chemical}}} = \frac{\text{Target Risk Value}}{\text{Chemical - specific Risk Value}}$$

or

$$\text{Chemical-specific Risk Value} = \frac{C_{W \text{ Chemical}} \times \text{Target Risk Value}}{C_{W \text{ No Action}}}$$

where

Chemical-specific Risk Value	=	cancer risk, hazard, or dose from groundwater exposure,
$C_{W \text{ Chemical}}$	=	chemical concentration in groundwater from modeling (mg/L or pCi/L),
Target Risk Value	=	basis for $C_{W \text{ No Action}}$ (i.e., cancer risk = 1×10^{-6} , hazard = 1, dose = 1 mrem/year),
$C_{W \text{ No Action}}$	=	risk-, hazard-, or dose-based, no-action screening value (mg/L or pCi/L).

Total risk, hazard, and dose estimates derived for the gradual failure scenario are presented in Figs. 5.1, 5.2, and 5.3, respectively. (These figures contain results for both groundwater user points of exposure so that results can be compared.) Chemical-specific risk, hazard, and dose estimates for chemicals and radionuclides “driving” the total estimates at the DOE property boundary point of exposure under the gradual failure scenario are presented in Figs. 5.4, 5.5, and 5.6, respectively. Additionally, Figs. 5.7, 5.8, and 5.9 show comparisons between risk and dose calculated using the results of the gradual and immediate failure scenarios. Tables with concentrations, hazards, risks, and doses used to produce Figs. 5.1 through 5.6 for the DOE property boundary point of exposure are presented in Appendix C in Tables C.1.1, C.1.2, C.1.3, and C.1.4, respectively. Table C.1.1 also contains the hazard-, risk-, and dose-based, no-action screening values (i.e., $C_{W \text{ No Action}}$) used in the analysis. Finally, Table C.1.5 shows the concentrations derived for the vinyl chloride analyte group and ^{99}Tc used to prepare Figs. 5.7 through 5.9. (Results for the other location are similar as shown in the figures and are not presented in the appendix.)

As shown in Fig. 5.1, the total cancer risk results from fate and transport modeling of the CERCLA-derived waste source term lead to a peak risk around year 1,000, followed by a decrease and an increase to year 10,000. The maximum risk for the property boundary point of exposure occurs at year 10,000, and the maximum risk for the Ohio River point of exposure occurs at year 540. Figure 5.2 shows a single hazard peak with the greatest hazard at the end of the simulation period (i.e., at 10,000 years). Greater hazard is probably present after 10,000 years, as shown by the positive slope of the hazard curve. Figure 5.3 shows that there is only one notable dose peak and that this peak occurs near year 2,000 for the property boundary point of exposure and near year 9,000 for the Ohio River point of exposure.

When compared to the EPA cancer risk benchmarks for site-related exposures (i.e., 10^{-6} to 10^{-4}), the total risk at both points of exposure (Fig. 5.1) is seen to be below the upper benchmark and below the lower benchmark for all but the property boundary point of exposure after year 7,000. The maximum peaks at the two points of exposure are 2×10^{-6} and 3×10^{-7} for the property boundary and the Ohio River points of exposure, respectively.

Like cancer risk, when the hazard values are compared to the EPA hazard benchmark for site-related exposures (i.e., 1), the maximum hazard values at both locations (Fig. 5.2) are seen to be below the EPA benchmark. (The hazard value for groundwater drawn at the two locations are 0.4 and 0.2 for the property boundary and Ohio River, respectively.) As noted above, peak hazard occurs after year 10,000.

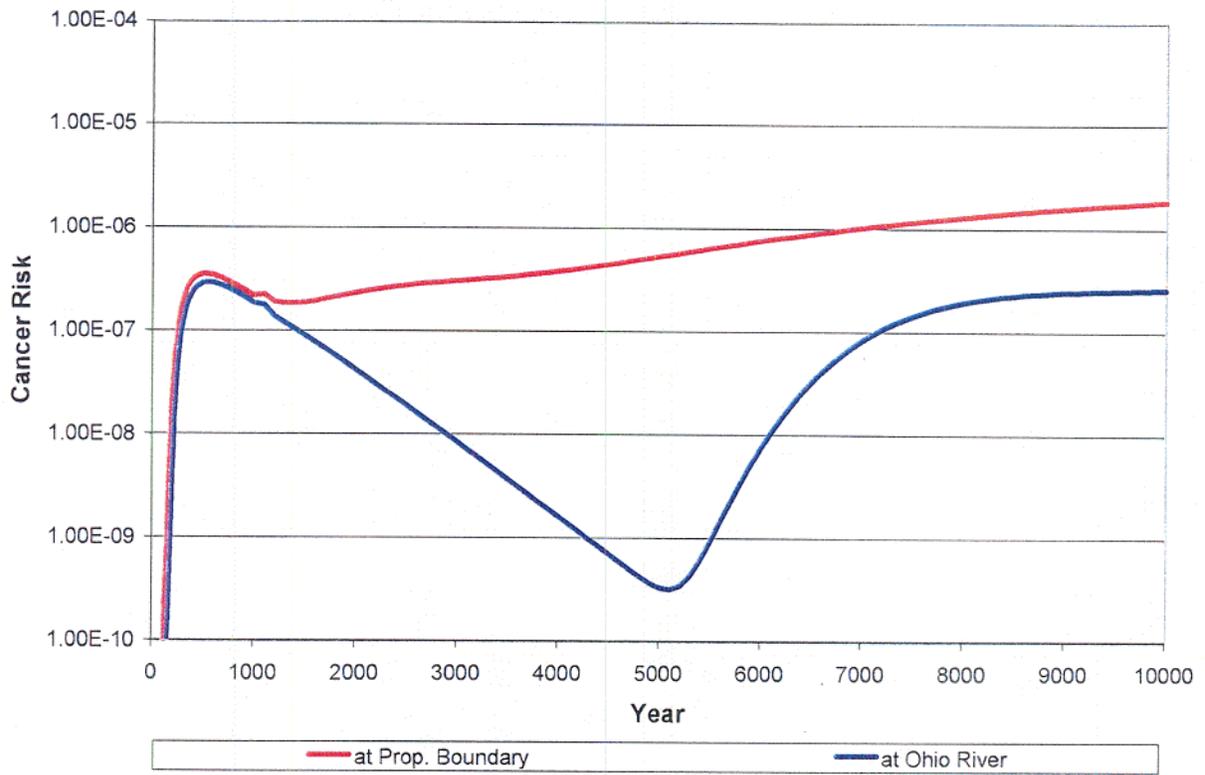


Fig. 5.1. Total cancer risk to residential groundwater user – gradual failure scenario.

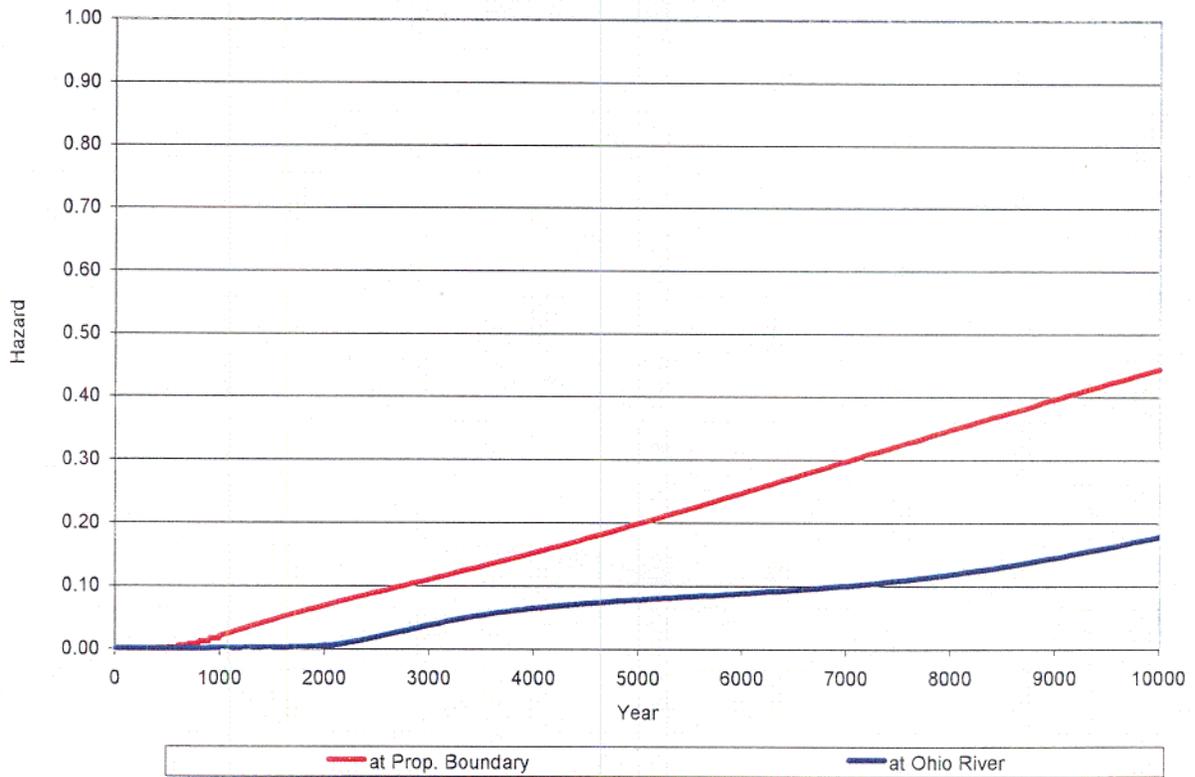


Fig. 5.2. Total hazard to residential groundwater user – gradual failure scenario.

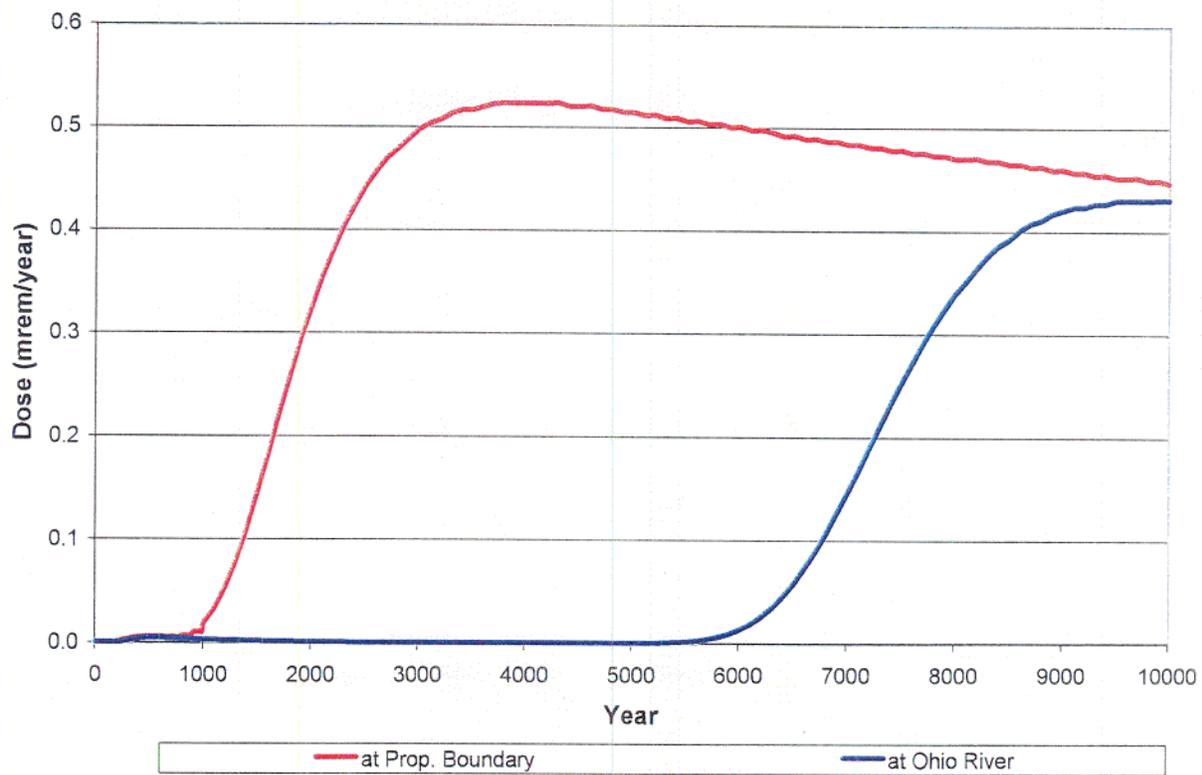


Fig. 5.3. Total dose to residential groundwater user – gradual failure scenario.

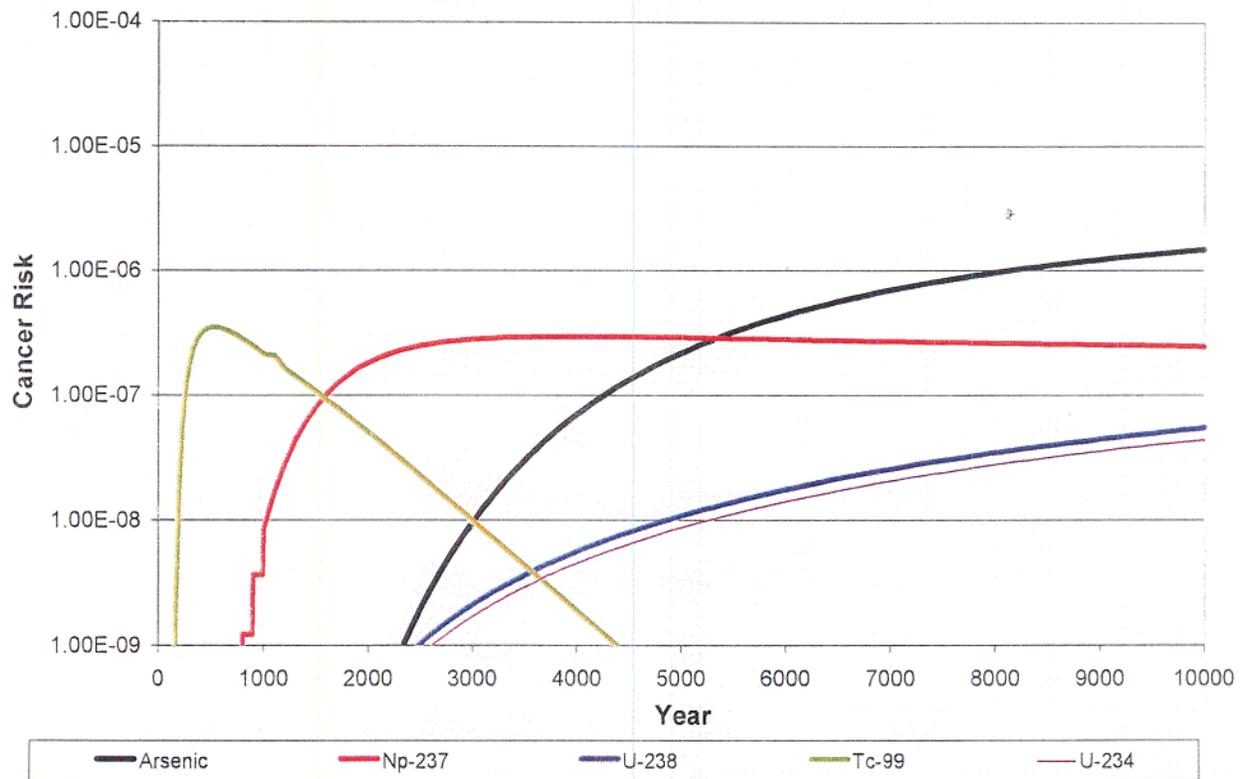


Fig. 5.4. Chemical-specific cancer risk to residential groundwater user – exposure point at property boundary – gradual failure scenario.

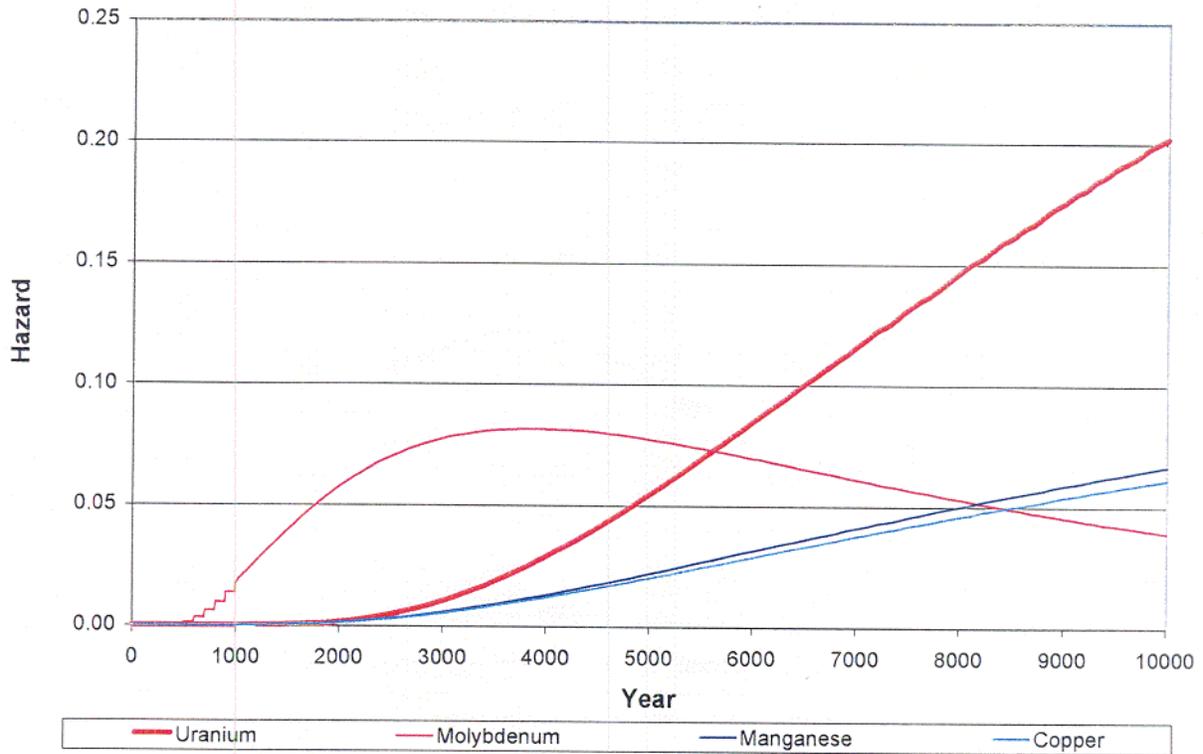


Fig. 5.5. Chemical-specific hazard to residential groundwater user – exposure point at property boundary – gradual failure scenario.

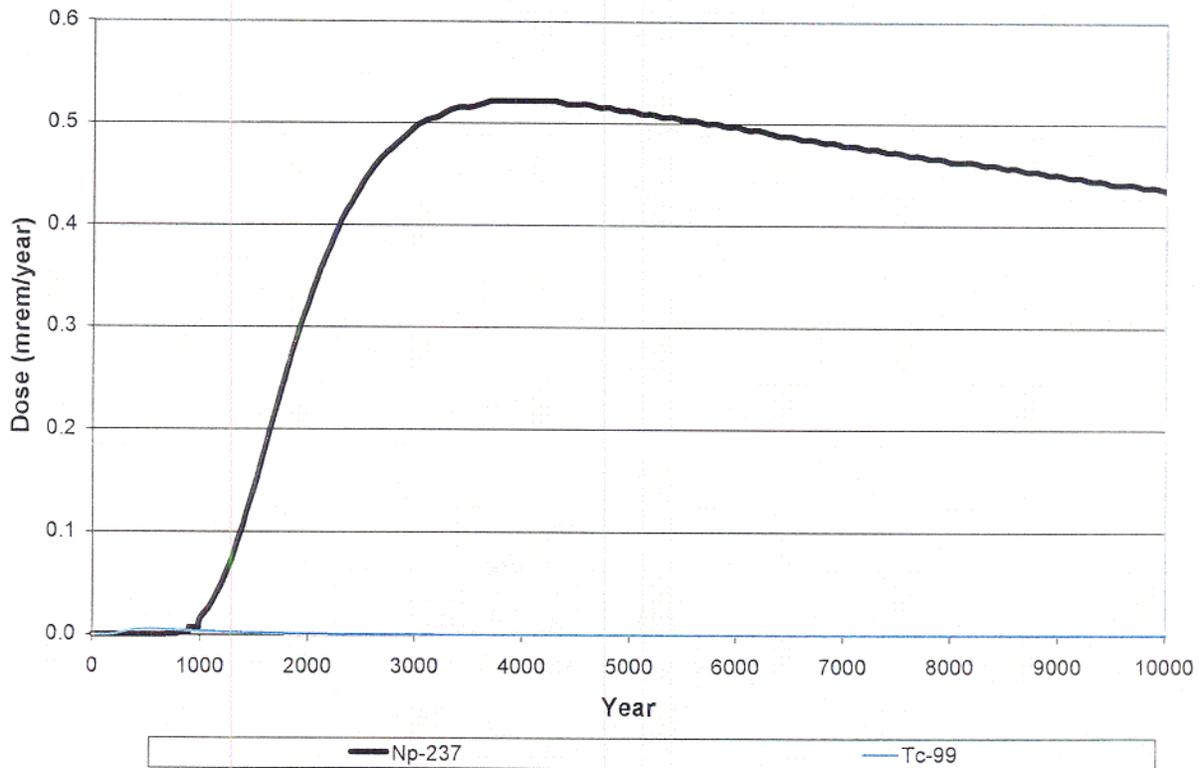


Fig. 5.6. Radionuclide-specific dose to residential groundwater user – exposure point at property boundary – gradual failure scenario.

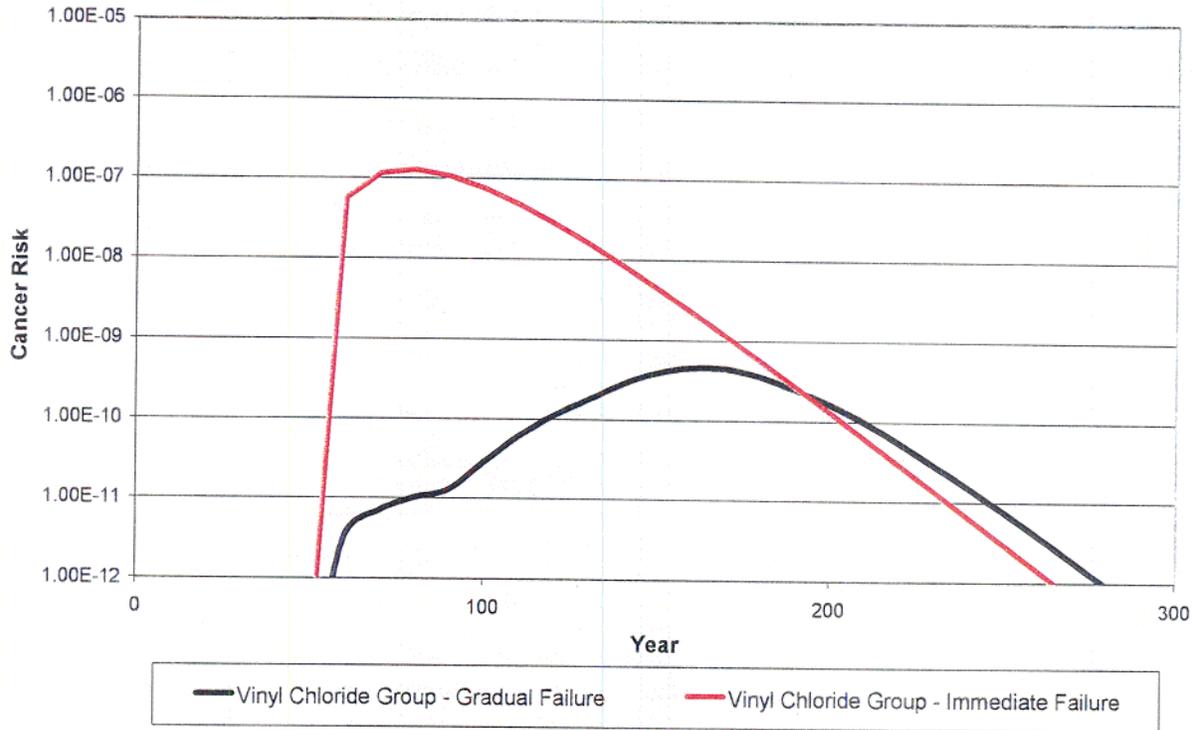


Fig. 5.7. Comparison of gradual versus immediate failure scenarios – estimated cancer risk to residential groundwater user from vinyl chloride group at property boundary.

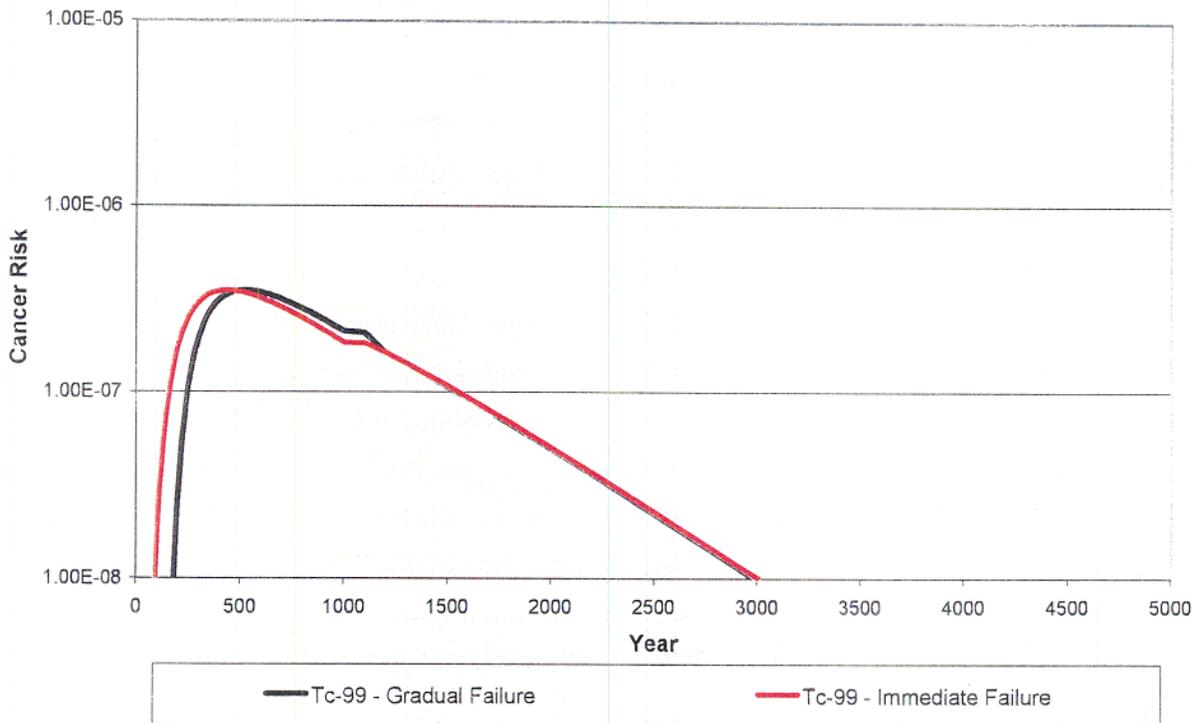


Fig. 5.8. Comparison of gradual versus immediate failure scenarios – estimated cancer risk to residential groundwater user from ⁹⁹Tc at property boundary.

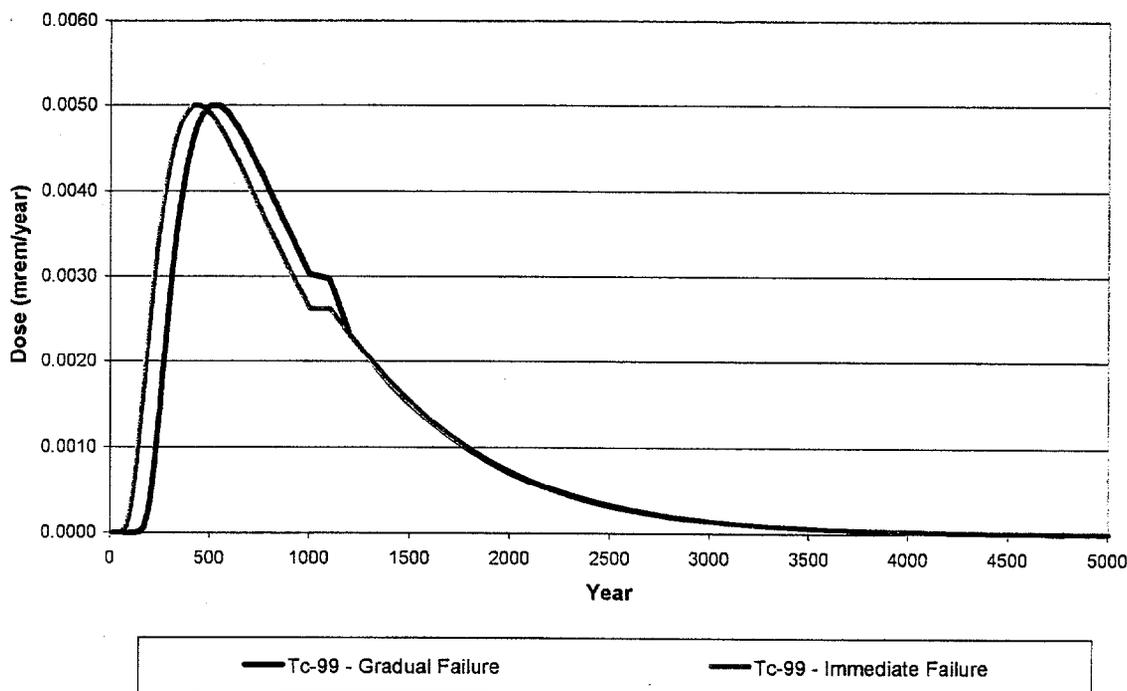


Fig. 5.9. Comparison of gradual versus immediate failure scenarios – estimated dose to residential groundwater user from ⁹⁹Tc at the DOE property boundary.

The dose peaks for both points of exposure (Fig. 5.3) are less than the dose benchmarks for exposure by a resident established in guidance by EPA [i.e., 15 mrem/year (EPA 1997)] and in rule by the Nuclear Regulatory Commission (NRC) [i.e., 25 mrem/year (NRC 1997)]. The maximum dose at the two points of exposure is 3.9 and 3.2 mrem/year, respectively.

When examined more closely (Fig. 5.4), risk is seen to be driven by one metal (arsenic) and four radionuclides (²³⁷Np, ²³⁴U, ²³⁸U, and ⁹⁹Tc). None of these drivers has a chemical-specific peak risk that exceeds the upper EPA benchmark of 10⁻⁴, and each has a chemical-specific risk below 1 × 10⁻⁶, except arsenic. The peak chemical-specific risks for the COPCs are 1.5 × 10⁻⁶, 2.9 × 10⁻⁷, 4.4 × 10⁻⁸, 5.4 × 10⁻⁸, and 3.5 × 10⁻⁷ for arsenic, ²³⁷Np, ²³⁴U, ²³⁸U, and ⁹⁹Tc, respectively.

Unlike the peak cancer risk, the hazard peak is driven by one chemical, uranium. The relative importance of uranium as the driver of hazard versus other chemicals is shown in Fig. 5.5. There, the three chemicals contributing the next highest peak hazards are shown along with uranium. These chemicals, their peak hazard, and time of peak are molybdenum (peak 0.08 at year 3,800), manganese (peak 0.07 at year 10,000), and copper (peak 0.06 at year 10,000). The maximum hazard for uranium is 0.20, and this hazard occurs at the end of the modeling period.

The radionuclide driving peak dose is ²³⁷Np (Fig. 5.6). ²³⁷Np has a peak dose of 0.5 mrem/year. The next highest chemical-specific dose is from ⁹⁹Tc. This dose is only 0.005 mrem/year at year 500.

As noted earlier, comparisons between risk and dose estimates for exposure to groundwater for the vinyl chloride analyte group and ⁹⁹Tc under the gradual and immediate failure scenarios are shown in Figs. 5.7 through 5.9. Results for these chemicals were selected for presentation because they represent the most mobile organic compounds and radionuclides contributing cancer risk and dose to the groundwater

user. [Because hazard is driven by an inorganic chemical that is released from the landfill after a long period of time (Fig. 5.5), a comparison of hazard estimates derived under the two scenarios is not presented.]

Results in Fig. 5.7 show that the peak cancer risk from exposure to organic compounds in the vinyl chloride group is higher and occurs sooner under the immediate failure scenario than under the gradual failure scenario. However, the peak cancer risk under the immediate failure scenario is still less than the EPA benchmark cancer risk of 10^{-6} .

Unlike the risk from organic compounds in the vinyl chloride group, the peak cancer risk from exposure to ^{99}Tc is the same size under the immediate failure scenario as under the gradual failure scenario (Fig. 5.8). Although both peaks are less than the EPA benchmark cancer risk of 10^{-6} , the peak cancer risk does occur earlier under the immediate failure scenario (i.e., year 420 versus year 500 for immediate and gradual failure, respectively).

Results for dose from exposure to ^{99}Tc under the two failure scenarios (Fig. 5.9) are similar to this radionuclide's cancer risk results. The peak doses are identical, and the peak dose occurs earlier under the immediate failure scenario than the gradual failure scenario.

The risk results for the most sensitive receptor indicate that the surrogate groups used for fate and transport modeling were adequate when identifying risk drivers. Additionally, these results indicate that risk, hazard, and dose posed to the most sensitive receptor (i.e., the groundwater user) do not exceed the EPA benchmark for either hazard or cancer risk, as contaminants migrate from a hypothetical source with characteristics similar to the CERCLA-derived waste inventory developed for the C-746-U Landfill. Therefore, acceptable waste concentrations (i.e., preliminary CERCLA-derived waste disposal criteria) were developed for the most sensitive receptor by using the DAFs for each chemical derived in Chap. 4 and risk-based groundwater concentrations not expected to present an unacceptable chemical-specific risk or hazard to a groundwater user drawing water from the RGA at the property boundary. The DAFs are presented in Chap. 4 and will not be presented here. The groundwater values used and the list of values from which they were selected are in Table 5.2.

As discussed in footnote d to Table 5.2, the preferred groundwater value used in the back-calculations was the lesser of the cancer risk- and hazard-based concentration unless each of these is less than the chemical's background concentration. If the risk- and hazard-based concentrations are less than the background concentration, then the background concentration was selected as the back-calculation value.

The method used to calculate the preliminary CERCLA-derived waste disposal criteria is presented in the following equations. As with the risk calculations described earlier, simple ratios were used to calculate all values.

$$\frac{\text{Prelim. criteria}}{C_{\text{chemical}}} = \frac{C_{\text{target}}}{C_{\text{chemical}}}$$

or

$$\text{Prelim. criteria} = \frac{C_{\text{target}} \times C_{\text{chemical}}}{C_{\text{chemical}}}$$

where

- Prelim. criteria = preliminary CERCLA-derived waste disposal criteria (mg/kg or pCi/g),
- C_{target} = target concentration for groundwater (i.e., back calculation value) from Table 5.2 (mg/L or pCi/L),
- C_{chemical} = constituent concentration in source as used in fate and transport model (mg/kg or pCi/g),
- C_{chemical} = constituent concentration in groundwater from modeling results (mg/L or pCi/L).

Table 5.2. Back-calculation concentrations used in the derivation of preliminary CERCLA-derived waste disposal criteria and their source

Chemical	Units	Cancer Risk-based Concentration ^a	Hazard-based Concentration ^b	Background Concentration ^c	Back-calculation Concentration ^d
<i>Inorganic chemicals</i>					
Antimony	mg/l	NV	0.00564	<0.06	0.00564
Arsenic	mg/l	0.000350	0.00452	<0.005	0.000350
Barium	mg/l	NV	1.04	0.202	1.04
Beryllium	mg/l	NV	0.0264	<0.004	0.0264
Cadmium	mg/l	NV	0.00661	<0.010	0.00661
Chromium	mg/l	NV	17.6 ^e	0.134	17.6 ^d
Copper	mg/l	NV	0.557	0.034	0.557
Fluoride	mg/l	NV	0.906	0.245	0.906
Iron	mg/l	NV	4.49	3.72	4.49
Lead	mg/l	NV	0.015 ^f	0.25	0.25
Manganese	mg/l	NV	0.350	0.082	0.350
Mercury	mg/l	NV	0.00444	<0.0002	0.00444
Molybdenum	mg/l	NV	0.0753	<0.050	0.0753
Nickel	mg/l	NV	0.301	0.682	0.682
Nitrate	mg/l	NV	24.1	13.5	24.1
Nitrite	mg/l	NV	1.51	NV	1.51
Selenium	mg/l	NV	0.0754	<0.005	0.0754
Silver	mg/l	NV	0.0750	<0.011	0.0750
Sulfate	mg/l	NV	NV	19.1	19.1
Thallium	mg/l	NV	0.00120 ^g	<0.0560	0.00120
Uranium	mg/l	NV	0.00906	<0.002	0.00906
Vanadium	mg/l	NV	0.0925	0.131	0.131
Zinc	mg/l	NV	4.50	0.0250	4.50
<i>Organic compounds</i>					
Acenaphthene	mg/l	NV	0.136	NV	0.136
Acenaphthylene	mg/l	NV	0.136 ^h	NV	0.136
Acrylonitrile	mg/l	0.000426	0.00170	NV	0.000426
Anthracene	mg/l	NV	0.766	NV	0.766
Benzene	mg/l	0.00385	0.00504	NV	0.00385
Butanone, 2-	mg/l	NV	0.868	NV	0.868
Carbon Tetrachloride	mg/l	0.00181	0.00190	NV	0.00181
Chlordane, alpha- ⁱ	mg/l	0.00128	0.00658	NV	0.00128
Chlordane, gamma- ⁱ	mg/l	0.00128	0.00658	NV	0.00128
Chlorobenzene	mg/l	NV	0.0466	NV	0.0466
Chloroform	mg/l	0.00218	0.000287	NV	0.000287
Dichlorobenzene, 1,4-	mg/l	0.00578	0.0810	NV	0.00578
Dichloroethane, 1,2-	mg/l	0.00147	0.00465	NV	0.00147
Dichloroethylene, 1,1-	mg/l	0.000470	0.0246	NV	0.000470
Dichloroethylene, 1,2- Mixed Isomers)	mg/l	NV	0.0247	NV	0.0247
Dichloroethylene, 1,2-cis-	mg/l	NV	0.0273	NV	0.0273
Dichloroethylene, 1,2-trans-	mg/l	NV	0.0548	NV	0.0548
Dinitrotoluene, 2,4	mg/l	0.000769	0.0300	NV	0.000769
Dioxins/Furans (Total)	mg/l	0.00000000609	NV	NV	0.00000000609
Ethylbenzene	mg/l	0.0468	0.563	NV	0.0468
Fluoranthene	mg/l	NV	0.226	NV	0.226
Fluorene	mg/l	NV	0.0972	NV	0.0972
Heptachlor epoxide	mg/l	0.0000512	0.000177	NV	0.0000512
Hexachlorobenzene	mg/l	0.000192	0.00754	NV	0.000192
Hexachlorobutadiene	mg/l	0.00480	0.00225	NV	0.00225
Hexachloroethane	mg/l	0.0329	0.0135	NV	0.0135
Methoxychlor	mg/l	NV	0.0715	NV	0.0715
Methylphenol, 2-	mg/l	NV	0.723	NV	0.723
Methylphenol, 3-	mg/l	NV	0.725	NV	0.725
Methylphenol, 4-	mg/l	NV	0.0727	NV	0.0727
Naphthalene	mg/l	NV	0.00285	NV	0.00285
Nitrobenzene	mg/l	NV	0.00153	NV	0.00153

Table 5.2. Back-calculation concentrations used in the derivation of preliminary CERCLA-derived waste disposal criteria and their source (continued)

Chemical	Units	Cancer Risk-based	Hazard-based	Background	Back-calculation
		Concentration ^a	Concentration ^b	Concentration ^c	Concentration ^d
Phenanthrene	mg/l	NV	0.226 ^f	NV	0.226
Pentachlorophenol	mg/l	0.00208	0.234	NV	0.00208
Polychlorinated Biphenyls (Total)	mg/l	0.000793	NV	NV	0.000793
Polynuclear Aromatic Hydrocarbons (Total)	mg/l	0.00000951	NV	NV	0.00000951
Pyridine	mg/l	NV	0.0149	NV	0.0149
Pyrene	mg/l	NV	0.182	NV	0.182
Tetrachloroethylene	mg/l	0.00582	0.0842	NV	0.00582
Toxaphene	mg/l	0.000456	NV	NV	0.000456
Trichloroethylene	mg/l	0.0173	0.0160	NV	0.0160
Trichlorophenol, 2,4,5-	mg/l	NV	1.29	NV	1.29
Trichlorophenol, 2,4,6-	mg/l	0.0399	NV	NV	0.0399
Vinyl Chloride	mg/l	0.000350	0.0306	NV	0.000350
Xylene, m-	mg/l	NV	4.39	NV	4.39
Xylene, Mixture	mg/l	NV	0.653	NV	0.653
Xylene, o-	mg/l	NV	4.39	NV	4.39
Xylene, p-	mg/l	NV	4.39 ^g	NV	4.39
<i>Radionuclides^h</i>					
Neptunium-237	pCi/l	5.73 ⁱ	NV	0.8	5.73
Plutonium-238	pCi/l	2.95	NV	NV	2.95
Plutonium-239	pCi/l	2.86	NV	0.1	2.86
Plutonium-240	pCi/l	2.86	NV	NV	2.86
Radium-226	pCi/l	0.233 ^m	NV	0.1	0.233
Technetium-99	pCi/l	140	NV	10.8	140
Thorium-230	pCi/l	0.221 ^m	NV	0.54	0.54
Thorium-232	pCi/l	0.268 ^m	NV	NV	0.268
Uranium-234	pCi/l	5.46	NV	0.7	5.46
Uranium-235	pCi/l	5.38 ⁿ	NV	0.3	5.38
Uranium-238	pCi/l	4.43 ⁿ	NV	0.7	4.43

Note: NV indicates that a value was not available.

^a Cancer risk-based concentrations were developed from the no action screening values for residential use presented in Table A.5 in Appendix A of the human health risk methods document (DOE 2001b). The chemical-specific cancer risk target used in the derivation of the concentration for each individual constituent was 1×10^{-5} . The routes of exposure included were ingestion of groundwater, inhalation of vapors emitted by groundwater during house-hold use, inhalation of vapors emitted by groundwater while showering, and dermal contact while bathing. The cancer risk-based concentrations were for an exposure duration of 6 years as child and 34 years as adult. The exposure frequency for both the adult and child was 350 days per year. Intake of drinking water was 2 L/day for an adult and 1 L/day for a child.

^b Hazard-based concentrations were developed from the no action screening values for residential use presented in Table A.5 in Appendix A of the human health risk methods document (DOE 2001b). The chemical-specific hazard target used in the derivation of the concentration for each individual constituent was 1. The routes of exposure included in derivation of concentrations were ingestion of groundwater, inhalation of vapors emitted by groundwater during house-hold use, inhalation of vapors emitted by groundwater while showering, and dermal contact while bathing. The hazard-based concentrations were for exposure by a child at an exposure frequency of 350 days/year. Intake of drinking water was 1 L/day.

^c The background concentrations are provisional values for water drawn from the RGA reported in Table A.13 in Appendix A of the human health risk methods document (DOE 2001b). Values preceded by "<" indicate that the background concentration reported in the Table A.13 was presented as a "qualitative" value.

^d Concentrations from which the preliminary CERCLA-derived waste disposal criteria (and contaminant inventory limits) were calculated. This value is the lesser of the cancer risk- and hazard-based concentrations unless these are less than the background concentration. If the risk- and hazard-based values were less than the background concentration, and the background concentration is not preceded by "<", then the background concentration is reported.

^e Concentration is for total chromium.

^f Concentration is a regulatory value because a risk- or hazard-based values is not available.

^g Concentration is for thallium chloride because a value for thallium metal is not available.

^h Concentration for acenaphthene is listed because a value for acenaphthylene is not available.

ⁱ Concentrations listed are for chlordane.

^j Concentration for fluoranthene is listed because a value for phenanthrene is not available.

^k Concentration for o-xylene is listed because a value for p-xylene is not available.

^l Five radionuclides included in the PGDP significant COPC list are not included because they would decay to either stable isotopes or would decay to isotopes more relevant to the risk and performance evaluation prior to reaching the exposure point. The four radionuclides decaying to stable isotopes and their half-lives are ⁶⁰Co (5.3 years), ¹³⁷Cs (30.1 years), ⁹⁰Sr (28.8 years), and ²²⁸Th (1.9 years). (Note that ²²⁸Th decays though several other radionuclides with half-lives of less than 1 day prior to reaching the stable isotope. Also note that Thorium-228 and its short-lived decay products are included in the derivation of the ²³²Th risk-based value as discussed in footnote m.) The isotope decaying to a more relevant isotope is ²⁴¹Am. Americium-241 has a half-life of 432 years and decays to ²³⁷Np. Finally, the radionuclide ²²²Rn, which also appears on the PGDP significant COPC list, is not included because it is a gas and would not be placed in the landfill.

Table 5.2. Back-calculation concentrations used in the derivation of preliminary CERCLA-derived waste disposal criteria and their source (continued)

^m The cancer risk-based value reported here was derived considering secular equilibrium of the listed radionuclide's decay chain. The radionuclides considered in the analysis for the ²²⁶Ra series were ²²⁶Ra and ²¹⁰Pb and their short-lived decay products. The radionuclides considered in the analysis for the ²³²Th series were ²³²Th, ²²⁸Ra, and ²²⁸Th and their short-lived decay products. For ²³⁰Th, the radionuclides were ²³⁰Th, ²²⁶Ra, and ²¹⁰Pb, and their short-lived decay products. Please see footnote n for a discussion of short-lived decay products.

ⁿ The cancer risk-based value for this radionuclide was derived using a cancer slope factor that included consideration of short-lived decay products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment. In the Health Effects Assessment Summary Table (HEAST) for Radionuclides (see <http://www.epa.gov/radiation/heast/>), short-lived decay products are defined as those having a half-life less than about 3 months.

The resulting preliminary disposal criteria are shown in Table 5.3. As noted in Table 5.3 (see footnotes b and c), the criteria for some chemicals exceed either unity (i.e., 1,000,000 mg/kg) or the maximum mass limit assumed for the landfill (1,800,000,000 kg based on a volume of 1.56 million cubic yards and an average waste density of 1.5 g/cm³). To address this happenstance, which was an artifact of the method used to back-calculate the CERCLA-derived waste disposal criteria from a groundwater concentration (see below), the criteria for those chemicals meeting either of the aforementioned criteria were reduced to unity and the preliminary contaminant inventories were reduced to that of the landfill. Additionally, as noted in the table title, the preliminary criteria shown in Table 5.3 were not corrected for either the chemical's soil saturation limit or solubility in water. Disposal criteria were corrected for the soil saturation limit because exceedence of that value would mean that liquids would be placed in the landfill. However, placement of liquids is prohibited under the current permit. Disposal criteria were corrected for solubility because the solubility of a chemical in water is a limiting factor for transport.

An example of how the use of ratios led to CERCLA-derived waste disposal criteria that exceed possible values is the derivation of the criterion for nickel. For nickel, the estimated concentration in the CERCLA-derived waste (see Table 3.4) is 68,987 mg/kg. With migration from the landfill, the maximum concentration expected at the property boundary point of exposure is 0.00135 mg/L (see Table C.1.1). Finally, the groundwater back-calculation concentration is 0.682 mg/L (see Table 5.2). Solving the ratio (see below) yields a preliminary CERCLA-derived waste disposal criterion greater than unity (i.e., 1,000,000 mg/kg) and a preliminary contaminant inventory limit greater than the estimated mass limit of the landfill assuming a waste density of 1.50 g/cm³ (1,800,000,000 kg). Therefore, the criterion for nickel was reduced to unity, resulting in an inventory limit equal to the mass limit of the landfill.

$$\frac{\text{Criteria}}{0.682 \text{ mg/L}} = \frac{68,987 \text{ mg/kg}}{0.00135 \text{ mg/L}} \text{ or } \text{Criteria} = 34,851,210 \text{ mg/kg}$$

$$\text{Inventory} = 34,851,210 \text{ mg/kg} \times 1,192,706 \text{ m}^3 \times 1,500 \text{ kg/m}^3 \times \frac{1 \text{ kg}}{1,000,000 \text{ mg}} = 62,350,870,910 \text{ kg}$$

The resulting corrected preliminary CERCLA-derived waste disposal criteria and contaminant inventory limits are in Table 5.4. Table 5.4 also contains the predicted concentrations at all points of exposure derived from forward modeling from the corrected preliminary contaminant inventory limits.

5.1.2 Risk Evaluation for Other Human Receptors

This section contains the risk evaluation for human receptors selected for quantitative analysis in Chap. 3. As with the risk evaluation performed for the most sensitive receptor, the evaluations for the receptors are performed using risk-based screening levels taken from the PGDP human health risk methods document (DOE 2001b).

Table 5.3. Preliminary CERCLA risk-based disposal criteria and preliminary contaminant inventory limits not corrected for exceeding unity, exceeding volume of landfill, or solubility limit in water

Chemical Groups	Groundwater Concentration (mg/L or pCi/L) ^a	Preliminary CERCLA-derived waste disposal criteria (mg/kg pCi/g)	Preliminary contaminant inventory limit (kg or Ci)
<i>Inorganic Chemicals</i>			
Antimony	5.64E-03	6.79E+01	1.215E+05
Arsenic	3.50E-04	2.88E+01	5.144E+04
Barium	1.04E+00	1.14E+04	2.041E+07
Beryllium	2.64E-02	2.40E+04	4.293E+07
Cadmium	6.61E-03	5.70E+02	1.020E+06
Chromium	1.76E+01	1.72E+04	3.073E+07
Copper	5.57E-01	5.22E+03	9.333E+06
Iron	4.49E+00	3.91E+07 ^b	7.002E+10 ^c
Lead	2.50E-01	7.77E+04	1.389E+08
Manganese	3.50E-01	4.68E+03	8.378E+06
Mercury	4.44E-03	6.18E+01	1.105E+05
Molybdenum	7.53E-02	3.87E+01	6.920E+04
Nickel	6.82E-01	3.49E+07 ^b	6.235E+10 ^c
Selenium	7.54E-02	7.77E+01	1.389E+05
Silver	7.50E-02	7.77E+03	1.389E+07
Thallium	1.20E-03	9.80E+01	1.754E+05
Uranium	9.06E-03	7.79E+02	1.394E+06
Vanadium	1.31E-01	1.51E+05	2.696E+08
Zinc	4.50E+00	7.47E+04	1.336E+08
<i>Organic Compounds</i>			
Acenaphthene	1.36E-01	1.24E+09 ^b	2.218E+12 ^c
Acenaphthylene	1.36E-01	1.87E+09 ^b	3.350E+12 ^c
Acrylonitrile	4.26E-04	2.59E+04	4.634E+07
Anthracene	7.66E-01	3.35E+10 ^b	5.992E+13 ^c
Benzene	3.85E-03	4.78E+07 ^b	8.552E+10 ^c
Butanone, 2-	8.68E-01	1.28E+09 ^b	2.290E+12 ^c
Carbon Tetrachloride	1.81E-03	2.33E+05	4.167E+08
Chlordane, alpha-	1.28E-03	7.13E+22 ^b	1.276E+26 ^c
Chlordane, gamma-	1.28E-03	7.13E+22 ^b	1.276E+26 ^c
Chlorobenzene	4.66E-02	2.97E+09 ^b	5.319E+12 ^c
Chloroform	2.87E-04	3.88E+03	6.948E+06
Dichlorobenzene, 1,4-	5.78E-03	1.01E+09 ^b	1.814E+12 ^c
Dichloroethane, 1,2-	1.47E-03	1.43E+04	2.551E+07
Dichloroethene, 1,1-	4.70E-03	7.80E+04	1.395E+08
Dichloroethene, 1,2- (mixed isomers)	2.47E-02	4.89E+05	8.744E+08
Dichloroethene, cis-1,2-	2.73E-02	2.47E+05	4.427E+08
Dichloroethene, trans-1,2-	5.48E-02	5.32E+05	9.512E+08
Dinitrotoluene, 2,4-	7.69E-04	2.00E+07 ^b	3.571E+10 ^c
Dioxins/Furans (Total)	6.09E-10	^d	^d
Ethylbenzene	4.68E-02	1.91E+09 ^b	3.416E+12 ^c
Fluoranthene	2.26E-01	2.07E+10 ^b	3.696E+13 ^c
Fluorene	9.72E-02	1.39E+09 ^b	2.495E+12 ^c
Heptachlor Epoxide	5.12E-05	4.03E+21 ^b	7.213E+24 ^c
Hexachlorobenzene	1.92E-04	4.37E+09 ^b	7.827E+12 ^c
Hexachlorobutadiene	2.25E-03	2.25E+08 ^b	4.022E+11 ^c
Hexachloroethane	1.35E-02	4.47E+07 ^b	7.999E+10 ^c
Methoxychlor	7.15E-02	5.41E+24 ^b	9.685E+27 ^c
Methylphenol, 2-	7.23E-01	3.93E+09 ^b	7.031E+12 ^c
Methylphenol, 3-	7.25E-01	1.12E+10 ^b	2.009E+13 ^c
Methylphenol, 4-	7.27E-02	7.11E+08 ^b	1.273E+12 ^c
Naphthalene	2.85E-03	6.31E+06 ^b	1.129E+10 ^c
Nitrobenzene	1.53E-03	4.95E+07 ^b	8.852E+10 ^c
Pentachlorophenol	2.08E-03	2.29E+06 ^b	4.099E+09 ^c
Phenanthrene	2.26E-01	5.89E+09 ^b	1.053E+13 ^c
Polychlorinated Biphenyls (Total)	7.93E-04	2.89E+13 ^b	5.168E+16 ^c

Table 5.3. Preliminary CERCLA risk-based disposal criteria and preliminary contaminant inventory limits not corrected for exceeding unity, exceeding volume of landfill, or solubility limit in water (continued)

Chemical Groups	Groundwater Concentration (mg/L or pCi/L)^a	Preliminary CERCLA-derived waste disposal criteria (mg/kg pCi/g)	Preliminary contaminant inventory limit (kg or Ci)
Polynuclear Aromatic Hydrocarbons (Total)	9.51E-06		
Pyrene	1.82E-01	2.30E+10 ^b	4.120E+13 ^c
Pyridine	1.49E-02	1.76E+07 ^b	3.157E+10 ^c
Tetrachloroethene	5.82E-03	1.31E+06 ^b	2.336E+09 ^c
Toxaphene	4.56E-04	4.13E+22 ^b	7.396E+25 ^c
Trichloroethene	1.60E-02	1.27E+06 ^b	2.278E+09 ^c
Trichlorophenol, 2,4,5-	1.29E+00	1.16E+12 ^b	2.076E+15 ^c
Trichlorophenol, 2,4,6-	3.99E-02	3.35E+10 ^b	5.995E+13 ^c
Vinyl Chloride	3.50E-04	1.66E+03	2.978E+06
Xylene, m-	4.39E+00	1.73E+11 ^b	3.087E+14 ^c
Xylene, Mixture	6.53E-01	3.55E+10 ^b	6.346E+13 ^c
Xylene, o-	4.39E+00	2.12E+11 ^b	3.794E+14 ^c
Xylene, p-	4.39E+00	2.74E+11 ^b	4.895E+14 ^c
Radionuclides			
Neptunium-237+D	5.73E+00	2.26E+01	4.040E+01
Plutonium-238	2.95E+00	5.66E+03	1.012E+04
Plutonium-239	2.86E+00	5.49E+03	9.813E+03
Plutonium-240	2.86E+00	5.49E+03	9.813E+03
Radium-226	2.33E-01	4.06E+02	7.268E+02
Technetium-99	1.40E+02	2.02E+01	3.606E+01
Thorium-230	2.21E-01	2.47E+03	4.412E+03
Thorium-232	2.68E-01	2.99E+03	5.350E+03
Uranium-234	5.46E+00	1.27E+03	2.275E+03
Uranium-235	5.38E+00	1.25E+03	2.242E+03
Uranium-238	4.43E+00	1.03E+03	1.846E+03

Notes:

^a Back-calculation value from Table 5.2.

^b Preliminary CERCLA risk-based disposal criterion exceeds unity (i.e., 1,000,000 mg/kg).

^c Preliminary contaminant inventory limit exceeds total mass capacity of landfill based on a volume of 1.56 million cubic yards and a density of 1.5 g/cm³.

^d The modeled concentration at the property boundary point of exposure was so small that it could not be estimated. Therefore, a CERCLA-derived waste disposal criteria could not be calculated for this organic compound.

5.1.2.1 Groundwater user and rural resident

Table 5.5 shows the comparison between the expected peak concentrations of contaminants in groundwater taken from Table 5.4 and the risk-based groundwater screening values protective of a groundwater user. As shown in Table 5.5, the expected peak concentration of each contaminant at each point of exposure is either equal to or less than its respective groundwater screening value for all chemicals except lead and vanadium. This result is expected because most concentrations in groundwater presented in Table 5.5 were calculated from the preliminary contaminant inventory limits derived using the same risk-based concentrations used in this screening. Therefore, because these preliminary contaminant inventory limits either remained as derived or were subsequently decreased to account for unity, the mass limit of the landfill, the soil saturation limit of the chemical, or the solubility limit of the chemical in water (see Sect. 5.1.1), the forward calculated concentrations in groundwater can only be equal to or less than the groundwater screening values at the DOE property boundary point of exposure. Additionally, because the contaminant concentrations in groundwater can only decrease as the distance from the source (i.e., the landfill) increases, the groundwater concentrations at the downgradient points of exposure must be less than the groundwater screening values.

Table 5.4. Predicted concentrations of COPCs in water at all points of exposure derived from preliminary CERCLA risk-based disposal criteria corrected for unity, C-746-U Landfill volume, and solubility

Chemical ^a	Saturation ^b	Preliminary CERCLA-derived Waste Disposal Criteria (mg/kg or pCi/g)	Preliminary Contaminant Inventory Limit (kg or Ci)	Water Concentration in Leachate above the Liner System ^c (mg/l or pCi/l)	Concentration in Leachate above the Water Table ^c (mg/l or pCi/l)	Groundwater Concentration in RGA at DOE Property Boundary (mg/l or pCi/l)	Groundwater Concentration in RGA at Ohio River (mg/l or pCi/l)
<i>Inorganic Chemicals</i>							
Antimony		6.79E+01	1.215E+05	2.32E-01	7.86E-03	5.64E-03	3.03E-03
Arsenic		2.88E+01	5.144E+04	1.67E-02	3.36E-03	3.50E-04	0.00E+00
Barium		1.14E+04	2.041E+07	4.27E+01	1.45E+00	1.04E+00	5.60E-01
Beryllium		2.40E+04	4.293E+07	1.37E+00	3.86E-02	2.64E-02	3.02E-03
Cadmium		5.70E+02	1.020E+06	3.43E-01	9.67E-03	6.61E-03	7.56E-04
Chromium		1.72E+04	3.073E+07	3.72E+02	1.73E+02	1.76E+01	1.46E+01
Copper		5.22E+03	9.333E+06	2.29E+01	7.76E-01	5.57E-01	3.00E-01
Iron	Y	1.00E+06	1.789E+09	6.98E+01	6.67E+00	4.04E-01	0.00E+00
Lead		7.77E+04	1.389E+08	1.30E+01	3.66E-01	2.50E-01	2.86E-02
Manganese		4.68E+03	8.378E+06	1.44E+01	4.88E-01	3.50E-01	1.88E-01
Mercury		3.13E+00	5.603E+03	9.25E-03	3.14E-04	2.25E-04	1.21E-04
Molybdenum		3.87E+01	6.920E+04	1.59E+00	7.39E-01	7.53E-02	6.25E-02
Nickel	Y	1.00E+06	1.789E+09	4.72E+02	7.00E+00	1.99E-01	0.00E+00
Selenium		7.77E+01	1.389E+05	2.39E+00	5.71E-01	7.54E-02	6.27E-02
Silver		7.77E+03	1.389E+07	3.89E+00	1.10E-01	7.50E-02	8.58E-03
Thallium		9.80E+01	1.754E+05	6.22E-02	1.76E-03	1.20E-03	1.37E-04
Uranium		7.79E+02	1.394E+06	4.39E-01	6.19E-03	9.06E-03	1.82E-03
Vanadium		1.51E+05	2.696E+08	6.79E+00	1.92E-01	1.31E-01	1.50E-02
Zinc		7.47E+04	1.336E+08	1.85E+02	6.27E+00	4.50E+00	2.42E+00
<i>Organic Compounds</i>							
Acenaphthene	X	1.75E+01	3.125E+04	3.12E-04	3.85E-08	1.92E-09	4.83E-13
Acenaphthylene	X	9.85E+01	1.763E+05	1.17E-03	1.44E-07	7.16E-09	1.80E-12
Acrylonitrile	X	1.47E+04	2.632E+07	5.64E+03	4.01E-03	2.42E-04	1.19E-06
Anthracene	X	8.25E-01	1.475E+03	3.07E-06	3.79E-10	1.89E-11	4.76E-15
Benzene	X	4.38E+02	7.830E+05	6.19E-01	5.91E-07	3.52E-08	5.81E-11
Butanone, 2-	X	5.53E+04	9.885E+07	3.49E+02	7.07E-04	3.75E-05	3.04E-07
Carbon Tetrachloride	X	2.57E+02	4.600E+05	9.28E-01	2.53E-05	2.00E-06	7.77E-08
Chlordane, alpha-	X	2.65E+00	4.740E+03	6.91E-10	1.74E-14	4.75E-26	0
Chlordane, gamma-	X	2.65E+00	4.739E+03	6.91E-10	1.74E-14	4.75E-26	0
Chlorobenzene	X	1.79E+02	3.205E+05	3.32E-02	6.08E-08	2.81E-09	3.17E-14
Chloroform	X	1.92E+03	3.439E+06	9.36E-02	1.97E-03	1.42E-04	3.15E-05
Dichlorobenzene, 1,4-	X	5.11E+01	9.150E+04	3.44E-03	6.31E-09	2.92E-10	3.29E-15
Dichloroethane, 1,2-		2.00E+03	3.583E+06	1.36E-01	2.87E-03	2.06E-04	4.58E-05
Dichloroethene, 1,1-	X	5.72E+02	1.024E+06	2.27E-02	4.78E-04	3.45E-05	7.65E-06
Dichloroethene, 1,2- (mixed isomers)		2.10E+02	3.758E+05	7.00E-03	1.47E-04	1.06E-05	2.35E-06
Dichloroethene, cis-1,2-	X	8.01E+02	1.432E+06	5.82E-02	1.23E-03	8.83E-05	1.96E-05

Table 5.4. Predicted concentrations of COPCs in water at all points of exposure derived from preliminary CERCLA risk-based disposal criteria corrected for unity, C-746-U Landfill volume, and solubility (continued)

Chemical ^a	Saturation ^b	Preliminary CERCLA- derived Waste Disposal Criteria (mg/kg or pCi/g)	Preliminary Contaminant Inventory Limit (kg or Ci)	Water Concentration in Leachate above the Liner System ^c (mg/l or pCi/l)	Concentration in Leachate above the Water Table ^c (mg/l or pCi/l)	Groundwater Concentration in RGA at DOE Property Boundary (mg/l or pCi/l)	Groundwater Concentration in RGA at Ohio River (mg/l or pCi/l)
Dichloroethene, trans-1,2-	X	1.46E+03	2.606E+06	9.90E-02	2.08E-03	1.50E-04	3.33E-05
Dinitrotoluene, 2,4-	X	7.46E+01	1.335E+05	6.70E-02	4.77E-08	2.88E-09	1.41E-11
Dioxins/Furan (Total)	X	2.64E+01	4.723E+04	3.28E-15	1.63E-22	5.45496E-24	0
Ethylbenzene	X	6.15E+01	1.100E+05	2.64E-02	2.52E-08	1.51E-09	2.48E-12
Fluoranthene	X	8.14E+00	1.456E+04	1.45E-05	1.79E-09	8.90E-11	2.24E-14
Fluorene	X	1.26E+01	2.256E+04	1.43E-04	1.77E-08	8.79E-10	2.22E-13
Heptachlor Epoxide	X	1.34E+01	2.389E+04	2.47E-09	6.22E-14	1.70E-25	0
Hexachlorobenzene	X	3.98E+02	7.121E+05	2.06E-04	3.78E-10	1.75E-11	1.97E-16
Hexachlorobutadine	X	1.39E+02	2.494E+05	2.27E-04	2.80E-08	1.40E-09	3.52E-13
Hexachloroethane	X	8.12E+01	1.453E+05	3.99E-03	4.93E-07	2.45E-08	6.18E-12
Methoxychlor	X	2.89E+00	5.169E+03	5.55E-10	1.40E-14	3.82E-26	0
Methylphenol, 2-	X	4.32E+03	7.729E+06	1.85E+01	1.32E-05	7.95E-07	3.90E-09
Methylphenol, 3-	X	4.91E+03	8.788E+06	7.39E+00	5.26E-06	3.17E-07	1.56E-09
Methylphenol, 4-	X	5.03E+03	9.005E+06	1.20E+01	8.53E-06	5.14E-07	2.52E-09
Naphthalene	X	3.57E+01	6.389E+04	2.63E-03	3.24E-07	1.61E-08	4.07E-12
Nitrobenzene	X	6.17E+02	1.104E+06	4.45E-01	3.16E-07	1.91E-08	9.36E-11
Pentachlorophenol	X	1.31E+03	2.350E+06	1.94E-01	2.40E-05	1.19E-06	3.01E-10
Phenanthrene	X	1.37E+01	2.447E+04	8.55E-05	1.06E-08	5.25E-10	1.32E-13
Polychlorinated biphenyls (Total)	X	1.73E+02	3.098E+05	4.80E-05	1.05E-08	4.75E-15	0
Polynuclear Aromatic Hydrocarbons (Total)	X	7.75E+00	1.387E+04	3.28E-15	1.63E-22	7.92658E-23	0
Pyrene	X	7.37E+00	1.319E+04	9.48E-06	1.17E-09	5.83E-11	1.47E-14
Pyridine	X	2.03E+05	3.640E+08	4.01E+03	2.85E-03	1.72E-04	8.43E-07
Tetrachloroethene	X	8.27E+01	1.480E+05	1.71E-01	4.66E-06	3.69E-07	1.43E-08
Toxaphene	X	5.69E+01	1.017E+05	9.12E-09	2.30E-13	6.27E-25	0
Trichloroethene	X	3.04E+02	5.433E+05	1.77E+00	4.82E-05	3.82E-06	1.48E-07
Trichlorophenol, 2,4,5-	X	3.42E+03	6.114E+06	8.86E-02	6.30E-08	3.80E-09	1.86E-11
Trichlorophenol, 2,4,6-	X	2.14E+03	3.824E+06	5.93E-02	4.22E-08	2.55E-09	1.25E-11
Vinyl Chloride	X	6.00E+02	1.073E+06	8.31E-02	1.75E-03	1.26E-04	2.80E-05
Xylene (mixture)	X	8.35E+01	1.494E+05	2.70E-02	2.58E-08	1.54E-09	2.53E-12
Xylene, m-	X	5.76E+01	1.030E+05	2.57E-02	2.46E-08	1.47E-09	2.41E-12
Xylene, o-	X	6.89E+01	1.232E+05	2.50E-02	2.39E-08	1.43E-09	2.35E-12
Xylene, p-	X	8.32E+01	1.488E+05	2.34E-02	2.24E-08	1.33E-09	2.20E-12

Table 5.4. Predicted concentrations of COPCs in water at all points of exposure derived from preliminary CERCLA risk-based disposal criteria corrected for unity, C-746-U Landfill volume, and solubility (continued)

Chemical ^a	Saturation ^b	Preliminary CERCLA-derived Waste Disposal Criteria (mg/kg or pCi/g)	Preliminary Contaminant Inventory Limit (kg or Ci)	Water Concentration in Leachate above the Liner System ^c (mg/l or pCi/l)	Concentration in Leachate above the Water Table ^c (mg/l or pCi/l)	Groundwater Concentration in RGA at DOE Property Boundary (mg/l or pCi/l)	Groundwater Concentration in RGA at Ohio River (mg/l or pCi/l)
<i>Radionuclides</i>							
Neptunium-237		4.040E+01	2.26E+01	1.11E+02	5.76E+01	5.73E+00	4.71E+00
Plutonium-238		1.012E+04	5.66E+03	1.64E+02	1.87E+01	2.95E+00	4.36E-01
Plutonium-239		9.813E+03	5.49E+03	1.59E+02	1.82E+01	2.86E+00	4.22E-01
Plutonium-240		9.813E+03	5.49E+03	1.59E+02	1.82E+01	2.86E+00	4.22E-01
Radium-226		7.268E+02	4.06E+02	1.30E+01	1.48E+00	2.33E-01	3.44E-02
Technetium-99		3.606E+01	2.02E+01	2.69E+03	1.41E+03	1.40E+02	1.17E+02
Thorium-230		4.412E+03	2.47E+03	1.23E+01	1.40E+00	2.21E-01	3.26E-02
Thorium-232		5.350E+03	2.99E+03	1.49E+01	1.70E+00	2.68E-01	3.96E-02
Uranium-234		2.275E+03	1.27E+03	3.04E+02	3.47E+01	5.46E+00	8.07E-01
Uranium-235		2.242E+03	1.25E+03	2.99E+02	3.42E+01	5.38E+00	7.95E-01
Uranium-238		1.846E+03	1.03E+03	2.46E+02	2.81E+01	4.43E+00	6.54E-01

Notes:

^a Chemicals listed match the waste characterization presented in Chap. 3, except that several radionuclides were removed. Please see Table 5.2, footnote 1 for additional discussion.

^b Chemicals marked with an "X" had a preliminary CERCLA risk-based disposal criteria in Table 5.3 that exceeded the chemical's soil saturation limit. Therefore, the groundwater concentrations displayed were those calculated after reducing the preliminary CERCLA-derived waste disposal criteria to the soil saturation limit. Chemicals marked with a "Y" had a preliminary contaminant inventory limit that exceeded the volume of the landfill. Therefore, the water concentrations shown were calculated after reducing the inventory limit to the estimated mass limit of the landfill.

^c Values in these columns are provided for information only.

DOE = U.S. Department of Energy

RGA = Regional Gravel Aquifer

Table 5.5. Comparison of groundwater concentrations in RGA at all exposure points against PGDP risk-based values protective of a groundwater user

Chemical ^a	Groundwater Concentration in RGA at DOE Property Boundary ^b (mg/l or pCi/l)	Groundwater Concentration in RGA at Ohio River ^b (mg/l or pCi/l)	Groundwater User Risk-based Concentrations ^c (mg/l or pCi/l)	Results ^d
<i>Inorganic Chemicals</i>				
Antimony	5.64E-03	3.03E-03	5.64E-03	Equal/Less
Arsenic	3.50E-04	0	3.50E-04	Equal/Less
Barium	1.04E+00	5.60E-01	1.04E+00	Equal/Less
Beryllium	2.64E-02	3.02E-03	2.64E-02	Equal/Less
Cadmium	6.61E-03	7.56E-04	6.61E-03	Equal/Less
Chromium	1.76E+01	1.46E+01	1.76E+01	Equal/Less
Copper	5.57E-01	3.00E-01	5.57E-01	Equal/Less
Iron	4.04E-01	0	4.49E+00	Less/Less
Lead	2.50E-01	2.86E-02	1.50E-02	Greater/Greater
Manganese	3.50E-01	1.88E-01	3.50E-01	Equal/Less
Mercury	2.25E-04	1.21E-04	4.44E-03	Less/Less
Molybdenum	7.53E-02	6.25E-02	7.53E-02	Equal/Less
Nickel	1.99E-01	0	3.01E-01	Less/Less
Selenium	7.54E-02	6.27E-02	7.54E-02	Equal/Less
Silver	7.50E-02	8.58E-03	7.50E-02	Equal/Less
Thallium	1.20E-03	1.37E-04	1.20E-03	Equal/Less
Uranium	9.06E-03	1.82E-03	9.06E-03	Equal/Less
Vanadium	1.31E-01	1.50E-02	9.25E-02	Greater/Less
Zinc	4.50E+00	2.42E+00	4.50E+00	Equal/Less
<i>Organic Compounds</i>				
Acenaphthene	1.92E-09	4.83E-13	1.36E-01	Less/Less
Acenaphthylene	7.16E-09	1.80E-12	1.36E-01	Less/Less
Acrylonitrile	2.42E-04	1.19E-06	4.26E-04	Less/Less
Anthracene	1.89E-11	4.76E-15	7.66E-01	Less/Less
Benzene	3.52E-08	5.81E-11	3.85E-03	Less/Less
Butanone, 2-	3.75E-05	3.04E-07	8.68E-01	Less/Less
Carbon Tetrachloride	2.00E-06	7.77E-08	1.81E-03	Less/Less
Chlordane, alpha-	4.75E-26	0	1.28E-03	Less/Less
Chlordane, gamma-	4.75E-26	0	1.28E-03	Less/Less
Chlorobenzene	2.81E-09	3.17E-14	4.66E-02	Less/Less
Chloroform	1.42E-04	3.15E-05	2.87E-04	Less/Less
Dichlorobenzene, 1,4-	2.92E-10	3.29E-15	5.78E-03	Less/Less
Dichloroethane, 1,2-	2.06E-04	4.58E-05	1.47E-03	Less/Less
Dichloroethene, 1,1-	3.45E-05	7.65E-06	4.70E-03	Less/Less
Dichloroethene, 1,2- (mixed isomers)	1.06E-05	2.35E-06	2.47E-02	Less/Less
Dichloroethene, cis-1,2-	8.83E-05	1.96E-05	2.73E-02	Less/Less
Dichloroethene, trans-1,2-	1.50E-04	3.33E-05	5.48E-02	Less/Less
Dinitrotoluene, 2,4-	2.88E-09	1.41E-11	7.69E-04	Less/Less
Dioxins/Furans (Total)	5.45E-24	0	6.09E-10	Less/Less
Ethylbenzene	1.51E-09	2.48E-12	4.68E-02	Less/Less
Fluoranthene	8.90E-11	2.24E-14	2.26E-01	Less/Less
Fluorene	8.79E-10	2.22E-13	9.72E-02	Less/Less
Heptachlor Epoxide	1.70E-25	0	5.12E-05	Less/Less
Hexachlorobenzene	1.75E-11	1.97E-16	1.92E-04	Less/Less
Hexachlorobutadine	1.40E-09	3.52E-13	2.25E-03	Less/Less
Hexachloroethane	2.45E-08	6.18E-12	1.35E-02	Less/Less
Methoxychlor	3.82E-26	0	7.15E-02	Less/Less
Methylphenol, 2-	7.95E-07	3.90E-09	7.23E-01	Less/Less
Methylphenol, 3-	3.17E-07	1.56E-09	7.25E-01	Less/Less
Methylphenol, 4-	5.14E-07	2.52E-09	7.27E-02	Less/Less
Naphthalene	1.61E-08	4.07E-12	2.85E-03	Less/Less
Nitrobenzene	1.91E-08	9.36E-11	1.53E-03	Less/Less
Pentachlorophenol	1.19E-06	3.01E-10	2.08E-03	Less/Less
Phenanthrene	5.25E-10	1.32E-13	2.26E-01	Less/Less

Table 5.5. Comparison of groundwater concentrations in RGA at all exposure points against PGDP risk-based values protective of a groundwater user (continued)

Chemical ^a	Groundwater Concentration in RGA at DOE Property Boundary ^b (mg/l or pCi/l)	Groundwater Concentration in RGA at Ohio River ^b (mg/l or pCi/l)	Groundwater User Risk-based Concentrations ^c (mg/l or pCi/l)	Results ^d
Polychlorinated biphenyls (Total)	4.75E-15	0	7.93E-04	Less/Less
Polynuclear Aromatic Hydrocarbons (Total)	7.93E-23	0	9.51E-06	Less/Less
Pyrene	5.83E-11	1.47E-14	1.82E-01	Less/Less
Pyridine	1.72E-04	8.43E-07	1.49E-02	Less/Less
Tetrachloroethene	3.69E-07	1.43E-08	5.82E-03	Less/Less
Toxaphene	6.27E-25	0	4.56E-04	Less/Less
Trichloroethene	3.82E-06	1.48E-07	1.60E-02	Less/Less
Trichlorophenol, 2,4,5-	3.80E-09	1.86E-11	1.29E+00	Less/Less
Trichlorophenol, 2,4,6-	2.55E-09	1.25E-11	3.99E-02	Less/Less
Vinyl Chloride	1.26E-04	2.80E-05	3.50E-04	Less/Less
Xylene (mixture)	1.54E-09	2.53E-12	4.39E+00	Less/Less
Xylene, m-	1.47E-09	2.41E-12	6.53E-01	Less/Less
Xylene, o-	1.43E-09	2.35E-12	4.39E+00	Less/Less
Xylene, p-	1.33E-09	2.20E-12	4.39E+00	Less/Less
Radionuclides				
Technetium-99	1.40E+02	1.17E+02	1.40E+02	Equal/Less
Neptunium-237	5.73E+00	4.71E+00	5.73E+00	Equal/Less
Plutonium-238	2.95E+00	4.36E-01	2.95E+00	Equal/Less
Plutonium -239	2.86E+00	4.22E-01	2.86E+00	Equal/Less
Plutonium -240	2.86E+00	4.22E-01	2.86E+00	Equal/Less
Radium-226	2.33E-01	3.44E-02	2.33E-01	Equal/Less
Thorium-230	2.21E-01	3.26E-02	2.21E-01	Equal/Less
Thorium-232	2.68E-01	3.96E-02	2.68E-01	Equal/Less
Uranium-234	5.46E+00	8.07E-01	5.46E+00	Equal/Less
Uranium-235	5.38E+00	7.95E-01	5.38E+00	Equal/Less
Uranium-238	4.43E+00	6.54E-01	4.43E+00	Equal/Less

Notes:

^a Chemicals listed match the waste characterization presented in Chap. 3, except several radionuclides were removed. Please see Table 5.2, footnote 1 for additional discussion.

^b Concentrations in groundwater taken from Table 5.4.

^c Groundwater risk-based concentrations are the back-calculation values contained in Table 5.2 except concentrations based upon background were replaced by risk-based concentrations.

^d The results of the comparison against the screening concentrations. The first result is for the comparison using the groundwater concentration at the property boundary. The second result is for the comparison using the groundwater concentration at the Ohio River. "Equal" indicates that the predicted groundwater concentration equals the risk-based screening level. "Greater" indicates that the predicted concentration is greater than the risk-based screening level. "Less" indicates that the predicted concentration is less than the risk-based screening level.

DOE = U.S. Department of Energy

RGA = Regional Gravel Aquifer

The results for lead and vanadium are also as expected because the preliminary CERCLA-derived waste criteria and contaminant inventory limits for these chemicals were back-calculated from groundwater background concentrations that exceed the chemical's risk-based concentration (see Table 5.2).

The results for lead and vanadium do indicate that a reduction in the preliminary CERCLA-derived waste disposal criteria would be appropriate if contaminant migration was to groundwater with a lower background concentration. If the criteria were reduced so that groundwater concentrations at both points of exposure are equal to or less than the risk-based concentrations in groundwater, the new criteria would be 4,660 and 107,000 mg/kg, respectively. The new contaminant inventory limits would be 8.334×10^6 and 1.904×10^6 kg, respectively.

5.1.2.2 Recreational user and industrial worker

Table 5.6 shows the comparison between the concentrations in water in springs at the Ohio River and risk-based screening criteria for a recreational user and industrial worker coming into direct contact with the water in these springs through wading. As shown in Table 5.6, at the hypothetical springs along the Ohio River, no chemicals have a concentration in water that exceeds the risk-based screening levels. Note that screening values for radionuclides are not applicable to these receptors because water is assumed to act as an effective barrier against ionizing radiation.

5.1.3 Preliminary CERCLA-derived Waste Disposal Criteria Protective of Human Health

The analyses contained in Sect. 5.1.2 indicate that the disposal criteria developed using the groundwater user are protective for all other receptors quantitatively evaluated. The only exceptions to this may be the criteria derived for lead and vanadium. However, as discussed earlier, to be protective per this risk evaluation, the criteria would have to be set at concentrations less than those resulting in the background concentration in groundwater. As this is clearly nonsensical, the criteria for these inorganic chemicals were not reduced to these lower levels. Therefore, the values presented in Table 5.4 were selected as the preliminary CERCLA-derived waste disposal criteria and preliminary contaminant mass inventory limits protective of human health. These values are listed in Table 5.7.

5.2 ECOLOGICAL

This section evaluates the potential for adverse impact to aquatic and sediment-dwelling biota in the Ohio River and terrestrial mammals and birds drinking water from hypothetical springs along the Ohio River. This evaluation is based upon a screening level risk assessment using predicted maximum analyte concentrations in groundwater from the C-746-U Landfill potentially discharging to the Ohio River and to springs along the river. Derivation of the predicted maximum modeled concentrations in groundwater were described in Sect. 5.1.1 and will not be discussed here. The screening-level risk evaluation is presented in Sect. 5.2.1. Based on the results of the risk evaluation, Sect. 5.2.2 derives preliminary CERCLA-derived waste disposal criteria that are protective of ecological receptors. The final CERCLA-derived waste disposal criteria and the contaminant inventory limits based upon these criteria and those for human health are presented in Sect. 5.3.

5.2.1 Risk Evaluation

A risk evaluation was performed, using methods and data similar to those described for Step 2 of the PGDP ecological risk assessment process (DOE 2001b). In step 2 of the ecological risk assessments at PGDP, the maximum concentrations of substances in a given abiotic exposure medium are compared to screening-level toxicity benchmarks. If the maximum concentrations exceed the toxicity benchmarks, then the ecological receptors exposed to that medium by the associated exposure route are presumed to be at risk until further evaluation indicates otherwise. Further evaluation with various kinds of data and analyses is warranted to evaluate more thoroughly whether actual adverse impacts are likely to occur. In the context of the risk and performance evaluation for the C-746-U Landfill, disposal criteria based on screening-level risk are potentially more stringent than necessary to be protective of ecological receptors.

Modeled maximum concentrations of analytes in groundwater from the C-746-U Landfill potentially discharging to the Ohio River and outcropping at springs at the Ohio River were compared to benchmark concentrations associated with no or little adverse effect on ecological receptors. Predicted concentrations in Ohio River surface water and sediment were screened to evaluate the potential for risk to aquatic biota and sediment-dwelling biota, respectively. In addition, the concentrations of those COPCs in groundwater

Table 5.6. Comparison of water concentration in hypothetical springs located at the Ohio River against PGDP risk-based values protective of a surface water recreational user and industrial worker

Chemical ^a	Groundwater Concentration in RGA at Ohio River (mg/l or pCi/l) ^b	Recreational User Surface Water Risk-based Concentration ^c (mg/l or pCi/l)	Industrial Worker Surface Water Risk-based Concentration ^d (mg/l or pCi/l)	Results ^e
<i>Inorganic Chemicals</i>				
Antimony	3.03E-03	3.12E-02	7.31E-02	Less
Arsenic	0	4.09E-02	7.00E-02	Less
Barium	5.60E-01	1.91E+01	4.48E+01	Less
Beryllium	3.02E-03	7.80E-02	1.83E-01	Less
Cadmium	7.56E-04	1.95E-02	5.85E-02	Less
Chromium	1.46E+01	2.92E+01	6.86E+01	Less
Copper	3.00E-01	4.33E+01	1.01E+02	Less
Iron	0	1.75E+02	4.11E+02	Less
Lead ^f	2.86E-02	NV	NV	NV
Manganese	1.88E-01	3.74E+00	8.78E+00	Less
Mercury	1.21E-04	8.19E-02	2.12E-01	Less
Molybdenum	6.25E-02	7.41E+00	1.74E+01	Less
Nickel	0	2.10E+01	4.94E+01	Less
Selenium	6.27E-02	8.58E+00	2.01E+01	Less
Silver	8.58E-03	3.51E+00	8.23E+00	Less
Thallium	1.37E-04	6.24E-02	1.46E-01	Less
Uranium	1.82E-03	1.99E+00	4.66E+00	Less
Vanadium	1.50E-02	2.73E-01	6.40E-01	Less
Zinc	2.42E+00	2.34E+02	4.65E+02	Less
<i>Organic Compounds</i>				
Acenaphthene	4.83E-13	2.90E-01	6.80E-01	Less
Acenaphthylene	1.80E-12	NV	NV	NV
Acrylonitrile	1.19E-06	1.58E-01	2.71E-01	Less
Anthracene	4.76E-15	4.04E+00	9.47E+00	Less
Benzene	5.81E-11	1.26E-01	2.15E-01	Less
Butanone, 2-	3.04E-07	1.70E+03	3.99E+03	Less
Carbon Tetrachloride	7.77E-08	3.40E-02	5.82E-02	Less
Chlordane, alpha-	0	4.11E-03	7.03E-03	Less
Chlordane, gamma-	0	4.11E-03	7.03E-03	Less
Chlorobenzene	3.17E-14	5.89E-01	1.38E+00	Less
Chloroform	3.15E-05	5.51E-01	9.43E-01	Less
Dichlorobenzene, 1,4-	3.29E-15	9.04E-02	1.55E-01	Less
Dichloroethane, 1,2	4.58E-05	3.10E-01	5.31E-01	Less
Dichloroethene, 1,1-	7.65E-06	2.80E-02	4.79E-02	Less
Dichloroethene, 1,2- (mixed isomers)	2.35E-06	2.55E+01	5.98E+01	Less
Dichloroethene, cis-1,2-	1.96E-05	3.90E+00	9.14E+00	Less
Dichloroethene, trans-1,2-	3.33E-05	7.09E+01	1.66E+02	Less
Dinitrotoluene, 2,4-	1.41E-11	4.92E-02	8.42E-02	Less
Dioxins/Furans (Total)	0	3.56E-10	6.09E-10	Less
Ethylbenzene	2.48E-12	5.11E+00	1.20E+01	Less
Fluoranthene	2.24E-14	1.34E-01	3.15E-01	Less
Fluorene	2.22E-13	3.12E-01	7.31E-01	Less
Heptachlor Epoxide	0	2.15E-04	3.68E-04	Less
Hexachlorobenzene	1.97E-16	2.23E-04	3.81E-04	Less
Hexachlorobutadiene	3.52E-13	3.24E-03	7.62E-03	Less
Hexachloroethane	6.18E-12	4.64E-02	1.09E-01	Less
Methoxychlor	0	4.87E-01	1.14E+00	Less
Methylphenol, 2-	3.90E-09	6.09E+00	1.43E+01	Less
Methylphenol, 3-	1.56E-09	6.50E+00	1.52E+01	Less
Methylphenol, 4-	2.52E-09	7.04E-01	1.65E+00	Less
Naphthalene	4.07E-12	9.04E-01	2.12E+00	Less
Nitrobenzene	9.36E-11	2.74E-01	6.43E-01	Less
Polychlorinated biphenyls (Total)	3.01E-10	9.61E-04	1.65E-03	Less
Polynuclear aromatic hydrocarbons (Total)	1.32E-13	5.29E-06	9.06E-06	Less

Table 5.6. Comparison of water concentration in hypothetical springs located at the Ohio River against PGDP risk-based values protective of a surface water recreational user and industrial worker (continued)

Chemical^a	Groundwater Concentration in RGA at Ohio River (mg/l or pCi/l)^b	Recreational User Surface Water Risk-based Concentration^c (mg/l or pCi/l)	Industrial Worker Surface Water Risk-based Concentration^d (mg/l or pCi/l)	Results^e
Pentachlorophenol	0	1.92E-03	3.28E-03	Less
Phenanthrene	0	NV	NV	NV
Pyrene	1.47E-14	1.13E-01	2.66E-01	Less
Pyridine	8.43E-07	3.68E-01	8.62E-01	Less
Tetrachloroethene	1.43E-08	7.77E-03	1.33E-02	Less
Toxaphene	0	4.53E-03	7.76E-03	Less
Trichloroethene	1.48E-07	1.27E-01	2.18E-01	Less
Trichlorophenol, 2,4,5-	1.86E-11	3.30E+00	7.75E+00	Less
Trichlorophenol, 2,4,6-	1.25E-11	1.15E-01	1.97E-01	Less
Vinyl chloride	2.80E-05	1.46E-02	2.50E-02	Less
Xylene (mixture)	2.53E-12	7.55E+01	1.77E+02	Less
Xylene, m-	2.41E-12	7.80E+01	1.83E+02	Less
Xylene, o-	2.35E-12	7.80E+01	1.83E+02	Less
Xylene, p-	2.20E-12	NV	NV	NV
Radionuclides				
Technetium-99	1.17E+02	NV	NV	NV
Neptunium-237	4.71E+00	NV	NV	NV
Plutonium-238	4.36E-01	NV	NV	NV
Plutonium -239	4.22E-01	NV	NV	NV
Plutonium -240	4.22E-01	NV	NV	NV
Radium-226	3.44E-02	NV	NV	NV
Thorium-230	3.26E-02	NV	NV	NV
Thorium-232	3.96E-02	NV	NV	NV
Uranium-234	8.07E-01	NV	NV	NV
Uranium-235	7.95E-01	NV	NV	NV
Uranium-238	6.54E-01	NV	NV	NV

Notes:

^a Chemicals listed match the waste characterization presented in Chap. 3, except several radionuclides were removed. Please see Table 5.2, footnote 1 for additional discussion.

^b Concentrations in groundwater at Ohio River taken from Table 5.4.

^c Surface water risk-based values for the recreational user match those in Table A.19 in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1* (DOE 2001b) except the cancer-risk target was increased to 1×10^{-5} , and the hazard target was increased to 1. (Values were not adjusted for background concentration in groundwater.) In all cases, the concentrations are the lesser of the cancer-risk-based and hazard-based values for the child recreational user exposed while wading. For both the cancer-risk-based and hazard-based value, under the wading scenario, the exposure route considered is dermal exposure. For the cancer-risk-based value, a lifetime exposure is used with the following rates of exposure:

- Exposure durations for child, teen, and adult are 6, 12, and 22 years, respectively.
- Exposure frequencies for child, teen, and adult are 140 days per year, 140 days per year, and 52 days per year, respectively.
- Exposure time for all age cohorts is 2.6 hours per day.

For the hazard-based value, only a child exposure is used with the following rates of exposure:

- Exposure duration for child is 6 years.
- Exposure frequency for child is 140 days per year.
- Exposure time for child is 2.6 hours per day.

Note that screening values for radionuclides are not available because water is assumed to shield the receptor from ionizing radiation.

^d Surface water risk-based values for the industrial user match those in Table A.19 in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1* (DOE 2001b) except the cancer-risk target was increased to 1×10^{-5} , and the hazard target was increased to 1. (Values were not adjusted for background concentration in groundwater.) In all cases, the concentrations are the lesser of the cancer-risk-based and hazard-based values for the industrial worker exposed while working at a spring. For both the cancer-risk-based and hazard-based value, the exposure route considered is dermal exposure. For the cancer-risk-based value, a lifetime exposure is used with the following rates of exposure:

- Exposure duration is 25 years.
- Exposure frequency is 250 days per year.
- Exposure time 2.6 hours per day.

For the hazard-based value, the following rates of exposure were used:

- Exposure duration is 25 years.
- Exposure frequency is 250 days per year.
- Exposure time is 2.6 hours per day.

Table 5.6. Comparison of water concentration in hypothetical springs located at the Ohio River against PGDP risk-based values protective of a surface water recreational user and industrial worker (continued)

Note that screening values for radionuclides are not available because water is assumed to shield the receptor from ionizing radiation

^e The results of the comparison against the screening concentration. "Greater" indicates that the predicted concentration in water is greater than a risk-based screening level. "Less" indicates that the predicted concentration is less than a risk-based screening level.

^f Table A.19 in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1* (DOE 2001b) lists 1.50E-02 mg/l as the no action screening value for the recreational user and industrial worker. Because this value is actually based upon an analysis that considers groundwater ingestion as the primary route of exposure, use of this value was deemed inappropriate for this evaluation and is not considered here.

NV = a screening value is not available.

RGA = Regional Gravel Aquifer

Table 5.7. Preliminary CERCLA-derived waste disposal criteria protective of human health

Chemical ^a	Preliminary CERCLA-derived Waste Disposal Criteria (mg/kg or pCi/g)	Preliminary Contaminant Inventory Limit (kg or Ci)
<i>Inorganic Chemicals</i>		
Antimony	6.79E+01	1.215E+05
Arsenic	2.88E+01	5.144E+04
Barium	1.14E+04	2.041E+07
Beryllium	2.40E+04	4.293E+07
Cadmium	5.70E+02	1.020E+06
Chromium	1.72E+04	3.073E+07
Copper	5.22E+03	9.333E+06
Iron	1.00E+06	1.789E+09
Lead ^b	7.77E+04	1.389E+08
Manganese	4.68E+03	8.378E+06
Mercury	3.13E+00	5.603E+03
Molybdenum	3.87E+01	6.920E+04
Nickel	1.00E+06	1.789E+09
Selenium	7.77E+01	1.389E+05
Silver	7.77E+03	1.389E+07
Thallium	9.80E+01	1.754E+05
Uranium	7.79E+02	1.394E+06
Vanadium ^b	1.51E+05	2.696E+08
Zinc	7.47E+04	1.336E+08
<i>Organic Compounds</i>		
Acenaphthene	1.75E+01	3.125E+04
Acenaphthylene	9.85E+01	1.763E+05
Acrylonitrile	1.47E+04	2.632E+07
Anthracene	8.25E-01	1.475E+03
Benzene	4.38E+02	7.830E+05
Butanone, 2-	5.53E+04	9.885E+07
Carbon Tetrachloride	2.57E+02	4.600E+05
Chlordane, alpha-	2.65E+00	4.740E+03
Chlordane, gamma-	2.65E+00	4.739E+03
Chlorobenzene	1.79E+02	3.205E+05
Chloroform	1.92E+03	3.439E+06
Dichlorobenzene, 1,4-	5.11E+01	9.150E+04
Dichloroethane, 1,2-	2.00E+03	3.583E+06
Dichloroethene, 1,1-	5.72E+02	1.024E+06
Dichloroethene, 1,2- (mixed isomers)	2.10E+02	3.758E+05
Dichloroethene, cis-1,2-	8.01E+02	1.432E+06
Dichloroethene, trans-1,2-	1.46E+03	2.606E+06
Dinitrotoluene, 2,4-	7.46E+01	1.335E+05
Dioxins/Furan (Total)	2.64E+01	4.723E+04
Ethylbenzene	6.15E+01	1.100E+05
Fluoranthene	8.14E+00	1.456E+04
Fluorene	1.26E+01	2.256E+04
Heptachlor Epoxide	1.34E+01	2.389E+04
Hexachlorobenzene	3.98E+02	7.121E+05
Hexachlorobutadine	1.39E+02	2.494E+05
Hexachloroethane	8.12E+01	1.453E+05
Methoxychlor	2.89E+00	5.169E+03
Methylphenol, 2-	4.32E+03	7.729E+06
Methylphenol, 3-	4.91E+03	8.788E+06
Methylphenol, 4-	5.03E+03	9.005E+06
Naphthalene	3.57E+01	6.389E+04
Nitrobenzene	6.17E+02	1.104E+06
Pentachlorophenol	1.31E+03	2.350E+06
Phenanthrene	1.37E+01	2.447E+04
Polychlorinated biphenyls (Total)	1.73E+02	3.098E+05
Polynuclear Aromatic Hydrocarbons (Total)	7.75E+00	1.387E+04

Table 5.7. Preliminary CERCLA-derived waste disposal criteria protective of human health (continued)

Chemical^a	Preliminary CERCLA-derived Waste Disposal Criteria (mg/kg or pCi/g)	Preliminary Contaminant Inventory Limit (kg or Ci)
Pyrene	7.37E+00	1.319E+04
Pyridine	2.03E+05	3.640E+08
Tetrachloroethene	8.27E+01	1.480E+05
Toxaphene	5.69E+01	1.017E+05
Trichloroethene	3.04E+02	5.433E+05
Trichlorophenol, 2,4,5-	3.42E+03	6.114E+06
Trichlorophenol, 2,4,6-	2.14E+03	3.824E+06
Vinyl Chloride	6.00E+02	1.073E+06
Xylene (mixture)	8.35E+01	1.494E+05
Xylene, m-	5.76E+01	1.030E+05
Xylene, o-	6.89E+01	1.232E+05
Xylene, p-	8.32E+01	1.488E+05
Radionuclides		
Neptunium-237	2.26E+01	4.040E+01
Plutonium-238	5.66E+03	1.012E+04
Plutonium-239	5.49E+03	9.813E+03
Plutonium-240	5.49E+03	9.813E+03
Radium-226	4.06E+02	7.268E+02
Technetium-99	2.02E+01	3.606E+01
Thorium-230	2.47E+03	4.412E+03
Thorium-232	2.99E+03	5.350E+03
Uranium-234	1.27E+03	2.275E+03
Uranium-235	1.25E+03	2.242E+03
Uranium-238	1.03E+03	1.846E+03

Notes:

^a Chemicals listed match the waste characterization presented in Chap. 3, except several radionuclides were removed. Please see Table 5.2, footnote 1, for additional discussion.

^b The preliminary CERCLA-derived waste disposal criteria and preliminary contaminant inventory limit for lead and vanadium would be lowered if calculated using risk-based groundwater concentrations instead of background values. These values would be 4.66E+03 mg/kg and 8.334E+06 kg for lead and 1.07E+05 and 1.904E+06 for vanadium. Please see discussion in Sect. 5.1.2.1.

at potential at the Ohio River were screened to evaluate the potential for risk to terrestrial mammals [short-tailed shrew (*Blarina brevicauda*)] and birds [marsh wren (*Cistothorus palustris*)] from drinking water at hypothetical springs along the river. The maximum predicted concentrations of analytes in groundwater at the points of discharge were derived as discussed in Sect. 5.1. The predicted concentrations of analytes in groundwater were also used along with the partition coefficients (K_{ds}) to estimate the expected concentrations of contaminants in sediment, assuming equilibrium conditions between the surface water and sediment. The K_{ds} used in this analysis were those discussed and presented in Chap. 4. The resulting maximum predicted surface water and sediment exposure concentrations were compared to dietary benchmarks corresponding to no adverse effect levels for mammals and birds, PGDP surface water no further action (NFA) concentrations for aquatic biota, and PGDP sediment NFAs or alternative concentrations for sediment-dwelling biota.

PGDP NFAs are conservative estimates of chemical concentrations in abiotic media that will not adversely affect ecological receptors with high probability. The surface water NFA concentrations come from four sources (DOE 2001b). The first choice is the Kentucky state warm water chronic criterion. The second choice is the lower of KDEP freshwater screening values, EPA Region 4 freshwater ecological screening values, as published in the June 2000 memo from Ted Simon (EPA 2000), and the chronic Tier II value calculated by Suter and Tsao (1996). For individual radionuclides, the NFAs were calculated from the NFA dose of 0.1 rad/day (DOE 2001b).

PGDP sediment NFA concentrations for nonradionuclides came from four possible sources: the Canadian threshold effect levels (TELs); consensus-based threshold effects concentrations (TECs); KDEP; and TELs for the sediment-dwelling amphipod, *Hyaella azteca* (DOE 2001b). For individual radionuclides, the NFAs were calculated from the NFA dose of 0.1 rad/day (DOE 2001b).

Several analytes on the PGDP list of significant COPCs did not have an NFA concentration for surface water or sediment. For those analytes, published toxicity benchmarks were used as alternative NFAs. For example, the PGDP NFA concentration for m-xylene in water, 0.0018 mg/L, was used as an alternative NFA for o-xylene and p-xylene. For sediments, sources of toxicity benchmarks that served as alternative NFAs included Jones et al. (1997), Washington State Sediment Quality Standards (Ginn and Pastorak 1992), the Ontario Ministry of the Environment "Low" concentrations (Persaud et al. 1993), Mierzykowski et al. (1997), and Dervees and Canton (1997).

Comparing the surface water or sediment maximum concentration of an analyte against its PGDP NFA concentration or an alternative benchmark concentration yields a hazard quotient (HQ). If the HQ for an analyte in surface water or sediment is less than or equal to 1.0, the analyte is assumed to pose negligible adverse impact to aquatic or sediment-dwelling biota, respectively. However, if the HQ exceeds 1.0, the analyte concentration is high enough to indicate the need for further evaluation of potential risk to the biota.

Because the predicted concentrations of analytes in the C-746-U Landfill groundwater would undoubtedly be diluted before and after the groundwater discharges to the Ohio River, the HQs for sediment and surface water in the Ohio River likely overestimate the actual risk to biota. For example, the predicted volume of groundwater that discharges to the Ohio River is approximately 200,000 L/day, whereas the approximate volume of flow in the Ohio River near the Paducah site is 474,000,000,000 L/day. Therefore, the influx of groundwater from the C-746-U Landfill is approximately 0.00004 % of the total flow of the Ohio River at the point of discharge. Thus, there is about a 7-order-of-magnitude dilution of the groundwater once it enters the Ohio River. The dilution of groundwater in the hyporheic zone of the Ohio River is likely large as well, although it cannot be estimated. The dilution effect in relation to the HQs and potential risk to the biota is discussed immediately after the presentation of HQs.

For the terrestrial small mammal's and bird's exposures to chemical analytes in groundwater used as drinking water at springs, the following equation was used to calculate the dose

$$ADD_{sw} = (C_{sw} \times I_{sw}) \times AUF$$

where:

- ADD_{sw} = spring water exposure dose for terrestrial receptor (mg/kg/d)
- C_{sw} = maximum concentration in spring water (mg/L)
- I_{sw} = receptor-specific ingestion rate of spring water (L/kg/d)
- AUF = area use factor (dimensionless, assumed to be 1).

The dietary exposure doses to terrestrial small mammals and birds were compared to published dietary no observed adverse effect levels (NOAELs). The NOAELs represent the maximum amount of chemical that can be consumed by the receptor per unit body weight per day and not produce any adverse effect to an endpoint such as survival or reproduction. For this screening evaluation, the NOAELs were not adjusted for the body weight of the receptor. That is, the NOAELs were based on the published doses that were reported for a specific laboratory test species such as a mouse or rat for the mammal, or a chicken or duck for the bird. The NOAELs for mammals and birds are presented in Appendix C.2 Tables C.2.1 and C.2.2, respectively.

For terrestrial ecological receptors exposed to radionuclides in groundwater used for drinking water at springs, the benchmarks for radionuclides are calculated from the recommended National Commission

on Radiological Protection (NCRP) (1991) threshold dose for mammals (0.1 rad/day) times a safety factor of 0.1, or 0.01 rad/day. The radionuclide screening benchmarks are derived for parent isotopes and short-lived daughter products using the radionuclide exposure model of Sample et al. (1997) for internal exposures from all major alpha, beta, and gamma emissions for each isotope. Internal exposure was calculated as the product of uptake by ingestion and a radiation dose factor

$$D = C_w \times IR_w \times Ba \times 0.001 \times CF_a \times (QF_\alpha \times E_{\alpha n_\alpha} + E_{\beta n_\beta} + E_{\gamma n_\gamma} \times \Phi_\gamma)$$

where:

- D = radiation dose (rad/day)
- C_w = concentration in water (pCi/L)
- IR_w = water ingestion rate (L/day)
- Ba = tissue uptake factor (pCi/kg tissue per pCi ingested/day)
- 0.001 = conversion factor, kg/g
- CF_a = conversion factor to go from MeV/nt to rad/d per pCi/g
- QF_α = quality factor for relative biological effect of alpha radiation (20)
- E_{αn_α} = alpha energy of the radionuclide (MeV) × proportion of disintegrations producing an α-particle (Table A.1, Eckerman and Ryman 1993)
- E_{βn_β} = beta energy of the radionuclide (MeV) × proportion of disintegrations producing a β-particle (Table A.1, Eckerman and Ryman 1993)
- E_{γn_γ} = photon energy emitted during transition from a higher to a lower energy state (MeV) (Table A.1, Eckerman and Ryman 1993)
- Φ_γ = absorbed fraction of energy E_γ (Blaylock, Frank, and O'Neal 1993).

Water ingestion rates for shrews and robins and the resulting ingestion factors are shown in Appendix C.2, Table C.2.3. The benchmarks were calculated by setting D = 0.01 rad/day and solving the equation for C_w. Benchmarks are shown in Appendix C.2, Table C.2.4, for mammals and Appendix C.2, Table C.2.5, for birds.

5.2.1.1 Groundwater discharge of chemicals to the Ohio River

Twenty inorganic chemicals, 30 VOCs, 11 semivolatile organic compounds (SVOCs), one PCB (total PCBs) and six pesticides are on the list of COPCs screened; chromium is counted twice, once as trivalent, once as hexavalent. Predicted concentrations in groundwater discharging to the Ohio River were derived for each of these analytes (Table 5.8). All 20 of the inorganic chemicals have NFAs. Eleven HQs for the inorganic analytes exceeded 1, including barium, beryllium, chromium (III and VI), copper, lead, manganese, mercury, selenium, silver, and zinc. Thus, based on the HQs, these eleven inorganic chemicals potentially could pose adverse impacts to aquatic biota exposed to undiluted groundwater. Based on the largest HQ among the inorganic chemicals (i.e., chromium VI HQ = 1,330), the groundwater would require a 1,330-fold dilution to be protective of aquatic biota in the Ohio River. As discussed previously, the dilution of groundwater flowing into the Ohio River is approximately 10,000,000-fold, so the resulting HQs after dilution would be much less than 1. Thus, inorganic chemicals in the groundwater contaminated by analytes migrating from the C-746-U Landfill and potentially discharging to the Ohio River should pose no adverse impacts to aquatic biota.

Twenty-one of the 30 VOCs in the C-746-U Landfill groundwater had NFA concentrations (Table 5.8). Although PGDP NFAs were not available for cis-1,2-dichloroethylene, 3-methylphenol, 4-methylphenol, 2,4,5-trichlorophenol, o-xylene, or p-xylene, alternative NFAs were used for each of them. The NFA for m-xylene was used as an alternative NFA for o-xylene and p-xylene. The PGDP NFA for trans-1,2-dichloroethylene was used as an alternative NFA for cis-1,2-dichloroethylene. The PGDP NFA for 2-methylphenol was used as an alternative NFA for 3-methylphenol and 4-methylphenol. The PGDP

Table 5.8. Ecological risk screening of predicted maximum concentrations for selected chemicals in groundwater from the C-746-U Landfill discharging to the Ohio River

Analytes	Maximum (mg/L)	Maximum (µg/L)	PGDP NFA values (µg/L)	HQ based on PGDP NFAs	Alternative NFA value (µg/L)	Alternative NFA source	HQ based on Alternative NFA values
<i>Inorganics</i>							
Antimony	3.03E-03	3.03E+00	1.60E+02	1.89E-02	—	—	—
Arsenic	0.00E+00	0.00E+00	5.00E+01	0.00E+00	—	—	—
Barium	5.60E-01	5.60E+02	4.00E+00	1.40E+02	—	—	—
Beryllium	3.02E-03	3.02E+00	5.30E-01	5.70E+00	—	—	—
Cadmium	7.56E-04	7.56E-01	1.42E+00	5.32E-01	—	—	—
Chromium (III)	1.46E+01	1.46E+04	4.89E+01	2.99E+02	—	—	—
Chromium (VI)	1.46E+01	1.46E+04	1.10E+01	1.33E+03	—	—	—
Copper	3.00E-01	3.00E+02	5.16E+00	5.81E+01	—	—	—
Iron	0.00E+00	0.00E+00	1.00E+03	0.00E+00	—	—	—
Lead	2.86E-02	2.86E+01	1.32E+00	2.17E+01	—	—	—
Manganese	1.88E-01	1.88E+02	1.20E+02	1.57E+00	—	—	—
Mercury	1.21E-04	1.21E-01	1.20E-02	1.01E+01	—	—	—
Molybdenum	6.25E-02	6.25E+01	3.70E+02	1.69E-01	—	—	—
Nickel	0.00E+00	0.00E+00	2.90E+01	0.00E+00	—	—	—
Selenium	6.27E-02	6.27E+01	5.00E+00	1.25E+01	—	—	—
Silver	8.58E-03	8.58E+00	1.20E-02	7.15E+02	—	—	—
Thallium	1.37E-04	1.37E-01	4.00E+00	3.43E-02	—	—	—
Uranium	1.82E-03	1.82E+00	2.60E+00	7.00E-01	—	—	—
Vanadium	1.50E-02	1.50E+01	2.00E+01	7.50E-01	—	—	—
Zinc	2.42E+00	2.42E+03	6.70E+01	3.61E+01	—	—	—
<i>Volatile organic compounds</i>							
Benzene	5.81E-11	5.81E-08	5.30E+01	1.10E-09	—	—	—
2-Butanone	3.04E-07	3.04E-04	1.40E+04	2.17E-08	—	—	—
Carbon tetrachloride	7.77E-08	7.77E-05	3.52E+02	2.21E-07	—	—	—
Chlorobenzene	3.17E-14	3.17E-11	1.95E+02	1.63E-13	—	—	—
Chloroform	3.15E-05	3.15E-02	2.89E+02	1.09E-04	—	—	—
1,4-Dichlorobenzene	3.29E-15	3.29E-12	1.12E+01	2.94E-13	—	—	—
1,2-Dichloroethane	4.58E-05	4.58E-02	2.00E+03	2.29E-05	—	—	—
1,1-Dichloroethylene	7.65E-06	7.65E-03	3.03E+02	2.52E-05	—	—	—
1,2-Dichloroethylene	2.35E-06	2.35E-03	5.90E+02	3.98E-06	—	—	—

Table 5.8. Ecological Risk Screening of Predicted Maximum Concentrations for Selected Chemicals in Groundwater from the C-746-U Landfill Discharging to Ohio River (continued)

Analytes	Maximum (mg/L)	Maximum (µg/L)	PGDP NFA values (µg/L)	HQ based on PGDP NFAs	Alternative NFA value (µg/L)	Alternative NFA source	HQ based on Alternative NFA values
1,2-Dichloroethylene-cis	1.96E-05	1.96E-02	none	no PGDP NFA	1.35E+03	a	1.45E-05
1,2-Dichloroethylene-trans	3.33E-05	3.33E-02	1.35E+03	2.47E-05	—	—	—
2,4-Dinitrotoluene	1.41E-11	1.41E-08	3.10E+02	4.55E-11	—	—	—
Ethylbenzene	2.48E-12	2.48E-09	4.53E+02	5.47E-12	—	—	—
Hexachlorobenzene	1.97E-16	1.97E-13	none	no PGDP NFA	None	None	no alternative NFA
Hexachlorobutadiene	3.52E-13	3.52E-10	9.30E-01	3.78E-10	—	—	—
Hexachloroethane	6.18E-12	6.18E-09	9.80E+00	6.31E-10	—	—	—
2-Methylphenol	3.90E-09	3.90E-06	1.30E+01	3.00E-07	—	—	—
3-Methylphenol	1.56E-09	1.56E-06	none	no PGDP NFA	1.30E+01	b	1.20E-07
4-Methylphenol	2.52E-09	2.52E-06	none	no PGDP NFA	1.30E+01	b	1.94E-07
Nitrobenzene	9.36E-11	9.36E-08	2.70E+02	3.47E-10	—	—	—
Pyridine	8.43E-07	8.43E-04	none	no PGDP NFA	None	None	no alternative NFA
Tetrachloroethylene	1.43E-08	1.43E-05	8.40E+01	1.70E-07	—	—	—
Trichloroethene	1.48E-07	1.48E-04	4.70E+01	3.15E-06	—	—	—
2,4,5-Trichlorophenol	1.86E-11	1.86E-08	none	no PGDP NFA	3.20E+00	c	5.81E-09
2,4,6-Trichlorophenol	1.25E-11	1.25E-08	3.20E+00	3.91E-09	—	—	—
Vinyl chloride	2.80E-05	2.80E-02	None	no PGDP NFA	None	None	no alternative NFA
Xylene, total	2.53E-12	2.53E-09	1.30E+01	1.95E-10	—	—	—
Xylene, m-	2.41E-12	2.41E-09	1.80E+00	1.34E-09	—	—	—
Xylene, o-	2.35E-12	2.35E-09	none	no PGDP NFA	1.80E+00	d	1.31E-09
Xylene, p-	2.20E-12	2.20E-09	none	no PGDP NFA	1.80E+00	d	1.22E-09
<i>Semivolatile organic compounds</i>							
Acenaphthene	4.83E-13	4.83E-10	1.70E+01	2.84E-11	—	—	—
Acenaphthylene	1.80E-12	1.80E-09	None	no PGDP NFA	1.70E+01	e	1.06E-10
Acrylonitrile	1.19E-06	1.19E-03	7.55E+01	1.58E-05	—	—	—
Anthracene	4.76E-15	4.76E-12	7.30E-01	6.52E-12	—	—	—
Dioxins/furans total	0.00E+00	0.00E+00	None	no PGDP NFA	None	None	no alternative NFA
Fluoranthene	2.24E-14	2.24E-11	3.98E+01	5.63E-13	—	—	—
Fluorene	2.22E-13	2.22E-10	None	no PGDP NFA	None	None	no alternative NFA
Naphthalene	4.07E-12	4.07E-09	6.20E+01	6.56E-11	—	—	—
Phenanthrene	1.32E-13	1.32E-10	None	no PGDP NFA	None	None	no alternative NFA
Polyaromatic hydrocarbons	0.00E+00	0.00E+00	None	no PGDP NFA	1.40E-02	f	0.00E+00
Pyrene	1.47E-14	1.47E-11	None	no PGDP NFA	None	None	no alternative NFA

Table 5.8. Ecological Risk Screening of Predicted Maximum Concentrations for Selected Chemicals in Groundwater from the C-746-U Landfill Discharging to Ohio River (continued)

	<i>Pesticides/PCBs</i>						
Polychlorinated biphenyls	0.00E+00	0.00E+00	1.40E-03	0.00E+00	—	—	—
alpha-Chlordane	0.00E+00	0.00E+00	none	no PGDP NFA	4.30E-03	g	0.00E+00
gamma-Chlordane	0.00E+00	0.00E+00	none	no PGDP NFA	4.30E-03	g	0.00E+00
Heptachlor epoxide	0.00E+00	0.00E+00	3.80E-03	0.00E+00	—	—	—
Methoxychlor	0.00E+00	0.00E+00	3.00E-02	0.00E+00	—	—	—
Pentachlorophenol	3.01E-10	3.01E-07	1.49E+01	2.02E-08	—	—	—
Toxaphene	0.00E+00	0.00E+00	2.00E-04	0.00E+00	—	—	—

PGDP NFA = Paducah Gaseous Diffusion Plant No Further Action benchmarks

HQ = hazard quotient = predicted maximum concentration in groundwater / PGDP NFA or alternative NFA

HQs in dark border exceed 1.0

a = alternative NFA value based on PGDP NFA for 1,2-dichloroethylene-trans

b = alternative NFA value based on PGDP NFA for 2-methylphenol

c = alternative NFA value based on PGDP NFA for 2,4,6-trichlorophenol

d = alternative NFA value based on PGDP NFA for xylene, o-

e = alternative NFA value based on PGDP NFA for acenaphthene

f = alternative NFA value based on NFA for benzo(a)pyrene, a human carcinogen

g = alternative NFA value based on PGDP NFA for chlordane

— = alternative NFA not necessary because a PGDP NFA was available

NFA for 2,4,6-trichlorophenol was used as an alternative NFA for 2,4,5-trichlorophenol. Hexachlorobenzene, pyridine, and vinyl chloride did not have any available toxicity benchmark for screening, so HQs could not be calculated for them. The HQs based on NFA concentrations or alternative NFAs do not exceed 1 for VOCs. Thus, VOCs in the groundwater contaminated by analytes migrating from the C-746-U Landfill should pose no adverse impacts to aquatic biota in the Ohio River.

Only five of the 11 SVOCs that were predicted to occur in the groundwater had PGDP NFA concentrations. These are acenaphthene, acrylonitrile, anthracene, fluoranthene, and naphthalene (Table 5.8). The PGDP NFA value for acenaphthene was used as an alternative NFA for acenaphthylene. Neither PGDP NFAs nor acceptable alternatives were available for dioxins/furans, fluorene, phenanthrene, total PAHs, or pyrene so HQs could not be calculated for those chemicals. None of the HQs based on the PGDP NFA concentrations or alternative NFAs exceeded 1. Thus, based on the HQs, the SVOCs in the groundwater contaminated by analytes migrating from the C-746-U Landfill pose no adverse impacts to aquatic biota in the Ohio River.

The one PCB (total PCBs) and five of the six pesticides (alpha-chlordane, gamma-chlordane, heptachlor epoxide, methoxychlor, and toxaphene) in the groundwater are predicted to occur at concentrations so low they essentially are considered 0 µg/L. The HQs for those chemicals are also assumed to be zero (Table 5.8). The HQ for the sixth pesticide, pentachlorophenol, was less than 1 (HQ = 0.000000014). Thus, the total PCBs in the undiluted groundwater contaminated by analytes migrating from the C-746-U Landfill are not expected to cause adverse impacts to aquatic biota in the Ohio River.

In summary, even the largest HQ (i.e., 1,330 for chromium VI) for groundwater potentially discharging into the Ohio River should pose no adverse impact to aquatic biota because the groundwater will be diluted approximately 10 million-fold by the Ohio River, bringing all the HQs to far less than 1.

5.2.1.2 Groundwater discharge of radionuclides to Ohio River

Eleven radionuclides are on the PGDP list of significant COPCs. Predicted concentrations in groundwater potentially discharging to the Ohio River were derived for each of these radionuclides (Table 5.9). The maximum concentrations in groundwater discharging at the Ohio River ranged from 117 pCi/L for ⁹⁹Tc to 0.0326 pCi/L for ²³⁰Th. All 11 of the radionuclides had a NFA. All of the HQs for radionuclides were less than 1, ranging from 0.00351 (²³⁷Np) to 0.0000601 (⁹⁹Tc). Thus, radionuclides in the groundwater that discharges into the Ohio River are not expected to cause adverse impacts to aquatic biota.

5.2.1.3 Chemicals in groundwater in springs used as drinking water by mammals

Twenty inorganic chemicals, 30 VOCs, 11 SVOCs, one PCB (total PCBs) and six pesticides are on the landfill list of COPCs screened. Predicted concentrations in groundwater at a spring located at the Ohio River were derived for each analyte. This water was assumed to act as a drinking water source for shrews as a conservative representative of all mammals potentially exposed (Table 5.10). Iron was the only inorganic chemical that did not have a dietary NOAEL so an HQ could not be calculated for iron. None of the inorganic chemicals had an HQ exceeding 1 for shrews. Thus, based on the HQs, none of the inorganic chemicals could potentially pose adverse impacts to mammals exposed to undiluted groundwater as their sole source of drinking water.

Twenty of the 30 VOCs modeled had dietary NOAELs; alternative NOAELs were selected for 7 of the other 10 VOCs (cis-1,2-dichloroethylene; trans-1,2-dichloroethylene; 4-methylphenol; 2,4,6-trichlorophenol; m-xylene; o-xylene; and p-xylene) (Table 5.10). The dietary NOAEL for 1,2-dichloroethylene was used as an alternative value for cis-1,2-dichloroethylene and trans-1,2-dichloroethylene. The dietary NOAEL

Table 5.9. Ecological risk screening of predicted maximum concentrations for selected radionuclides in groundwater from the C-746-U Landfill discharging to the Ohio River

Radionuclide	Maximum (pCi/L)	PGDP NFA (pCi/L)	HQ
Neptunium-237	4.71E+00	1.34E+03	3.51E-03
Plutonium-238	4.36E-01	1.17E+03	3.72E-04
Plutonium-239	4.22E-01	1.25E+03	3.38E-04
Plutonium-240	4.22E-01	1.24E+03	3.41E-04
Radium-226	3.44E-02	1.60E+02	2.15E-04
Technecium-99	1.17E+02	1.94E+06	6.01E-05
Thorium-230	3.26E-02	4.13E+02	7.90E-05
Thorium-232	3.96E-02	4.78E+02	8.28E-05
Uranium-234	8.07E-01	4.04E+03	2.00E-04
Uranium-235	7.95E-01	4.37E+03	1.82E-04
Uranium-238	6.54E-01	4.55E+03	1.44E-04

pCi/L = picocuries per liter

PGDP NFA = Paducah Gaseous Diffusion Plant No Further Action Level

HQ = hazard quotient = (maximum pCi/l) / PGDP NFA

for 2-methylphenol was used as an alternative for 3-methylphenol and 4-methylphenol. The dietary NOAEL for 2,4,5-trichlorophenol was used as an alternative for 2,4,6-trichlorophenol. The dietary NOAEL for total xylenes was used as an alternative for m-xylene, o-xylene, and p-xylene. The HQs based on dietary NOAELs did not exceed 1 for any VOC. Thus, based on the HQs, none of the VOCs should pose adverse impacts to mammals exposed to undiluted groundwater from the C-746-U Landfill discharged at a spring at the Ohio River, even if the spring was the mammal's sole source of drinking water.

Eight of the 11 SVOCs modeled at the seep had dietary NOAELs (Table 5.10). Alternative NOAELs were not available for acrylonitrile or dioxins/furans. The dietary NOAEL for benzo(a)pyrene was used as an alternative for total PAHs. None of the HQs based on dietary NOAELs or alternatives exceeded 1 for the SVOCs. Thus, based on the HQs, the SVOCs pose no adverse impacts to mammals exposed to undiluted groundwater from the C-746-U Landfill discharged to a spring at the Ohio River, even if the spring is the mammal's sole source of drinking water.

Dietary NOAELs were available for all six pesticides in the groundwater (Table 5.10). A dietary NOAEL was not available for total PCBs for shrews. Predicted concentrations of total PCBs and all pesticides except pentachlorophenol were 0 µg/L. Therefore the HQs for all compounds, except pentachlorophenol, were also 0. The HQ for pentachlorophenol was far less than 1 (Table 5.10). Thus, the total PCBs and six pesticides are not expected to cause adverse impacts to mammals using groundwater in springs at the Ohio River as their sole source of drinking water.

In summary, none of the HQs for the COPCs exceeded 1. Therefore, mammals should not face unacceptable levels of risk from ingestion of groundwater in springs at the Ohio River.

5.2.1.4 Radionuclides in groundwater in springs used as drinking water by mammals

Eleven radionuclides were modeled (Table 5.11). The maximum concentrations ranged from 117 pCi/L for ⁹⁹Tc to 0.0326 pCi/L for ²³⁰Th. All radionuclides had a benchmark. All of the HQs for radionuclides were much less than 1. Thus, radionuclides in groundwater are not expected to cause adverse impacts to mammals if they ingest the water at the spring as drinking water even if they obtain 100% of their drinking water from the spring. Reductions in the preliminary CERCLA-derived waste disposal criteria for radionuclides are not required to protect mammals.

Table 5.10. Ecological risk screening of for mammals exposed to predicted maximum concentrations for selected chemicals in groundwater discharging from the C-746-U Landfill to springs at the Ohio River

Analytes	Maximum (mg/L)	ADD _w (mg/KgBW/d) Maximum *IR _w	Dietary NOAELs values (mg/kg/d)	HQ based on NOAELs	Alternative dietary NOAEL (mg/kg body wt/d)	Alternative NOAEL source	HQ based on alternative NOAELs
<i>Inorganic chemicals</i>							
Antimony	3.03E-03	6.67E-04	1.25E-01	5.33E-03	—	—	—
Arsenic	0.00E+00	0.00E+00	1.26E-01	0.00E+00	—	—	—
Barium	5.60E-01	1.23E-01	5.06E+00	2.43E-02	—	—	—
Beryllium	3.02E-03	6.64E-04	6.60E-01	1.01E-03	—	—	—
Cadmium	7.56E-04	1.66E-04	1.00E+00	1.66E-04	—	—	—
Chromium (III)	1.46E+01	3.21E+00	2.74E+03	1.17E-03	—	—	—
Chromium (VI)	1.46E+01	3.21E+00	2.74E+03	1.17E-03	—	—	—
Copper	3.00E-01	6.60E-02	1.17E+01	5.64E-03	—	—	—
Iron	0.00E+00	0.00E+00	None	No NOAEL	None	None	No alternative NOAEL
Lead	2.86E-02	6.29E-03	8.00E+00	7.87E-04	—	—	—
Manganese	1.88E-01	4.14E-02	8.80E+01	4.70E-04	—	—	—
Mercury	1.21E-04	2.66E-05	1.01E+00	2.64E-05	—	—	—
Molybdenum	6.25E-02	1.38E-02	2.58E-01	5.33E-02	—	—	—
Nickel	0.00E+00	0.00E+00	4.00E+01	0.00E+00	—	—	—
Selenium	6.27E-02	1.38E-02	2.00E-01	6.90E-02	—	—	—
Silver	8.58E-03	1.89E-03	1.01E+02	1.87E-05	—	—	—
Thallium	1.37E-04	3.01E-05	7.40E-03	4.07E-03	—	—	—
Uranium	1.82E-03	4.00E-04	3.07E+00	1.30E-04	—	—	—
Vanadium	1.50E-02	3.30E-03	2.10E-01	1.57E-02	—	—	—
Zinc	2.42E+00	5.32E-01	1.60E+02	3.33E-03	—	—	—
<i>Volatile organic compounds</i>							
Benzene	5.81E-11	1.28E-11	2.64E+01	4.84E-13	—	—	—
2-Butanone	3.04E-07	6.69E-08	1.77E+03	3.78E-11	—	—	—
Carbon tetrachloride	7.77E-08	1.71E-08	1.60E+01	1.07E-09	—	—	—
Chlorobenzene	3.17E-14	6.97E-15	5.00E+01	1.39E-16	—	—	—
Chloroform	3.15E-05	6.93E-06	1.50E+01	4.62E-07	—	—	—
1,4-Dichlorobenzene	3.29E-15	7.24E-16	No NOAEL	No NOAEL	None	None	No alternative NOAEL
1,2-Dichloroethane	4.58E-05	1.01E-05	5.00E+01	2.02E-07	—	—	—
1,1-Dichloroethylene	7.65E-06	1.68E-06	3.00E+01	5.61E-08	—	—	—
1,2-Dichloroethylene	2.35E-06	5.17E-07	4.52E+01	1.14E-08	—	—	—
1,2-Dichloroethylene-cis	1.96E-05	4.31E-06	None	No NOAEL	4.52E+01	a	9.54E-08

Table 5.10. Ecological risk screening of for mammals exposed to predicted maximum concentrations for selected chemicals in groundwater discharging from the C-746-U Landfill to springs at the Ohio River (continued)

Analytes	Maximum (mg/L)	ADD _w (mg/KgBW/d) Maximum *IR _w	Dietary NOAELs values (mg/kg/d)	HQ based on NOAELs	Alternative dietary		HQ based on alternative NOAELs
					NOAEL (mg/kg body wt/d)	Alternative NOAEL source	
1,2-Dichloroethylene-trans	3.33E-05	7.33E-06	None	No NOAEL	4.52E+01	a	1.62E-07
2,4-Dinitrotoluene	1.41E-11	3.10E-12	1.35E+01	2.30E-13	—	—	—
Ethylbenzene	2.48E-12	5.46E-13	9.71E+00	5.62E-14	—	—	—
Hexachlorobenzene	1.97E-16	4.33E-17	8.00E-02	5.42E-16	—	—	—
Hexachlorobutadiene	3.52E-13	7.74E-14	None	No NOAEL	None	None	No alternative NOAEL
Hexachloroethane	6.18E-12	1.36E-12	1.00E+00	1.36E-12	—	—	—
2-Methylphenol	3.90E-09	8.58E-10	5.00E+01	1.72E-11	—	—	—
3-Methylphenol	1.56E-09	3.43E-10	5.00E+01	6.86E-12	—	—	—
4-Methylphenol	2.52E-09	5.54E-10	None	No NOAEL	5.00E+01	b	1.11E-11
Nitrobenzene	9.36E-11	2.06E-11	None	No NOAEL	None	None	No alternative NOAEL
Pyridine	8.43E-07	1.85E-08	1.00E+00	1.85E-08	—	—	—
Tetrachloroethylene	1.43E-08	3.15E-09	1.40E+00	2.25E-09	—	—	—
Trichloroethene	1.48E-07	3.26E-08	7.00E-01	4.65E-08	—	—	—
2,4,5-Trichlorophenol	1.86E-11	4.09E-12	1.00E+02	4.09E-14	—	—	—
2,4,6-Trichlorophenol	1.25E-11	2.75E-12	None	No NOAEL	1.00E+02	c	2.75E-14
Vinyl chloride	2.80E-05	6.16E-06	1.70E-01	3.62E-05	—	—	—
Xylene, total	2.53E-12	5.57E-13	2.06E+00	2.70E-13	—	—	—
Xylene, m-	2.41E-12	5.30E-13	None	No NOAEL	2.06E+00	d	2.57E-13
Xylene, o-	2.35E-12	5.17E-13	None	No NOAEL	2.06E+00	d	2.51E-13
Xylene, p-	2.20E-12	4.84E-13	None	No NOAEL	2.06E+00	d	2.35E-13
<i>Semivolatile organic compounds</i>							
Acenaphthene	4.83E-13	1.06E-13	1.75E+02	6.07E-16	—	—	—
Acenaphthylene	1.80E-12	3.96E-13	1.00E+01	3.96E-14	—	—	—
Acrylonitrile	1.19E-06	2.62E-07	None	No NOAEL	None	None	No alternative NOAEL
Anthracene	4.76E-15	1.05E-15	1.00E+02	1.05E-17	—	—	—
Dioxins/furans total	0.00E+00	0.00E+00	None	No NOAEL	None	None	No alternative NOAEL
Fluoranthene	2.24E-14	4.93E-15	5.00E+01	9.86E-17	—	—	—
Fluorene	2.22E-13	4.88E-14	1.25E+00	3.91E-14	—	—	—
Naphthalene	4.07E-12	8.95E-13	5.00E+00	1.79E-13	—	—	—
Phenanthrene	1.32E-13	2.90E-14	1.00E+00	2.90E-14	--	--	--
Polyaromatic hydrocarbons	0.00E+00	0.00E+00	None	No NOAEL	1.00E+00	e	0.00E+00
Pyrene	1.47E-14	3.23E-15	1.00E+00	3.23E-15	—	—	—

Table 5.10. Ecological risk screening of for mammals exposed to predicted maximum concentrations for selected chemicals in groundwater discharging from the C-746-U Landfill to springs at the Ohio River (continued)

			<i>Pesticides/PCBs</i>		6.80E-02	f	0.00E+00
	0.00E+00	0.00E+00	None	no NOAEL			
Polychlorinated biphenyls	0.00E+00	0.00E+00	None	no NOAEL	6.80E-02	f	0.00E+00
alpha-Chlordane	0.00E+00	0.00E+00	4.58E+00	0.00E+00	—	—	—
gamma-Chlordane	0.00E+00	0.00E+00	4.58E+00	0.00E+00	—	—	—
Heptachlor epoxide	0.00E+00	0.00E+00	1.00E-01	0.00E+00	—	—	—
Methoxychlor	0.00E+00	0.00E+00	4.00E+00	0.00E+00	—	—	—
Pentachlorophenol	3.01E-10	6.62E-11	2.40E-01	2.76E-10	—	—	—
Toxaphene	0.00E+00	0.00E+00	8.00E+00	0.00E+00	—	—	—

ADD_w = Average daily dose of chemical from ingestion of drinking water

IR_w = ingestion rate of water for shrews (0.22 L/kg body weight/day)

NOAEL = no observed adverse effect level

HQ = hazard quotient = ADD_w / dietary NOAEL or alternative NOAEL

— = alternative NOAEL not necessary because a NOAEL was available

a = alternative NOAEL based on dietary NOAEL for 1,2-dichloroethylene [Palmer et al. (1979) in Sample et al. (1996)]

b = alternative NOAEL based on dietary NOAEL for 2-methylphenol

c = alternative NOAEL based on dietary NOAEL for 2,4,5-trichlorophenol

d = alternative NOAEL based on dietary NOAEL for total xylene [Marks et al. (1982) in Sample et al. (1996)]

e = alternative NOAEL based on dietary NOAEL for benzo(a)pyrene [Mackenzie and Angevine (1981) in Sample et al. (1996)]

f = alternative NOAEL based on dietary NOAEL for aroclor 1254 for oldfield mouse [McCoy et al. (1995) in Sample et al. (1996)]

Table 5.11. Ecological risk screening for mammals exposed to predicted maximum concentrations for selected radionuclides in groundwater discharging from the C-746-U Landfill to springs at the Ohio River

Radionuclide	Maximum (pCi/L)	Benchmark (pCi/L)	HQ
Neptunium-237	4.71E+00	1.10E+10	4.28E-10
Plutonium-238	4.36E-01	1.05E+12	4.15E-13
Plutonium-239	4.22E-01	1.12E+12	3.77E-13
Plutonium-240	4.22E-01	1.12E+12	3.77E-13
Radium-226	3.44E-02	2.41E+09	1.43E-11
Technicium-99	1.17E+02	7.05E+07	1.65E-06
Thorium-230	3.26E-02	1.03E+11	3.17E-13
Thorium-232	3.96E-02	1.20E+11	3.30E-13
Uranium-234	8.07E-01	3.02E+09	2.67E-10
Uranium-235	7.95E-01	3.27E+09	2.43E-10
Uranium-238	6.54E-01	3.43E+09	1.91E-10

HQ = hazard quotient = predicted maximum concentration in leachate / benchmark
 Drinking water benchmarks for mammals are derived in Appendix Table C.2.4

5.2.1.5 Chemicals in groundwater in springs used as drinking water by birds

Predicted concentrations in groundwater at springs located at the Ohio River were derived for each analyte. This water was assumed to act as a drinking water source for marsh wrens as a conservative representative of all birds potentially exposed (Table 5.12). Two inorganics, including iron and thallium did not have a dietary NOAEL so an HQ could not be calculated for these chemicals. Chromium (III and VI) was the only inorganic chemical with an HQ exceeding 1 for wrens. Thus, based on the HQs, only one of the 20 inorganic chemicals potentially could pose adverse impacts to birds exposed to undiluted groundwater as their sole source of drinking water. The maximum percentage of drinking water that a bird could obtain from the spring without exceeding the dietary NOAEL for chromium III or VI is 25.4%. Thus, reductions in the preliminary CERCLA-derived waste disposal criterion for chromium is suggested in Sect. 5.2.2 to address unacceptable levels of risk to birds ingesting groundwater at springs as drinking water.

Only one of the 30 VOCs modeled, 1,2-dichloroethane, had a dietary NOAEL for wrens (Table 5.12). In addition, surrogate NOAELs were not available for any of the 30 VOCs. The sole HQ for VOCs was much less than 1.0. Thus, based on the HQs, this VOC in undiluted groundwater is not expected to cause adverse impacts to birds if they utilize the spring as their sole source of drinking water. However, HQs could not be calculated for the other 29 VOCs so those VOCs in the spring pose an uncertain risk to birds that ingest it as their sole source of drinking water.

Eight of the 11 SVOCs modeled had dietary NOAELs for wrens (Table 5.12). Alternative NOAELs were not available for the three other SVOCs (i.e., acrylonitrile, dioxins/furans, and PAHs), so HQs could not be calculated for those chemicals. None of the SVOCs had HQs that exceeded 1 for wrens. Based on the HQs, the SVOCs do not pose adverse impacts to birds ingesting groundwater at springs as a sole drinking water source. Thus, reductions in the preliminary CERCLA-derived waste disposal criterion for the SVOCs are not needed to protect birds ingesting groundwater at springs as drinking water.

Dietary NOAELs were available for birds for three of the six pesticides, including alpha-chlordane, gamma-chlordane, and methoxychlor (Table 5.12). No surrogate dietary NOAELs were available for heptachlor epoxide, pentachlorophenol, or toxaphene, so HQs could not be calculated for those three pesticides. Predicted concentrations of total PCBs and all pesticides, except pentachlorophenol, were 0 µg/L. Therefore, the HQs for all SVOCs are also 0. Predicted concentrations of total PCBs and all pesticides,

Table 5.12. Ecological risk screening for birds exposed to predicted maximum concentrations for selected chemicals in groundwater discharging from the C-746-U Landfill to springs at the Ohio River

Analytes	Maximum (mg/L)	ADD _w (mg/KgBW/d) Maximum *IR _w	Dietary NOAELs values (mg/kg/d)	HQ based on NOAELs	Alternative dietary NOAEL (mg/kg/d)	Alternative NOAEL source	HQ based on alternative NOAELs
<i>Inorganic chemicals</i>							
Antimony	3.03E-03	8.18E-04	3.57E-01	2.29E-03	—	—	—
Arsenic	0.00E+00	0.00E+00	5.14E+00	0.00E+00	—	—	—
Barium	5.60E-01	1.51E-01	2.08E+01	7.26E-03	—	—	—
Beryllium	3.02E-03	8.15E-04	1.67E+00	4.88E-04	—	—	—
Cadmium	7.56E-04	2.04E-04	1.45E+00	1.41E-04	—	—	—
Chromium (III)	1.46E+01	3.94E+00	1.00E+00	3.94E+00	—	—	—
Chromium (VI)	1.46E+01	3.94E+00	1.00E+00	3.94E+00	—	—	—
Copper	3.00E-01	8.10E-02	4.70E+01	1.72E-03	—	—	—
Iron	0.00E+00	0.00E+00	None	No NOAEL	None	None	No alternative NOAEL
Lead	2.86E-02	7.72E-03	1.13E+00	6.83E-03	—	—	—
Manganese	1.88E-01	5.08E-02	9.77E+02	5.20E-05	—	—	—
Mercury	1.21E-04	3.27E-05	4.50E-01	7.26E-05	—	—	—
Molybdenum	6.25E-02	1.69E-02	3.53E+00	4.78E-03	—	—	—
Nickel	0.00E+00	0.00E+00	7.74E+01	0.00E+00	—	—	—
Selenium	6.27E-02	1.69E-02	5.00E-01	3.39E-02	—	—	—
Silver	8.58E-03	2.32E-03	5.79E+01	4.00E-05	—	—	—
Thallium	1.37E-04	3.70E-05	None	No NOAEL	None	None	No alternative NOAEL
Uranium	1.82E-03	4.91E-04	1.60E+01	3.07E-05	—	—	—
Vanadium	1.50E-02	4.05E-03	1.14E+01	3.55E-04	—	—	—
Zinc	2.42E+00	6.53E-01	1.45E+01	4.51E-02	—	—	—
<i>Volatile organic compounds</i>							
Benzene	5.81E-11	1.57E-11	None	No NOAEL	None	None	No alternative NOAEL
2-Butanone	3.04E-07	8.21E-08	None	No NOAEL	None	None	No alternative NOAEL
Carbon tetrachloride	7.77E-08	2.10E-08	None	No NOAEL	None	None	No alternative NOAEL
Chlorobenzene	3.17E-14	8.56E-15	None	No NOAEL	None	None	No alternative NOAEL
Chloroform	3.15E-05	8.51E-06	None	No NOAEL	None	None	No alternative NOAEL
1,4-Dichlorobenzene	3.29E-15	8.88E-16	None	No NOAEL	None	None	No alternative NOAEL
1,2-Dichloroethane	4.58E-05	1.24E-05	1.72E+01	7.19E-07	—	—	—
1,1-Dichloroethylene	7.65E-06	2.07E-06	None	No NOAEL	None	None	No alternative NOAEL
1,2-Dichloroethylene	2.35E-06	6.35E-07	None	No NOAEL	None	None	No alternative NOAEL
1,2-Dichloroethylene-cis	1.96E-05	5.29E-06	None	No NOAEL	None	None	No alternative NOAEL
1,2-Dichloroethylene-trans	3.33E-05	8.99E-06	None	No NOAEL	None	None	No alternative NOAEL

Table 5.12. Ecological risk screening for birds exposed to predicted maximum concentrations for selected chemicals in groundwater discharging from the C-746-U Landfill to springs at the Ohio River (continued)

Analytes	Maximum (mg/L)	ADD _w (mg/KgBW/d) Maximum *IR _w	Dietary NOAELs values (mg/kg/d)	HQ based on NOAELs	Alternative dietary NOAEL (mg/kg/d)	Alternative NOAEL source	HQ based on alternative NOAELs
2,4-Dinitrotoluene	1.41E-11	3.81E-12	None	No NOAEL	None	None	No alternative NOAEL
Ethylbenzene	2.48E-12	6.70E-13	None	No NOAEL	None	None	No alternative NOAEL
Hexachlorobenzene	1.97E-16	5.32E-17	None	No NOAEL	None	None	No alternative NOAEL
Hexachlorobutadiene	3.52E-13	9.50E-14	None	No NOAEL	None	None	No alternative NOAEL
Hexachloroethane	6.18E-12	1.67E-12	None	No NOAEL	None	None	No alternative NOAEL
2-Methylphenol	3.90E-09	1.05E-09	None	No NOAEL	None	None	No alternative NOAEL
3-Methylphenol	1.56E-09	4.21E-10	None	No NOAEL	None	None	No alternative NOAEL
4-Methylphenol	2.52E-09	6.80E-10	None	No NOAEL	None	None	No alternative NOAEL
Nitrobenzene	9.36E-11	2.53E-11	None	No NOAEL	None	None	No alternative NOAEL
Pyridine	8.43E-07	2.28E-07	None	No NOAEL	None	None	No alternative NOAEL
Tetrachloroethylene	1.43E-08	3.86E-09	None	No NOAEL	None	None	No alternative NOAEL
Trichloroethene	1.48E-07	4.00E-08	None	No NOAEL	None	None	No alternative NOAEL
2,4,5-Trichlorophenol	1.86E-11	5.02E-12	None	No NOAEL	None	None	No alternative NOAEL
2,4,6-Trichlorophenol	1.25E-11	3.38E-12	None	No NOAEL	None	None	No alternative NOAEL
Vinyl chloride	2.80E-05	7.56E-06	None	No NOAEL	None	None	No alternative NOAEL
Xylene, total	2.53E-12	6.83E-13	None	No NOAEL	None	None	No alternative NOAEL
Xylene, m-	2.41E-12	6.51E-13	None	No NOAEL	None	None	No alternative NOAEL
Xylene, o-	2.35E-12	6.35E-13	None	No NOAEL	None	None	No alternative NOAEL
Xylene, p-	2.20E-12	5.94E-13	None	No NOAEL	None	None	No alternative NOAEL
<i>Semivolatile organic compounds</i>							
Acenaphthene	4.83E-13	1.30E-13	8.78E+01	1.49E-15	—	—	—
Acenaphthylene	1.80E-12	4.86E-13	9.97E+00	4.87E-14	—	—	—
Acrylonitrile	1.19E-06	3.21E-07	None	No NOAEL	None	None	No alternative NOAEL
Anthracene	4.76E-15	1.29E-15	3.30E+02	3.89E-18	—	—	—
Dioxins/furans total	0.00E+00	0.00E+00	None	No NOAEL	None	None	No alternative NOAEL
Fluoranthene	2.24E-14	6.05E-15	1.95E+02	3.10E-17	—	—	—
Fluorene	2.22E-13	5.99E-14	6.80E+01	8.81E-16	—	—	—
Naphthalene	4.07E-12	1.10E-12	3.39E+01	3.24E-14	—	—	—
Phenanthrene	1.32E-13	3.56E-14	9.97E+00	3.57E-15	—	—	—
Polyaromatic hydrocarbons	0.00E+00	0.00E+00	None	No NOAEL	None	None	No alternative NOAEL
Pyrene	1.47E-14	3.97E-15	9.97E+00	3.98E-16	—	—	—

Table 5.12. Ecological risk screening for birds exposed to predicted maximum concentrations for selected chemicals in groundwater discharging from the C-746-U Landfill to springs at the Ohio River (continued)

Analytes	Maximum (mg/L)	ADD _w (mg/KgBW/d) Maximum *IR _w	Dietary NOAELs values (mg/kg/d)	HQ based on NOAELs	Alternative dietary NOAEL (mg/kg/d)	Alternative NOAEL source	HQ based on alternative NOAELs
<i>Pesticides/PCBs</i>							
Polychlorinated biphenyls	0.00E+00	0.00E+00	None	No NOAEL	1.80E-01	a	0.00E+00
alpha-Chlordane	0.00E+00	0.00E+00	2.14E+00	0.00E+00	—	—	—
gamma-Chlordane	0.00E+00	0.00E+00	2.14E+00	0.00E+00	—	—	—
Heptachlor epoxide	0.00E+00	0.00E+00	None	No NOAEL	None	None	No alternative NOAEL
Methoxychlor	0.00E+00	0.00E+00	8.42E+00	0.00E+00	—	—	—
Pentachlorophenol	3.01E-10	8.13E-11	None	No NOAEL	None	None	No alternative NOAEL
Toxaphene	0.00E+00	0.00E+00	None	No NOAEL	None	None	No alternative NOAEL

ADD_w = Average daily dose of chemical from ingestion of drinking water

IR_w = ingestion rate of water for marsh wrens (0.27 L/kg body weight/day)

NOAEL = no observed adverse effect level

HQ = hazard quotient = ADD_w / dietary NOAEL

— = surrogate not necessary because a NOAEL was available

HQs in dark border exceed 1.0

a = surrogate benchmark based on aroclor-1254 NOAEL for birds [Dahlgren et al. (1972) in Sample et al. (1996)]

except pentachlorophenol, were 0 µg/L. Therefore, the HQs for alpha- and gamma-chlordane and methoxychlor were 0 because of their 0 concentration and the HQs for other pesticides and PCBs could not be calculated. Thus, the total PCBs and pesticides in the undiluted groundwater from the C-746-U Landfill discharged at springs are not expected to cause adverse impacts to birds even if the spring is the bird's sole source of drinking water.

In summary, only chromium (III and VI) poses risk to birds from ingestion of the undiluted groundwater in a spring at the Ohio River. The HQ is conservative because it assumes that birds obtain 100% of their drinking water from the spring. However, the HQ indicates that the birds could only obtain about 25.4% of their drinking water from the seep to avoid incurring unacceptable risk. Thus, reduction in the preliminary CERCLA-derived waste disposal criteria for chromium is required to reduce the risk to birds from ingestion of the groundwater as drinking water to acceptable levels and are discussed in Sect. 5.2.2.

5.2.1.6 Radionuclides in groundwater in springs used as drinking water by birds

Eleven radionuclides were modeled (Table 5.13). The maximum concentrations ranged from 117 pCi/L for ⁹⁹Tc to 0.0326 pCi/L for ²³⁰Th. All 11 of the radionuclides had a benchmark. All HQs for radionuclides were much less than 1. Thus, radionuclides in groundwater in springs at the Ohio River are not expected to cause adverse impacts to birds even if the birds obtain 100% of their drinking water from the springs.

Table 5.13. Ecological risk screening for birds exposed to predicted maximum concentrations for selected radionuclides in groundwater discharging from C-746-U Landfill to springs at the Ohio River

Radionuclide	Maximum (pCi/L)	Benchmark (pCi/L)	HQ
Neptunium-237	4.71E+00	3.09E+09	1.52E-09
Plutonium-238	4.36E-01	2.95E+11	1.48E-12
Plutonium-239	4.22E-01	3.14E+11	1.35E-12
Plutonium-240	4.22E-01	3.14E+11	1.35E-12
Radium-226	3.44E-02	6.77E+08	5.08E-11
Technicium-99	1.17E+02	1.98E+07	5.89E-06
Thorium-230	3.26E-02	2.89E+10	1.13E-12
Thorium-232	3.96E-02	3.37E+10	1.17E-12
Uranium-234	8.07E-01	8.49E+08	9.50E-10
Uranium-235	7.95E-01	9.19E+08	8.65E-10
Uranium-238	6.54E-01	9.65E+08	6.78E-10

HQ = hazard quotient = predicted maximum concentration in leachate/benchmark
 Drinking water benchmarks for birds are derived in Appendix Table C.2.5

5.2.1.7 Ohio River Sediment – chemical analytes

As noted earlier, contaminant concentrations in sediment at the Ohio River (Sect. 5.2.1) for the 20 inorganic chemicals, 30 VOCs, 11 SVOCs, one PCB (total PCBs), and six pesticides screened were estimated from the modeled groundwater concentrations. Because the magnitude of dilution of groundwater in the hyporheic zone of the Ohio River cannot be estimated, it is assumed for purposes of the screening-level risk calculations that dilution is zero. These estimated concentrations and their comparisons against benchmarks are presented in Table 5.14. Fifteen of the 20 inorganic chemicals had PGDP NFA concentrations. Neither PGDP NFAs nor alternative NFAs were available for the other five inorganic chemicals: barium, beryllium, molybdenum, thallium, and uranium.

Five analytes had HQs exceeding 1 after initial screening [chromium (III and VI) (11.7 and 7.44, respectively), selenium (6.27), silver (2,030), vanadium (75.0), and zinc (31.9)]. The groundwater concentrations of these five analytes were subsequently screened a second time using alternative NFAs to address the uncertainty in the initial screening due to the conservatism in the PGDP NFA values. The alternative NFAs used in the second screening were also conservative, published toxicity values that are deemed protective of sediment-dwelling organisms. The alternative NFAs for chromium, silver, and zinc are National Oceanic and Atmospheric Administration ER-Ls. These ER-Ls are concentrations with incidence of biological effect percentages of 2.9% (chromium), 2.6% (silver), and 6.1% (zinc). After the second screening, chromium (III and VI), selenium, and vanadium had HQs greater than 1. The largest was for vanadium (6.91) followed by those for chromium (III and VI) (5.03 and 3.94, respectively), and selenium (1.2). These chemicals and their HQs are reported in Sect. 5.2.2 (see Table 5.16) where modified preliminary CERCLA-derived waste disposal criteria are derived. However, the preliminary CERCLA-derived waste disposal criteria are not modified based on these results because subsequent consideration of dilution effects likely in the hyporheic zone in sediments in the Ohio River indicated that even these chemicals would be unlikely to be present at concentrations that would adversely impact sediment-dwelling organisms in the Ohio River. That is, even though HQs greater than 1 were identified for these four chemicals, it was deemed unlikely that the contribution of these chemicals to groundwater by the C-746-U Landfill would adversely impact sediment-dwelling organisms in the Ohio River. The uncertainty in these results is discussed in Chap. 6.

Ten of the 30 VOCs modeled in the Ohio River sediment had NFA levels: benzene, carbon tetrachloride, chloroform, 1,2-dichlorobenzene, 1,2-dichloroethane, 1,1-dichloroethylene, ethylbenzene, tetrachlorethylene, trichloroethene, and total xylenes (Table 5.14). Alternative NFAs were available for nine of the remaining VOCs. Alternative NFAs based on equilibrium partitioning-derived sediment quality benchmark for nonionic organic chemicals corresponding to conventional aqueous benchmarks (as described in Jones et al. 1997) were available for 2-butanone, chlorobenzene, 1,2-dichloroethylene, hexachloroethane, and 2-methylphenol. The PGDP NFA for total xylenes was used as an alternative NFA for m-xylene, o-xylene, and p-xylene. Eleven VOCs did not have any toxicity benchmarks so HQs could not be calculated for them. All of the HQs for VOCs in sediment were less than 1. Thus, none of the VOCs predicted to occur in the Ohio River sediments and that have toxicity benchmarks are expected to cause adverse impacts to sediment-dwelling biota.

Eight of the 11 SVOCs modeled in the Ohio River sediment had PGDP NFA concentrations (Table 5.14). No alternative NFAs were available for the three remaining SVOCs, so HQs could not be calculated for those three chemicals. All of the HQs for SVOCs in sediment were much less than 1. Thus, none of the SVOCs predicted to occur in the Ohio River sediments and that have toxicity benchmarks are expected to cause adverse impacts to sediment-dwelling biota.

The concentrations of the one PCB (total PCBs) and five of the six pesticides modeled are predicted to be 0 $\mu\text{g/L}$ (Table 5.14). Thus, the total PCBs and 5 pesticides in the Ohio River sediment are also considered to be 0 mg/kg, which results in the HQs being 0. The sole pesticide pentachlorophenol had an HQ less than 1, based on an alternative NFA from the Washington state sediment quality standards for ionizable organic chemicals. Therefore, the total PCBs and six pesticides discharged into the Ohio River would result in sediment PCB concentrations that are not expected to cause adverse impacts to sediment-dwelling biota.

In summary, discharge of groundwater from the C-746-U Landfill into the Ohio River may result in sediment concentrations of five inorganic chemicals [chromium (III and VI), silver, selenium, vanadium, and zinc], but no organic compounds, that may adversely impact to sediment-dwelling organisms. However, uncertainty in the screening results (i.e., conservative NFA values and dilution effects in the hyporheic zone along the Ohio River) suggests that the actual impacts from the five inorganic chemicals would be negligible. Therefore, no modifications to preliminary CERCLA-derived waste disposal criteria are not needed to protect sediment-dwelling organisms from potential releases to groundwater from the C-746-U Landfill.

Table 5.14. Ecological risk screening of predicted maximum concentrations for selected chemicals in sediment at the Ohio River resulting from discharge of groundwater from the C-746-U Landfill

Analytes	Maximum GW conc. (mg/L)	K _d s (L/kg)	Predicted maximum sediment conc. (mg/kg)	PGDP NFA values (mg/kg)	HQ based on PGDP NFAs	Alternative NFA values (mg/kg)	Alternative NFA source	HQ based on alternative NFA values
<i>Inorganic chemicals</i>								
Antimony	3.03E-03	4.50E+01	1.36E-01	2.00E+00	6.82E-02	—	—	—
Arsenic	0.00E+00	2.00E+02	0.00E+00	5.90E+00	0.00E+00	—	—	—
Barium	5.60E-01	4.10E+01	2.30E+01	None	No PGDP NFA	None	None	No alternative NFA
Beryllium	3.02E-03	7.90E+02	2.39E+00	None	No PGDP NFA	None	None	No alternative NFA
Cadmium	7.56E-04	7.50E+01	5.67E-02	2.70E-01	2.10E-01	—	—	—
Chromium (III)	1.46E+01	3.00E+01	4.38E+02	3.73E+01	1.17E+01	8.70E+01	a	5.03E+00
Chromium (VI)	1.46E+01	1.90E+01	2.77E+02	3.73E+01	7.44E+00	8.70E+01	a	3.19E+00
Copper	3.00E-01	3.50E+01	1.05E+01	3.00E+01	3.50E-01	—	—	—
Iron	0.00E+00	2.20E+02	0.00E+00	2.00E+03	0.00E+00	—	—	—
Lead	2.86E-02	2.70E+02	7.72E+00	1.20E+01	6.44E-01	—	—	—
Manganese	1.88E-01	5.00E+01	9.40E+00	6.14E+02	1.53E-02	—	—	—
Mercury	1.21E-04	5.20E+01	6.29E-03	1.60E-01	3.93E-02	—	—	—
Molybdenum	6.25E-02	1.00E+01	6.25E-01	None	No PGDP NFA	None	None	No alternative NFA
Nickel	0.00E+00	4.00E+02	0.00E+00	1.60E+01	0.00E+00	—	—	—
Selenium	6.27E-02	5.00E+00	3.14E-01	5.00E-02	6.27E+00	2.60E-01	b	1.21E+00
Silver	8.58E-03	9.00E+01	7.72E-01	3.80E-04	2.03E+03	1.00E+00	a	7.72E-01
Thallium	1.37E-04	7.10E+01	9.73E-03	None	No PGDP NFA	None	None	No alternative NFA
Uranium	1.82E-03	6.68E+01	1.21E-01	None	No PGDP NFA	None	None	No alternative NFA
Vanadium	1.50E-02	1.00E+03	1.50E+01	2.00E-01	7.50E+01	2.17E+00	c	6.91E+00
Zinc	2.42E+00	6.20E+01	1.50E+02	4.70E+00	3.19E+01	1.50E+02	a	1.00E+00

Table 5.14. Ecological Risk Screening of Predicted Maximum Concentrations for Selected Chemicals in Sediment at Ohio River Resulting from Discharge of Groundwater from C-746-U Landfill (continued)

Analytes	Maximum GW conc. (mg/L)	K _d s (L/kg)	Predicted maximum sediment conc. (mg/kg)	PGDP NFA values (mg/kg)	HQ based on PGDP NFAs	Alternative NFA values (mg/kg)	Alternative NFA source	HQ based on alternative NFA values
<i>Volatile organic compounds</i>								
Benzene	5.81E-11	4.96E-02	2.88E-12	5.70E-02	5.06E-11	—	—	—
2-Butanone	3.04E-07	9.20E-04	2.80E-10	None	No PGDP NFA	2.70E-01	d	1.04E-09
Carbon tetrachloride	7.77E-08	1.22E-01	9.48E-09	2.00E-02	4.74E-07	—	—	—
Chlorobenzene	3.17E-14	1.79E-01	5.67E-15	None	No PGDP NFA	4.10E-01	d	1.38E-14
Chloroform	3.15E-05	4.24E-02	1.34E-06	9.60E-02	1.39E-05	—	—	—
1,4-Dichlorobenzene	3.29E-15	4.93E-01	1.62E-15	3.30E-02	4.92E-14	—	—	—
1,2-Dichloroethane	4.58E-05	3.04E-02	1.39E-06	4.30E-02	3.24E-05	—	—	—
1,1-Dichloroethylene	7.65E-06	6.20E-02	4.74E-07	3.50E-02	1.36E-05	—	—	—
1,2-Dichloroethylene	2.35E-06	3.04E-02	7.14E-08	None	No PGDP NFA	4.00E-01	d	1.79E-07
1,2-Dichloroethylene-cis	1.96E-05	2.84E-02	5.57E-07	None	No PGDP NFA	None	None	No alternative NFA
1,2-Dichloroethylene-trans	3.33E-05	3.04E-02	1.01E-06	None	No PGDP NFA	None	None	No alternative NFA
2,4-Dinitrotoluene	1.41E-11	7.64E-02	1.08E-12	None	No PGDP NFA	None	None	No alternative NFA
Ethylbenzene	2.48E-12	1.63E-01	4.04E-13	5.40E-01	7.49E-13	—	—	—
Hexachlorobenzene	1.97E-16	6.40E+01	1.26E-14	None	No PGDP NFA	None	None	No alternative NFA
Hexachlorobutadiene	3.52E-13	4.30E+01	1.51E-11	None	No PGDP NFA	None	None	No alternative NFA
Hexachloroethane	6.18E-12	1.42E+00	8.78E-12	None	No PGDP NFA	1.00E+00	d	8.78E-12
2-Methylphenol	3.90E-09	1.60E-02	6.24E-11	None	No PGDP NFA	1.20E-02	d	5.20E-09
3-Methylphenol	1.56E-09	4.56E-02	7.11E-11	None	No PGDP NFA	None	None	No alternative NFA
4-Methylphenol	2.52E-09	2.88E-02	7.26E-11	None	No PGDP NFA	6.70E-01	e	1.08E-10
Nitrobenzene	9.36E-11	9.52E-02	8.91E-12	None	No PGDP NFA	None	None	No alternative NFA
Pyridine	8.43E-07	3.49E-03	2.94E-10	None	No PGDP NFA	None	None	No alternative NFA
Tetrachloroethylene	1.43E-08	2.12E-01	3.03E-09	3.20E-01	9.47E-09	—	—	—
Trichloroethene	1.48E-07	7.52E-02	1.11E-08	5.20E-02	2.14E-07	—	—	—
2,4,5-Trichlorophenol	1.86E-11	2.65E+00	4.93E-11	None	No PGDP NFA	None	None	No alternative NFA
2,4,6-Trichlorophenol	1.25E-11	2.47E+00	3.09E-11	None	No PGDP NFA	None	None	No alternative NFA
Vinyl chloride	2.80E-05	1.49E-02	4.17E-07	None	No PGDP NFA	None	None	No alternative NFA
Xylene, total	2.53E-12	2.17E-01	5.49E-13	1.60E-03	3.43E-10	—	—	—
Xylene, m-	2.41E-12	1.57E-01	3.78E-13	None	No PGDP NFA	1.60E-03	f	2.36E-10
Xylene, o-	2.35E-12	1.93E-01	4.54E-13	None	No PGDP NFA	1.60E-03	f	2.83E-10
Xylene, p-	2.20E-12	2.49E-01	5.48E-13	None	No PGDP NFA	1.60E-03	f	3.42E-10

Table 5.14. Ecological Risk Screening of Predicted Maximum Concentrations for Selected Chemicals in Sediment at Ohio River Resulting from Discharge of Groundwater from C-746-U Landfill (continued)

Analytes	Maximum GW conc. (mg/L)	K _d s (L/kg)	Predicted maximum sediment conc. (mg/kg)	PGDP NFA values (mg/kg)	HQ based on PGDP NFAs	Alternative NFA values (mg/kg)	Alternative NFA source	HQ based on alternative NFA values
<i>Semivolatile organic compounds</i>								
Acenaphthene	4.83E-13	3.92E+00	1.89E-12	8.90E-02	2.13E-11	—	—	—
Acenaphthylene	1.80E-12	5.92E+00	1.07E-11	None	No PGDP NFA	None	None	No alternative NFA
Acrylonitrile	1.19E-06	1.79E-04	2.13E-10	None	No PGDP NFA	None	None	No alternative NFA
Anthracene	4.76E-15	1.88E+01	8.95E-14	2.30E-02	3.89E-12	—	—	—
Dioxins/furans total	0.00E+00	2.64E+03	0.00E+00	None	No PGDP NFA	None	None	No alternative NFA
Fluoranthene	2.24E-14	3.93E+01	8.80E-13	5.40E-02	1.63E-11	—	—	—
Fluorene	2.22E-13	6.17E+00	1.37E-12	1.00E-02	1.37E-10	—	—	—
Naphthalene	4.07E-12	9.52E-01	3.87E-12	1.47E-02	2.64E-10	—	—	—
Phenanthrene	1.32E-13	1.12E+01	1.48E-12	4.19E-02	3.53E-11	—	—	—
Polyaromatic hydrocarbons	0.00E+00	7.75E+02	0.00E+00	1.61E+00	0.00E+00	—	—	—
Pyrene	1.47E-14	5.44E+01	8.00E-13	5.30E-02	1.51E-11	—	—	—
<i>Pesticides/PCBs</i>								
Polychlorinated biphenyls	0.00E+00	2.47E+02	0.00E+00	3.20E-02	0.00E+00	—	—	—
alpha-Chlordane	0.00E+00	4.71E+01	0.00E+00	None	No PGDP NFA	2.80E-04	g	0.00E+00
gamma-Chlordane	0.00E+00	4.71E+01	0.00E+00	None	No PGDP NFA	2.80E-04	g	0.00E+00
Heptachlor epoxide	0.00E+00	6.66E+01	0.00E+00	6.00E-04	0.00E+00	—	—	—
Methoxychlor	0.00E+00	6.40E+01	0.00E+00	None	No PGDP NFA	1.90E-02	d	0.00E+00
Pentachlorophenol	3.01E-10	4.74E-01	1.43E-10	None	No PGDP NFA	3.60E-01	e	3.96E-10
Toxaphene	0.00E+00	7.66E+01	0.00E+00	2.20E-03	0.00E+00	—	—	—

GW = groundwater

K_d = partition coefficient (L/kg)

PGDP NFA = Paducah Gaseous Diffusion Plant No Further Action benchmarks

HQ = hazard quotient = predicted maximum sediment concentration / PGDP NFA or alternative NFA

^a alternative NFA based on the National Oceanic and Atmospheric Administration Effects Range-Low

^b alternative NFA based on values in Derveer and Canton (1997)

^c alternative NFA based on values in Mierzykowski et al. (1997)

d = alternative NFA based on equilibrium partitioning-derived sediment quality benchmark for nonionic organic chemicals corresponding to conventional aqueous benchmarks (in Jones et al. 1997)

e = alternative NFA based on Washington state sediment quality standards for ionizable organic compounds (in Jones et al. 1997)

f = alternative NFA based on PGDP NFA for xylenes, total

g = alternative NFA based on PGDP NFA for chlordane

HQs in dark border exceed 1.0

— = alternative NFA not necessary because a PGDP NFA was available

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5.2.1.8 Ohio River Sediment – radionuclides

As noted earlier, contaminant concentrations in sediment at the Ohio River (Sect. 5.2.1) for the 11 radionuclides were estimated from the modeled groundwater concentrations (Table 5.15). The maximum predicted concentrations of radionuclides in the Ohio River sediments ranged from 0.0172 pCi/g for ²²⁶Ra to 0.329 pCi/g for ²³⁷Np. Plutonium-239 and ⁹⁹Tc did not have NFAs. All of the HQs for radionuclides were less than 1. Thus, radionuclides in the groundwater from the C-746-U Landfill that discharges into the Ohio River sediments are not expected to cause adverse impacts to sediment-dwelling biota.

Table 5.15. Ecological risk screening of predicted maximum concentrations for selected radionuclides in sediment at the Ohio River resulting from discharge of groundwater from the C-746-U Landfill

Radionuclide	Maximum GW conc. (pCi/L)	K _d (L/kg)	Predicted sediment maximum (pCi/g)	PGDP NFA (pCi/g)	HQ
Neptunium-237	4.71E+00	7.00E+01	3.29E-01	2.23E+04	1.48E-05
Plutonium-238	4.36E-01	5.50E+02	2.40E-01	9.59E+06	2.50E-08
Plutonium-239	4.22E-01	5.50E+02	2.32E-01	None	no PGDP NFA
Plutonium-240	4.22E-01	5.50E+02	2.32E-01	1.00E+07	2.32E-08
Radium-226	3.44E-02	5.00E+02	1.72E-02	2.82E+03	6.10E-06
Technecium-99	1.17E+02	1.40E+00	1.63E-01	None	no PGDP NFA
Thorium-230	3.26E-02	3.20E+03	1.04E-01	1.12E+07	9.33E-09
Thorium-232	3.96E-02	3.20E+03	1.27E-01	5.47E+03	2.32E-05
Uranium-234	8.07E-01	3.50E+01	2.82E-02	1.00E+07	2.82E-09
Uranium-235	7.95E-01	3.50E+01	2.78E-02	2.96E+04	9.40E-07
Uranium-238	6.54E-01	6.68E+01	4.37E-02	1.75E+05	2.50E-07

GW = groundwater

pCi/L = picocuries per liter

K_d = partition coefficient (L/kg)

PGDP NFA = Paducah Gaseous Diffusion Plant No Further Action Level

HQ = hazard quotient = (maximum pCi/g) / PGDP NFA

Table 5.16. Summary of ecological COPCs and maximum concentrations in groundwater at springs at the Ohio River and at discharge to the Ohio River to meet PGDP NFA or alternative NFA concentrations

Chemical ^a	Exposure Medium	Predicted Concentration (mg/L)	Hazard Quotient	Revised Target Concentration (mg/L)
Chromium III	Groundwater in Ohio River	1.46E+01	5.03	NR
Chromium VI	Groundwater in springs	1.46E+01	3.94	3.71E+00
Selenium	Groundwater in Ohio River	6.27E-02	1.21	NR
Vanadium	Groundwater in Ohio River	1.50E-02	6.91	NR and NA

^a Only chemicals identified as requiring an alternative concentration in the exposure medium are listed.

COPCs = contaminant of potential concern

NFA = No Further Action

NR = Target concentration not derived because dilution in the hyporheic zone along the Ohio River is expected to result in concentrations lower than predicted resulting in a HQ less than 1.

NA = Target concentration not derived because predicted groundwater concentration is less than the PGDP background concentration in groundwater (see Table 5.2).

5.2.2 Preliminary CERCLA-derived Waste Disposal Criteria Protective of Ecological Receptors

This section lists potential changes to the preliminary CERCLA-derived waste disposal criteria, which may be necessary to protect ecological receptors. The analytes with predicted maximum concentrations in groundwater at discharge to the Ohio River or to springs at the Ohio River resulting in exposures exceeding the screening toxicity benchmark exposures, as described above in Sect. 5.2.1, are listed in Table 5.16. Chromium, selenium, and vanadium in groundwater potentially discharging to the Ohio River have predicted maximum concentrations that result in sediment concentrations exceeding benchmarks by factors (HQs) ranging from 1.21 for selenium to 6.91 for vanadium. Chromium in springs at the Ohio River has a predicted maximum concentration that results in drinking water exposures exceeding NOAEL benchmarks for birds by a factor (HQ) of 3.94.

For each analyte, the groundwater discharge or spring concentration expected to occur must be lowered by a factor equal to the HQ. These revised target concentrations are also given in Table 5.16. The preliminary CERCLA-derived waste disposal criteria, in turn, must be lowered sufficiently to achieve the revised target concentrations, if the criteria are to be protective of ecological receptors potentially exposed. The modified preliminary CERCLA-derived waste criteria protective of ecological receptors are presented in Table 5.17. The final CERCLA-derived waste disposal criteria, which consider protection of human health as well, are derived in the following section.

Table 5.17. Modified preliminary CERCLA-derived waste disposal criteria

Chemical^a	Preliminary CERCLA risk-based disposal criteria protective of a groundwater user (mg/kg or pCi/g)	Preliminary CERCLA risk-based disposal criteria protective of a receptor ingesting groundwater at a spring at the Ohio River (mg/kg or pCi/g)	Preliminary CERCLA risk-based disposal criteria protective of sediment dwelling organisms at the Ohio River (mg/kg or pCi/g)
		<i>Inorganic Chemical</i>	
Chromium	1.72E+04	4.37E+03	NA

Notes:

^a Only chemicals identified as requiring an alternative concentration in the exposure medium are listed.

NA = An alternative concentration for the chemical and receptor combination is not needed.

5.3 DERIVATION OF FINAL CERCLA-DERIVED WASTE DISPOSAL CRITERIA AND INVENTORY LIMITS

Acceptable concentrations over all waste streams (i.e., the final CERCLA-derived waste disposal criteria) were derived by comparing the modified preliminary criteria presented in Sects. 5.1.3 and 5.2.2 and considering the uncertainties present in the development of each modified preliminary criteria (discussed in Chap. 6). As noted in Sects. 5.1.3 and 5.2.2, the modified preliminary criteria for the various receptors were calculated using simple ratios comparing the preliminary CERCLA-derived waste disposal criteria deemed protective of a groundwater user and the resulting exposure medium concentration for the alternative receptor against the modified preliminary criteria and a value protective of the alternative receptor (human or ecological) exposed to the exposure medium. The use of this simple ratio was deemed appropriate because the models used to derive COPC concentrations in exposure media at all exposure points are essentially, directly and linearly related to the preliminary CERCLA-derived waste disposal criteria.

These calculations can be represented as follows:

$$\frac{\text{Criteria}_{\text{preliminary}}}{C_{\text{ep}}} = \frac{\text{Criteria}_{\text{modified}}}{C_{\text{protective}}}$$

or

$$\text{Criteria}_{\text{modified}} = \frac{\text{Criteria}_{\text{preliminary}} \times C_{\text{protective}}}{C_{\text{ep}}}$$

where

- $\text{Criteria}_{\text{modified}}$ = the modified preliminary CERCLA-derived waste disposal criteria (mg/kg or pCi/g).
- $\text{Criteria}_{\text{preliminary}}$ = preliminary CERCLA-derived waste disposal criteria derived for the groundwater user from Table 5.4 (mg/kg or pCi/g).
- $C_{\text{protective}}$ = concentration in exposure medium protective of the alternative receptor from tables in Sect. 5.2 (mg/l or pCi/l).
- C_{ep} = concentration in the exposure medium derived from the preliminary CERCLA-derived waste disposal criteria for the groundwater user from Table 5.4 (mg/L or pCi/L).

Table 5.18 presents the various preliminary CERCLA-derived waste disposal criteria from which the final criteria were chosen. As shown in Table 5.18, the final CERCLA-derived waste disposal criteria were derived as follows:

- Chemicals and compounds that are liquid at a temperature less than 37°C – For these chemicals and compounds, the final CERCLA-derived waste disposal criterion is the smaller of the corrected preliminary disposal criterion for the groundwater user and the ecological-based criteria, unless the smallest criterion is greater than 100,000 mg/kg (i.e., 1.00E+05 mg/kg). If the smallest modified preliminary criterion is greater than 100,000 mg/kg, then the final criteria was reduced to 100,000 mg/kg to be consistent with guidance in DOE 2001b, which directs that concentrations back-calculated using risk-based targets that exceed 100,000 mg/kg should be reduced to this value. The corrected preliminary disposal criterion for the groundwater user, which is based on the soil saturation concentration of the chemical, is considered in this case to take into account restrictions on disposal of liquids in the C-746-U Landfill.
- Chemicals and compounds that are not liquid at a temperature less than 37°C – For these inorganic chemicals, the final CERCLA-derived waste disposal criterion is the smaller of the uncorrected preliminary disposal criterion for the groundwater user and the ecological-based criteria, unless the smallest criterion is greater than 100,000 mg/kg (i.e., 1.00E+05 mg/kg). If the smallest modified preliminary criterion is greater than 100,000 mg/kg, then the final criteria was reduced to 100,000 mg/kg to be consistent with guidance in DOE 2001b, as discussed above. The uncorrected preliminary disposal criterion for the groundwater user is considered in this case to eliminate the limits placed on the derivation of the groundwater concentrations at the two points of exposure by the chemical's solubility in water. That is, the solubility of the chemical or compound in water, and not the concentration of the chemical in the source term, becomes the factor regulating the migration of the chemical or compound to the point of exposure.
- For all radionuclides – For all radionuclides, the final CERCLA-derived waste disposal criterion is the smaller of the corrected preliminary disposal criterion for the groundwater user and the ecological-based criteria. The corrected preliminary disposal criterion for the groundwater user is used for radionuclides for convenience. The uncorrected and corrected values are identical because neither solubility nor soil saturation is of concern for the radionuclides modeled.

Table 5.18. Selection of final CERCLA risk-based disposal criteria from preliminary criteria for all receptors

Chemical	Uncorrected Preliminary Disposal Criteria for the Groundwater User ^a	Corrected Preliminary Disposal Criteria for the Groundwater User ^b	Ingestion of Water by Wildlife at Spring ^c	Sediment Dwelling Organism at Ohio River	Liquid at Temperature < 37.7° C? ^d	Background Concentration in Soil ^e	Final Values ^f	Basis ^g
<i>Inorganic Chemicals (mg/kg)</i>								
Antimony	6.79E+01	6.79E+01	Greater	Greater	NA	2.1E-01	6.79E+01	GW User
Arsenic	2.88E+01	2.88E+01	Greater	Greater	NA	1.2E+01	2.88E+01	GW User
Barium	1.14E+04	1.14E+04	Greater	Greater	NA	2.00E+02	1.14E+04	GW User
Beryllium	2.40E+04	2.40E+04	Greater	Greater	NA	6.7E-01	2.40E+04	GW User
Cadmium	5.70E+02	5.70E+02	Greater	Greater	NA	2.1E-01	5.70E+02	GW User
Chromium	1.72E+04	1.72E+04	4.37E+03	Greater	NA	4.3E+01	4.37E+03	Spring
Copper	5.22E+03	5.22E+03	Greater	Greater	NA	2.5E+01	5.22E+03	GW User
Iron	3.91E+07	1.00E+06	Greater	Greater	NA	2.8E+04	1.00E+05	GW User
Lead ^h	7.77E+04	7.77E+04	Greater	Greater	NA	3.6E+01	7.77E+04	GW User
Manganese	4.68E+03	4.68E+03	Greater	Greater	NA	1.5E+03	4.68E+03	GW User
Mercury	6.18E+01	3.13E+00	Greater	Greater	Yes	2.0E-01	3.13E+00	Saturation
Molybdenum	3.87E+01	3.87E+01	Greater	Greater	NA	NV	3.87E+01	GW User
Nickel	3.49E+07	1.00E+06	Greater	Greater	NA	2.2E+01	1.00E+05	Limit
Selenium	7.77E+01	7.77E+01	Greater	Greater	NA	8.0E-01	7.77E+01	GW User
Silver	7.77E+03	7.77E+03	Greater	Greater	NA	2.7E+00	7.77E+03	GW User
Thallium	9.80E+01	9.80E+01	Greater	Greater	NA	3.4E-01	9.80E+01	GW User
Uranium	7.79E+02	7.79E+02	Greater	Greater	NA	4.6E+00	7.79E+02	GW User
Vanadium ^h	1.51E+05	1.51E+05	Greater	Greater	NA	3.8E+01	1.00E+05	GW User
Zinc	7.47E+04	7.47E+04	Greater	Greater	NA	6.5E+01	7.47E+04	GW User
<i>Organic Compounds (mg/kg)</i>								
Acenaphthene	1.24E+09	1.75E+01	Greater	Greater	No	NA	1.00E+05	Limit
Acenaphthylene	1.87E+09	9.85E+01	Greater	Greater	No	NA	1.00E+05	Limit
Acrylonitrile	2.59E+04	1.47E+04	Greater	Greater	Yes	NA	1.47E+04	Saturation
Anthracene	3.35E+10	8.25E-01	Greater	Greater	No	NA	1.00E+05	Limit
Benzene	4.78E+07	4.38E+02	Greater	Greater	Yes	NA	4.38E+02	Saturation
Butanone, 2-	1.28E+09	5.53E+04	Greater	Greater	Yes	NA	5.53E+04	Saturation
Carbon Tetrachloride	2.33E+05	2.57E+02	Greater	Greater	Yes	NA	2.57E+02	Saturation
Chlordane, alpha-	7.13E+22	2.65E+00	Greater	Greater	No	NA	1.00E+05	Limit
Chlordane, gamma-	7.13E+22	2.65E+00	Greater	Greater	No	NA	1.00E+05	Limit
Chlorobenzene	2.97E+09	1.79E+02	Greater	Greater	Yes	NA	1.79E+02	Saturation
Chloroform	3.88E+03	1.92E+03	Greater	Greater	Yes	NA	1.92E+03	Saturation
Dichlorobenzene, 1,4-	1.01E+09	5.11E+01	Greater	Greater	No	NA	1.00E+05	Limit
Dichloroethane, 1,2-	1.43E+04	2.00E+03	Greater	Greater	Yes	NA	2.00E+03	Saturation
Dichloroethene, 1,1-	7.80E+04	5.72E+02	Greater	Greater	Yes	NA	5.72E+02	Saturation
Dichloroethene, 1,2- (mixed isomers)	4.89E+05	2.10E+02	Greater	Greater	Yes	NA	2.10E+02	Saturation
Dichloroethene, cis-1,2-	2.47E+05	8.01E+02	Greater	Greater	Yes	NA	8.01E+02	Saturation
Dichloroethene, trans-1,2-	5.32E+05	1.46E+03	Greater	Greater	Yes	NA	1.46E+03	Saturation

Table 5.18. Selection of final CERCLA risk-based disposal criteria from preliminary criteria for all receptors (continued)

Chemical	Uncorrected Preliminary Disposal Criteria for the Groundwater User ^a	Corrected Preliminary Disposal Criteria for the Groundwater User ^b	Ingestion of Water by Wildlife at Spring ^c	Sediment Dwelling Organism at Ohio River	Liquid at Temperature < 37.7° C? ^d	Background Concentration in Soil ^e	Final Values ^f	Basis ^g
Dinitrotoluene, 2,4-	2.00E+07	7.46E+01	Greater	Greater	No	NA	1.00E+05	Limit
Dioxins/Furan (Total)		2.64E+01	Greater	Greater	No	NA	1.00E+05	Limit
Ethylbenzene	1.91E+09	6.15E+01	Greater	Greater	Yes	NA	6.15E+01	Saturation
Fluoranthene	2.07E+10	8.14E+00	Greater	Greater	No	NA	1.00E+05	Limit
Fluorene	1.39E+09	1.26E+01	Greater	Greater	No	NA	1.00E+05	Limit
Heptachlor Epoxide	4.03E+21	1.34E+01	Greater	Greater	No	NA	1.00E+05	Limit
Hexachlorobenzene	4.37E+09	3.98E+02	Greater	Greater	No	NA	1.00E+05	Limit
Hexachlorobutadine	2.25E+08	1.39E+02	Greater	Greater	Yes	NA	1.39E+02	Saturation
Hexachloroethane	4.47E+07	8.12E+01	Greater	Greater	No	NA	1.00E+05	Limit
Methoxychlor	5.41E+24	2.89E+00	Greater	Greater	No	NA	1.00E+05	Limit
Methylphenol, 2-	3.93E+09	4.32E+03	Greater	Greater	Yes	NA	4.32E+03	Saturation
Methylphenol, 3-	1.12E+10	4.91E+03	Greater	Greater	Yes	NA	4.91E+03	Saturation
Methylphenol, 4-	7.11E+08	5.03E+03	Greater	Greater	Yes	NA	5.03E+03	Saturation
Naphthalene	6.31E+06	3.57E+01	Greater	Greater	No	NA	1.00E+05	Limit
Nitrobenzene	4.95E+07	6.17E+02	Greater	Greater	Yes	NA	6.17E+02	Saturation
Pentachlorophenol	2.29E+06	1.31E+03	Greater	Greater	No	NA	1.00E+05	Limit
Phenanthrene	5.89E+09	1.37E+01	Greater	Greater	No	NA	1.00E+05	Limit
Polychlorinated biphenyls (Total)	2.89E+13	1.73E+02	Greater	Greater	Yes	NA	1.73E+02	Saturation
Polynuclear Aromatic Hydrocarbons (Total)		7.75E+00	Greater	Greater	No	NA	1.00E+05	Limit
Pyrene	2.30E+10	7.37E+00	Greater	Greater	No	NA	1.00E+05	Limit
Pyridine	1.76E+07	2.03E+05	Greater	Greater	Yes	NA	1.00E+05	Saturation
Tetrachloroethene	1.31E+06	8.27E+01	Greater	Greater	Yes	NA	8.27E+01	Saturation
Toxaphene	4.13E+22	5.69E+01	Greater	Greater	No	NA	1.00E+05	Limit
Trichloroethene	1.27E+06	3.04E+02	Greater	Greater	Yes	NA	3.04E+02	Saturation
Trichlorophenol, 2,4,5-	1.16E+12	3.42E+03	Greater	Greater	No	NA	1.00E+05	Limit
Trichlorophenol, 2,4,6-	3.35E+10	2.14E+03	Greater	Greater	No	NA	1.00E+05	Limit
Vinyl Chloride	1.66E+03	6.00E+02	Greater	Greater	Yes	NA	6.00E+02	Saturation
Xylene (mixture)	1.73E+11	8.35E+01	Greater	Greater	Yes	NA	8.35E+01	Saturation
Xylene, m-	3.55E+10	5.76E+01	Greater	Greater	Yes	NA	5.76E+01	Saturation
Xylene, o-	2.12E+11	6.89E+01	Greater	Greater	Yes	NA	6.89E+01	Saturation
Xylene, p-	2.74E+11	8.32E+01	Greater	Greater	Yes	NA	8.32E+01	Saturation
Radionuclides (pCi/g)								
Neptunium-237	2.26E+01	2.26E+01	Greater	Greater	NA	1.00E+00	2.26E+01	GW User
Plutonium-238	5.66E+03	5.66E+03	Greater	Greater	NA	7.3E-02	5.66E+03	GW User
Plutonium-239	5.49E+03	5.49E+03	Greater	Greater	NA	2.5E-02	5.49E+03	GW User
Plutonium-240	5.49E+03	5.49E+03	Greater	Greater	NA	NV	5.49E+03	GW User
Radium-226	4.06E+02	4.06E+02	Greater	Greater	NA	1.5E+00	4.06E+02	GW User
Technetium-99	2.02E+01	2.02E+01	Greater	Greater	NA	2.8E+00	2.02E+01	GW User

Table 5.18. Selection of final CERCLA risk-based disposal criteria from preliminary criteria for all receptors (continued)

Chemical	Uncorrected Preliminary Disposal Criteria for the Groundwater User ^a	Corrected Preliminary Disposal Criteria for the Groundwater User ^b	Ingestion of Water by Wildlife at Spring ^c	Sediment Dwelling Organism at Ohio River	Liquid at Temperature < 37.7° C? ^d	Background Concentration in Soil ^e	Final Values ^f	Basis ^g
Thorium-230	2.47E+03	2.47E+03	Greater	Greater	NA	1.4E+00	2.47E+03	GW User
Thorium-232	2.99E+03	2.99E+03	Greater	Greater	NA	1.5E+00	2.99E+03	GW User
Uranium-234	1.27E+03	1.27E+03	Greater	Greater	NA	2.5E+00	1.27E+03	GW User
Uranium-235	1.25E+03	1.25E+03	Greater	Greater	NA	1.4E-01	1.25E+03	GW User
Uranium-238	1.03E+03	1.03E+03	Greater	Greater	NA	1.2E+00	1.03E+03	GW User

Notes:

^a Values taken from Table 5.3.

^b Values are taken from Table 5.7.

^c Concentrations are shown only for those chemicals with a preliminary criteria less than that for protection of human health.

^d Chemicals liquid at temperatures below 37°C may exist as free liquids in soil; therefore, their disposal criteria can not exceed the soil saturation limit. [Note that the soil saturation limit is the contaminant concentration in soil at which the absorptive limit of the soil particles, the solubility limits of pour water, and saturation of pour air have been reached. Above this concentration, the soil contaminant may be present in free phase (i.e., nonaqueous phase liquids, NAPLs) for contaminants that are liquid at ambient soil temperatures and pure solid phase for compounds that are solid at ambient soil temperatures.]

^e Provided to show the relationship between the various criteria and the background soil concentrations for the PGDP. Values are the larger surface and subsurface soil background values presented in Table A.12 in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky. Volume 1. Human Health* (DOE 2001b).

^f As explained in the text, for all inorganic chemicals and all organic compounds that are a liquid at a temperature less than 37° C, the final criterion is the smallest concentration across the groundwater user, wildlife, and sediment dwelling organism columns, unless the smallest concentration exceeds 100,000 mg/kg. If the smallest concentration exceeds 100,000 mg/kg, then the value was reduced to 100,000 mg/kg. For organic compounds that are not a liquid at a temperature less than 37° C, the final disposal criterion is the smallest concentration across the wildlife and sediment dwelling organism columns, if a concentration is presented for those receptors. If the concentrations for these receptors are listed as "Greater", then the final disposal criterion is the smaller of the uncorrected disposal criterion and 100,000 mg/kg. For all radionuclides, the final criterion is the smallest concentration across the groundwater user, wildlife, and sediment dwelling organism columns.

^g Codes are: GW User = final value based on appropriate result for the groundwater user; Spring = final value based upon result for ingestion of water by wildlife at a spring; Saturation = final value is that reported for the groundwater user but is set at the soil saturation concentration because the chemical or compound is a liquid at a temperature below 37° C; Limit = final value is 100,000 mg/kg because the smallest risk-based concentration exceeded this value.

^h Back-calculation user concentrations for lead and vanadium are based on the background concentration in groundwater. This resulted in disposal criteria that may lead to groundwater concentrations greater than a concentration protective of a groundwater user. Please see Sect. 5.1.2.1.

ⁱ The estimated concentration of this chemical in groundwater at all points of exposure was 0. Therefore, a criterion could not be back-calculated. The final criterion was set at 100,000 mg/kg for these chemicals.

After selecting the final CERCLA-derived waste disposal criteria, the contaminant inventory limits were calculated by assuming a landfill volume of 1.56 million cubic yards and a waste density (over all waste forms) of 1.5 g per cubic cm. For chemicals, these calculations are as follows:

$$\text{Inventory} = \text{Criteria} \times \frac{1 \text{ kg}}{1,000,000 \text{ mg}} \times \text{Volume} \times \left(\frac{0.7646 \text{ m}^3}{\text{yd}^3} \right) \times \text{Density} \times \left(\frac{100 \text{ cm}}{\text{m}} \right)^3 \times \frac{1 \text{ kg}}{1000 \text{ g}}$$

where

- Inventory = the contaminant inventory limit (kg),
- Criteria = the CERCLA-derived waste disposal criteria from Table 5.18 (mg/kg),
- Volume = C-746-U Landfill volume (1.56 million yd³),
- Density = average density over all waste forms (1.5 g/cm³).

For radionuclides, these calculations are as follows:

$$\text{Inventory} = \text{Criteria} \times \text{Volume} \times \left(\frac{0.7646 \text{ m}^3}{\text{yd}^3} \right) \times \text{Density} \times \left(\frac{100 \text{ cm}}{\text{m}} \right)^3 \times \frac{1 \text{ Ci}}{1,000,000,000,000 \text{ pCi}}$$

The resulting inventory limits calculated from the list of CERCLA-derived waste disposal criteria are in Table 5.19.

5.4 ESTIMATED CUMULATIVE CANCER RISK, HAZARD, AND DOSE POSED TO HUMAN HEALTH ASSUMING DISPOSAL OF CERCLA-DERIVED WASTE WITH CONSTITUENT CONCENTRATIONS AT THE FINAL CERCLA-DERIVED WASTE DISPOSAL CRITERIA

This section presents the results of cumulative risk calculations performed assuming the source term in the C-746-U Landfill is composed of wastes with COPC concentrations matching the final CERCLA-derived waste disposal criteria. [Note that this is a highly conservative assumption, as discussed in Chap. 7. As discussed there, the final CERCLA-derived waste disposal criteria for all COPCs except iron exceed the concentrations in the expected CERCLA-derived waste. Additionally, most criteria exceed the RCRA TCLP-based concentrations that will also limit the concentrations in disposed waste.] In addition, this section presents observations regarding the hypothetical cumulative risks and their relevance in the derivation of the C-746-U Landfill operational limits.

5.4.1 Methods and Results

The methods used to derive cumulative cancer risk, hazard, and dose estimates in this section are consistent with those used in the risk calculation presented in Sect. 5.1.1, except for three changes. The first of these changes is the consideration of risk posed to the groundwater user and recreational user at the Ohio River point of exposure in addition to risk posed to the groundwater user at the DOE property boundary point of exposure. (Note that cancer risk, hazard, and dose estimates are not derived for the industrial worker at the Ohio River point of exposure because these are less than those for the recreational user.) The second of these changes is the use of constituent concentrations at exposure points modeled from the CERCLA-derived waste disposal criteria instead of those modeled from the expected CERCLA-derived waste inventory. The third of these changes is the consideration of cancer risk posed by exposure to chemicals and compounds separately from the cancer risks posed by radionuclides to allow for simpler identification of risk-drivers. (Note that a total cancer risk over both chemicals and radionuclides is provided consistent with guidance in EPA 1997.)

Table 5.19. Contaminant inventory limits for the C-746-U Landfill

Chemical	Final CERCLA-derived waste disposal criteria (mg/kg or pCi/g) ^a	Final contaminant inventory limits (kg or Ci) ^a
<i>Inorganic Chemicals (mg/kg and kg)</i>		
Antimony	6.79E+01	1.215E+05
Arsenic	2.88E+01	5.153E+04
Barium	1.14E+04	2.040E+07
Beryllium	2.40E+04	4.294E+07
Cadmium	5.70E+02	1.020E+06
Chromium	4.37E+03	7.819E+06
Copper	5.22E+03	9.339E+06
Iron	1.00E+05 ^c	1.789E+08
Lead	7.77E+04	1.390E+08
Manganese	4.68E+03	8.373E+06
Mercury	3.13E+00 ^b	5.600E+03
Molybdenum	3.87E+01	6.924E+04
Nickel	1.00E+05 ^c	1.789E+08
Selenium	7.77E+01	1.390E+05
Silver	7.77E+03	1.390E+07
Thallium	9.80E+01	1.753E+05
Uranium	7.79E+02	1.394E+06
Vanadium	1.00E+05 ^c	1.789E+08
Zinc	7.47E+04	1.337E+08
<i>Organic Compounds (mg/kg and kg)</i>		
Acenaphthene	1.00E+05 ^c	1.789E+08
Acenaphthylene	1.00E+05 ^c	1.789E+08
Acrylonitrile	1.47E+04 ^b	2.630E+07
Anthracene	1.00E+05 ^c	1.789E+08
Benzene	4.38E+02 ^b	7.837E+05
Butanone, 2-	5.53E+04 ^b	9.894E+07
Carbon Tetrachloride	2.57E+02 ^b	4.598E+05
Chlordane, alpha-	1.00E+05 ^c	1.789E+08
Chlordane, gamma-	1.00E+05 ^c	1.789E+08
Chlorobenzene	1.79E+02 ^b	3.203E+05
Chloroform	1.92E+03 ^b	3.435E+06
Dichlorobenzene, 1,4-	1.00E+05 ^c	1.789E+08
Dichloroethane, 1,2-	2.00E+03 ^b	3.578E+06
Dichloroethene, 1,1-	5.72E+02 ^b	1.023E+06
Dichloroethene, 1,2- (mixed isomers)	2.10E+02 ^b	3.757E+05
Dichloroethene, cis-1,2-	8.01E+02 ^b	1.433E+06
Dichloroethene, trans-1,2-	1.46E+03 ^b	2.612E+06
Dinitrotoluene, 2,4-	1.00E+05 ^c	1.789E+08
Dioxins/Furan (Total)	1.00E+05 ^c	1.789E+08
Ethylbenzene	6.15E+01 ^b	1.100E+05
Fluoranthene	1.00E+05 ^c	1.789E+08
Fluorene	1.00E+05 ^c	1.789E+08
Heptachlor Epoxide	1.00E+05 ^c	1.789E+08
Hexachlorobenzene	1.00E+05 ^c	1.789E+08
Hexachlorobutadine	1.39E+02 ^b	2.487E+05
Hexachloroethane	1.00E+05 ^c	1.789E+08
Methoxychlor	1.00E+05 ^c	1.789E+08
Methylphenol, 2-	4.32E+03 ^b	7.729E+06
Methylphenol, 3-	4.91E+03 ^b	8.785E+06
Methylphenol, 4-	5.03E+03 ^b	8.999E+06
Naphthalene	1.00E+05 ^c	1.789E+08
Nitrobenzene	6.17E+02 ^b	1.104E+06
Pentachlorophenol	1.00E+05 ^c	1.789E+08
Phenanthrene	1.00E+05 ^c	1.789E+08
Polychlorinated biphenyls (Total)	1.73E+02 ^b	3.095E+05
Polynuclear Aromatic Hydrocarbons (Total)	1.00E+05 ^c	1.789E+08

Table 5.19. Contaminant inventory limits for the C-746-U Landfill (continued)

Chemical	Final CERCLA-derived waste disposal criteria (mg/kg or pCi/g) ^a	Final contaminant inventory limits (kg or Ci) ^a
Pyrene	1.00E+05 ^c	1.789E+08
Pyridine	1.00E+05 ^{b, c}	1.789E+08
Tetrachloroethene	8.27E+01 ^b	1.480E+05
Toxaphene	1.00E+05 ^c	1.789E+08
Trichloroethene	3.04E+02 ^b	5.439E+05
Trichlorophenol, 2,4,5-	1.00E+05 ^c	1.789E+08
Trichlorophenol, 2,4,6-	1.00E+05 ^c	1.789E+08
Vinyl Chloride	6.00E+02 ^b	1.073E+06
Xylene (mixture)	8.35E+01 ^b	1.494E+05
Xylene, m-	5.76E+01 ^b	1.031E+05
Xylene, o-	6.89E+01 ^b	1.233E+05
Xylene, p-	8.32E+01 ^b	1.489E+05
Radionuclides (pCi/g and Ci)		
Neptunium-237	2.26E+01	4.044E+01
Plutonium-238	5.66E+03	1.013E+04
Plutonium-239	5.49E+03	9.823E+03
Plutonium-240	5.49E+03	9.823E+03
Radium-226	4.06E+02	7.264E+02
Technetium-99	2.02E+01	3.614E+01
Thorium-230	2.47E+03	4.419E+03
Thorium-232	2.99E+03	5.350E+03
Uranium-234	1.27E+03	2.272E+03
Uranium-235	1.25E+03	2.236E+03
Uranium-238	1.03E+03	1.843E+03

Notes:

^a Final CERCLA-derived waste disposal criterion are the final values in Table 5.17. Contaminant inventory limits were calculated from the final CERCLA-derived waste disposal criteria as discussed in the text. Because of rounding error, the inventory limits reported here may differ slightly from those presented in earlier tables.

^b The final CERCLA-derived waste disposal criterion is the soil saturation limit in sand (0.08% organic content) for the chemical or compound. This value was chosen because liquids can not be disposed of in the C-746-U Landfill. The value may be greater if the chemical or compound is found in a different soil matrix (i.e., with a higher clay or organic carbon content).

^c The final CERCLA-derived waste disposal criterion was reduced to 100,000 mg/kg in order to be consistent with guidance in DOE 2001b concerning back-calculation of risk-based values. The actual back-calculated value is greater than that reported.

As in Sect. 5.1.1, risk estimates were derived by comparing constituent concentrations in groundwater over all periods of landfill performance (i.e., 10,000 years) to cancer risk-based, hazard-based, and dose-based no action screening levels taken from Appendix A in DOE 2001b. As before, these comparisons resulted in the calculation of chemical-specific risks, hazards, and doses at each time. These chemical-specific values were then summed within each period to derive cumulative cancer risk, hazard, and dose, respectively.

The equation used to calculate the chemical-specific cancer risk, hazard, and dose at each time is the same as that presented earlier.

$$\text{Chemical - specific Value} = \frac{C_{w \text{ Chemical}} \times \text{Target Value}}{C_{w \text{ No Action}}}$$

where:

Chemical-specific Value = cancer risk, hazard, or dose from exposure (unitless).

$C_{w \text{ Chemical}}$ = chemical concentration in groundwater from transport modeling (mg/L or pCi/L).

Target Value = basis for $C_{w \text{ No Action}}$ (i.e., cancer risk = 1×10^{-6} ; hazard = 0.1; dose = 1 mrem/year).

$C_{w \text{ No Action}}$ = cancer risk-based, hazard-based, or dose-based no action screening value (mg/L or pCi/L).

The cancer risk-based, hazard-based, and dose-based no action screening values used for the residential groundwater user and recreational user are shown in Table 5.20.

As noted above, cumulative risk estimates were generated for constituent concentrations in groundwater derived from a waste source term set equal to the disposal criteria. All other transport modeling methods and assumptions remained the same as those used under the gradual failure scenario.

The initial concentrations in the waste source term (i.e., those in the waste projected to be placed in the C-746-U Landfill, and those based upon the disposal criteria) and the maximum constituent concentrations in groundwater that result from using these initial concentrations in the fate and transport model are shown in Table 5.21. Constituent concentrations in RGA groundwater based upon the disposal criteria at all times, with constituents grouped by the chemical and radionuclide groups used earlier in the report, are shown in Appendix C in Tables C.1.6 and C.1.7. These tables provide constituent concentrations in groundwater at the at the DOE property boundary and at the Ohio River, respectively.

As shown in Table 5.21 and discussed in Sect. 5.1.2, for many organic compounds, the disposal criteria needed to be adjusted for solubility before generating concentrations in groundwater. By adjusting the disposal criteria for solubility in water, the limitation placed upon transport by solubility was considered, and a steady-state transport model for several organic compounds was derived. An example of this phenomenon is depicted in Fig. 5.10.

In Fig. 5.10, the concentration curve for vinyl chloride generated in the modeling used in Sect. 5.1.1, (i.e., "Waste-based" in the figure) is compared to the concentration curve for vinyl chloride generated in the criteria-based modeling. As shown there, when the disposal criterion is used as the source concentration, vinyl chloride attains a steady-state concentration at about year 150 and maintains that steady-state concentration until about year 210. This steady-state concentration profile is markedly different from the concentration profile that was developed under the gradual release scenario using the estimated waste concentration. In the profile developed in that modeling, the vinyl chloride concentration peaks and falls to zero within about a 250-year period.

The method used to estimate the period of time that contaminant flux is in a steady state is as follows:

$$T = \frac{M_T}{Q_{gw} \times S_w}$$

where:

- T = period of time a steady-state condition exists (yr).
- M_T = initial combined mass of organic constituent in the source material (i.e., the organic constituent's contaminant inventory limit from the RE/PE Report) (kg).
- Q_{gw} = groundwater flux passing through the contaminated area (L/yr).
- S_w = solubility limit of organic constituent (kg/L).

and, Q_{gw} is 8,317,500 L/yr and is calculated as follows:

$$Q_{gw} = q \times A \times (CF)$$

where:

- q = steady-state water percolation rate through the C-746-U Landfill (9.3 cm/yr).
- A = area of C-746-U landfill (22.1 acre).
- CF = conversion factors as follows 43,560 ft²/acre; 929.03 cm²/ft²; and 0.001 L/cm³.

Table 5.20. No Action screening values used to derive chemical-specific cancer risk, hazard, and dose estimates^a

Constituent	Groundwater User ^b					Recreational User ^c			
	Hazard No Action Level		Risk No Action Level	Dose No Action Level		Hazard No Action Level			Risk No Action Level
	Child	Adult	Lifetime	Child	Adult	Child	Teen	Adult	Lifetime
<i>Inorganic Chemicals (mg/L)</i>									
Antimony	5.64E-04	1.34E-03	NV	NV	NV	3.12E-03	4.66E-03	1.63E-02	NV
Arsenic	4.52E-04	1.09E-03	3.50E-05	NV	NV	4.79E-02	7.17E-02	2.50E-01	4.09E-03
Barium	1.04E-01	2.49E-01	NV	NV	NV	1.91E+00	2.86E+00	9.96E+00	NV
Beryllium	2.64E-03	6.18E-03	NV	NV	NV	7.80E-03	1.17E-02	4.06E-02	NV
Cadmium	6.61E-04	1.54E-03	NV	NV	NV	1.95E-03	2.91E-03	1.02E-02	NV
Chromium (Total)	1.76E+00	4.02E+00	NV	NV	NV	2.92E+00	4.37E+00	1.52E+01	NV
Copper	5.57E-02	1.34E-01	NV	NV	NV	4.33E+00	6.47E+00	2.26E+01	NV
Iron	4.49E-01	1.08E+00	NV	NV	NV	1.75E+01	2.62E+01	9.14E+01	NV
Lead	NV	NV	NV	NV	NV	NV	NV	NV	NV
Manganese	3.50E-02	8.38E-02	NV	NV	NV	3.74E-01	5.59E-01	1.95E+00	NV
Mercury	4.44E-04	1.07E-03	NV	NV	NV	8.19E-03	1.22E-02	4.27E-02	NV
Molybdenum	7.53E-03	1.82E-02	NV	NV	NV	7.41E-01	1.11E+00	3.86E+00	NV
Nickel	3.01E-02	7.25E-02	NV	NV	NV	2.10E+00	3.15E+00	1.10E+01	NV
Selenium	7.54E-03	1.82E-02	NV	NV	NV	8.58E-01	1.28E+00	4.47E+00	NV
Silver	7.50E-03	1.81E-02	NV	NV	NV	3.51E-01	5.24E-01	1.83E+00	NV
Thallium ^d	1.20E-04	2.89E-04	NV	NV	NV	6.24E-03	9.32E-03	3.25E-02	NV
Uranium	9.06E-04	2.19E-03	NV	NV	NV	1.99E-01	2.97E-01	1.04E+00	NV
Vanadium	9.25E-03	2.16E-02	NV	NV	NV	2.73E-02	4.08E-02	1.42E-01	NV
Zinc	4.50E-01	1.09E+00	NV	NV	NV	2.34E+01	3.50E+01	1.22E+02	NV
<i>Organic Compounds (mg/L)</i>									
Acenaphthene	1.36E-02	4.63E-02	NV	NV	NV	2.90E-02	4.34E-02	1.51E-01	NV
Acenaphthylene ^e	1.36E-02	4.63E-02	NV	NV	NV	2.90E-02	4.34E-02	1.51E-01	NV
Acrylonitrile	1.70E-04	7.39E-04	4.26E-05	NV	NV	2.23E-01	3.33E-01	1.16E+00	1.58E-02
Anthracene	7.66E-02	2.90E-01	NV	NV	NV	4.04E-01	6.04E-01	2.11E+00	NV
Benzene	5.04E-04	2.18E-03	3.85E-04	NV	NV	5.40E-02	8.07E-02	2.82E-01	1.26E-02
Butanone, 2-	8.68E-02	3.82E-01	NV	NV	NV	1.70E+02	2.54E+02	8.87E+02	NV
Carbon tetrachloride	1.90E-04	7.69E-04	1.81E-04	NV	NV	8.06E-03	1.21E-02	4.20E-02	3.40E-03
Chlordane, alpha-	6.58E-04	1.54E-03	1.28E-04	NV	NV	1.87E-03	2.80E-03	9.77E-03	4.11E-04
Chlordane, gamma-	6.58E-04	1.54E-03	1.28E-04	NV	NV	1.87E-03	2.80E-03	9.77E-03	4.11E-04
Chlorobenzene	4.66E-03	1.88E-02	NV	NV	NV	5.89E-02	8.81E-02	3.07E-01	NV
Chloroform	2.87E-05	1.38E-04	2.17E-04	NV	NV	8.76E-02	1.31E-01	4.57E-01	5.51E-02
Dichlorobenzene, 1,4-	8.10E-03	3.24E-02	5.78E-04	NV	NV	1.70E-01	2.54E-01	8.85E-01	9.04E-03
Dichloroethane, 1,2-	4.65E-04	2.22E-03	1.47E-04	NV	NV	2.21E+00	3.30E+00	1.15E+01	3.10E-02
Dichloroethene, 1,1-	2.46E-03	1.00E-02	4.70E-05	NV	NV	3.94E-01	5.89E-01	2.05E+00	2.80E-03
Dichloroethene, 1,2- (cis)	2.73E-03	1.11E-02	NV	NV	NV	3.90E-01	5.83E-01	2.03E+00	NV
Dichloroethene, 1,2- (Mixture)	2.47E-03	1.01E-02	NV	NV	NV	2.55E+00	3.81E+00	1.33E+01	NV
Dichloroethene, 1,2- (trans)	5.48E-03	2.24E-02	NV	NV	NV	7.09E+00	1.06E+01	3.69E+01	NV

Table 5.20. No Action screening values used to derive chemical-specific cancer risk, hazard, and dose estimates^a

Constituent	Groundwater User ^b					Recreational User ^c			
	Risk No			Dose No Action Level		Hazard No Action Level			Risk No
	Hazard No Action Level	No Action Level	Action Level	Child	Adult	Child	Teen	Adult	Action Level
Dinitrotoluene, 2,4-	3.00E-03	7.24E-03	7.69E-05	NV	NV	1.74E-01	2.61E-01	9.09E-01	4.92E-03
Dioxin/Furan (Total)	NV	NV	6.09E-11	NV	NV	NV	NV	NV	3.56E-11
Ethylbenzene	5.63E-02	1.89E-01	4.68E-03	NV	NV	5.11E-01	7.64E-01	2.66E+00	NV
Fluoranthene	2.26E-02	4.70E-02	NV	NV	NV	1.34E-02	2.01E-02	7.00E-02	NV
Fluorene	9.72E-03	3.51E-02	NV	NV	NV	3.12E-02	4.66E-02	1.63E-01	NV
Heptachlor epoxide	1.77E-05	4.17E-05	5.12E-06	NV	NV	6.63E-05	9.92E-05	3.46E-04	2.15E-05
Hexachlorobenzene	7.54E-04	1.66E-03	1.92E-05	NV	NV	7.42E-04	1.11E-03	3.87E-03	2.23E-05
Hexachlorobutadiene	2.25E-04	5.08E-04	4.80E-04	NV	NV	3.25E-04	4.86E-04	1.69E-03	7.99E-04
Hexachloroethane	1.35E-03	3.17E-03	3.29E-03	NV	NV	4.64E-03	6.94E-03	2.42E-02	1.27E-02
Methoxychlor	7.15E-03	1.70E-02	NV	NV	NV	4.87E-02	7.28E-02	2.54E-01	NV
Methylphenol, 2-	7.23E-02	7.72E-01	NV	NV	NV	6.09E-01	9.10E-01	3.18E+00	NV
Methylphenol, 3-	7.25E-02	1.73E-01	NV	NV	NV	6.50E-01	9.71E-01	3.39E+00	NV
Methylphenol, 4-	7.27E-03	1.74E-02	NV	NV	NV	7.04E-02	1.05E-01	3.67E-01	NV
Naphthalene	2.85E-04	1.36E-03	NV	NV	NV	9.04E-02	1.35E-01	4.71E-01	NV
Nitrobenzene	1.53E-04	6.12E-04	NV	NV	NV	2.74E-02	4.10E-02	1.43E-01	NV
Pentachlorophenol	2.34E-02	5.02E-02	2.08E-04	NV	NV	1.80E-02	2.69E-02	9.38E-02	1.92E-04
Phenanthrene ^d	2.26E-02	4.70E-02	NV	NV	NV	1.34E-02	2.01E-02	7.00E-02	NV
Polychlorinated biphenyls (Total)	NV	NV	7.93E-05	NV	NV	NV	NV	NV	9.61E-05
Polynuclear aromatic hydrocarbons (Total)	NV	NV	9.51E-07	NV	NV	NV	NV	NV	5.29E-07
Pyrene	1.82E-02	3.81E-02	NV	NV	NV	1.13E-02	1.69E-02	5.91E-02	NV
Pyridine	1.49E-03	3.58E-03	NV	NV	NV	3.68E-02	5.50E-02	1.92E-01	NV
Tetrachloroethene	8.42E-03	2.02E-02	5.82E-04	NV	NV	1.05E-02	1.57E-02	5.49E-02	7.77E-04
Toxaphene	NV	NV	4.56E-05	NV	NV	NV	NV	NV	4.53E-04
Trichloroethene	1.60E-03	6.34E-03	1.73E-03	NV	NV	2.19E-02	3.28E-02	1.14E-01	1.27E-02
Trichlorophenol, 2,4,5-	1.29E-01	3.01E-01	NV	NV	NV	3.30E-01	4.94E-01	1.72E+00	NV
Trichlorophenol, 2,4,6-	NV	NV	3.99E-03	NV	NV	NV	NV	NV	1.15E-02
Vinyl chloride	3.06E-03	8.76E-03	3.50E-05	NV	NV	1.60E-01	2.39E-01	8.35E-01	1.46E-03
Xylene	6.53E-02	3.07E-01	NV	NV	NV	7.55E+00	1.13E+01	3.94E+01	NV
Xylene, m-	4.39E-01	1.80E+00	NV	NV	NV	7.80E+00	1.17E+01	4.06E+01	NV
Xylene, o-	4.39E-01	1.80E+00	NV	NV	NV	7.80E+00	1.17E+01	4.06E+01	NV
Xylene, p-	4.39E-01	1.80E+00	NV	NV	NV	7.80E+00	1.17E+01	4.06E+01	NV
Radionuclides (pCi/L)^e									
Neptunium-237	NV	NV	5.73E-01	6.44E-01	3.22E-01	NV	NV	NV	NV
Plutonium-238	NV	NV	2.95E-01	8.93E-01	4.46E-01	NV	NV	NV	NV
Plutonium-239	NV	NV	2.86E-01	8.07E-01	4.04E-01	NV	NV	NV	NV
Plutonium-240	NV	NV	2.86E-01	8.07E-01	4.04E-01	NV	NV	NV	NV
Radium-226	NV	NV	2.33E-02	3.32E-01	1.66E-01	NV	NV	NV	NV

Table 5.20. No Action screening values used to derive chemical-specific cancer risk, hazard, and dose estimates^a

Constituent	Groundwater User ^b					Recreational User ^c			
	Hazard No Action Level		Risk No Action Level	Dose No Action Level		Hazard No Action Level			Risk No Action Level
	Child	Adult	Lifetime	Child	Adult	Child	Teen	Adult	Lifetime
Technetium-99	NV	NV	1.40E+01	1.96E+03	9.78E+02	NV	NV	NV	NV
Thorium-230	NV	NV	2.21E-02	3.27E-01	1.60E-01	NV	NV	NV	NV
Thorium-232	NV	NV	2.68E-02	5.74E-01	2.87E-01	NV	NV	NV	NV
Uranium-234	NV	NV	5.46E-01	1.01E+01	5.05E+00	NV	NV	NV	NV
Uranium-235	NV	NV	5.38E-01	1.07E+01	5.35E+00	NV	NV	NV	NV
Uranium-238	NV	NV	4.43E-01	1.06E+01	5.31E+00	NV	NV	NV	NV

^a Hazard and cancer risk no action screening values taken from Tables A.18 and A.19 in DOE 2001b. Dose no action screening values from methods similar to those used to derive no action screening values in Table A.9 in DOE 2001b.

^b Values derived considering ingestion of water, inhalation of vapors while using water in the home, and dermal contact with water while showering. Target cancer risk and hazard used were 1×10^{-6} and 0.1, respectively.

^c Values derived considering dermal contact with water while wading. Target cancer risk and hazard used were 1×10^{-6} and 0.1, respectively.

^d No action value for thallium chloride used because thallium metal does not have a toxicity value available.

^e Values for acenaphthylene not available. Values used are for acenaphthene.

^f Values for phenanthrene are not available. Values used are for fluoranthene.

^g Screening values for radionuclides are not pertinent to the wading scenario because water is assumed to prevent external exposure to ionizing radiation.

NV = a no action screening value is not available for the constituent, end-point, receptor combination.

Table 5.21. Concentrations in RGA groundwater at the DOE property boundary and Ohio River calculated from CERCLA-derived waste disposal criteria

Constituent	Concentration in Waste (mg/kg or pCi/g)			Maximum Concentration in RGA Groundwater (mg/L or pCi/L) ^d	
	Waste Characterization Concentration ^a	Disposal Criteria ^b	Adjusted Disposal Criteria ^c	Property Boundary	Ohio River
<i>Inorganic Chemicals</i>					
Antimony	1.24E+00	6.79E+01	6.79E+01	5.64E-03	3.03E-03
Arsenic	4.22E+00	2.88E+01	2.88E+01	3.51E-04	0.00E+00
Barium	2.82E+02	1.14E+04	1.14E+04	1.04E+00	5.60E-01
Beryllium	5.59E-01	2.40E+04	2.40E+04	2.64E-02	3.02E-03
Cadmium	6.23E-01	5.70E+02	5.70E+02	6.62E-03	7.58E-04
Chromium	7.07E+01	4.37E+03	4.37E+03	4.48E+00	3.72E+00
Copper	3.19E+02	5.22E+03	5.22E+03	5.57E-01	3.00E-01
Iron ^{e,f}	1.92E+05	1.00E+05	1.00E+05	1.15E-02	0.00E+00
Lead	1.66E+01	7.77E+04	7.77E+04	2.50E-01	2.86E-02
Manganese	3.13E+02	4.68E+03	4.68E+03	3.49E-01	1.88E-01
Mercury	7.00E-02	3.13E+00	3.13E+00	2.15E-04	1.16E-04
Molybdenum	3.15E+00	3.87E+01	3.87E+01	7.54E-02	6.26E-02
Nickel ^{e,f}	6.90E+04	1.00E+05	1.00E+05	1.96E-03	0.00E+00
Selenium	2.63E-01	7.77E+01	7.77E+01	7.55E-02	6.27E-02
Silver	8.85E-01	7.77E+03	7.77E+03	7.49E-02	8.57E-03
Thallium	4.41E-01	9.80E+01	9.80E+01	1.20E-03	1.37E-04
Uranium	1.57E+02	7.79E+02	7.79E+02	9.06E-03	1.82E-03
Vanadium ^{e,f}	4.18E+01	1.00E+05	1.00E+05	8.69E-02	9.94E-03
Zinc	5.16E+01	7.47E+04	7.47E+04	4.50E+00	2.42E+00
<i>Organic Compounds</i>					
Acenaphthene ^c	5.60E-02	1.00E+05	1.75E+01	1.91E-09	4.81E-13
Acenaphthylene ^c	5.80E-02	1.00E+05	9.85E+01	7.10E-09	1.79E-12
Acrylonitrile	2.00E-03	1.47E+04	1.47E+04	2.94E-04	1.44E-06
Anthracene ^c	8.60E-02	1.00E+05	8.25E-01	1.89E-11	4.77E-15
Benzene	4.10E-03	4.38E+02	4.38E+02	3.49E-08	5.76E-11
Butanone, 2-	9.14E-01	5.53E+04	5.53E+04	3.75E-05	3.04E-07
Carbon tetrachloride	3.40E-03	2.57E+02	2.57E+02	2.00E-06	7.77E-08
Chlordane, alpha- ^c	1.90E-03	1.00E+05	2.65E+00	4.76E-26	0.00E+00
Chlordane, gamma- ^c	1.90E-03	1.00E+05	2.65E+00	4.76E-26	0.00E+00
Chlorobenzene	4.56E-01	1.79E+02	1.79E+02	2.81E-09	3.17E-14
Chloroform	2.84E-02	1.92E+03	1.92E+03	1.42E-04	3.15E-05
Dichlorobenzene, 1,4- ^c	5.70E-02	1.00E+05	5.11E+01	2.92E-10	3.30E-15
Dichloroethane, 1,2-	3.40E-03	2.00E+03	2.00E+03	2.07E-04	4.58E-05
Dichloroethene, 1,1-	1.40E-02	5.72E+02	5.72E+02	3.44E-05	7.63E-06
Dichloroethene, 1,2-(Mixed Isomers)	9.00E-05	2.10E+02	2.10E+02	1.04E-05	2.30E-06
Dichloroethene, 1,2-cis	2.22E-01	8.01E+02	8.01E+02	8.86E-05	1.96E-05
Dichloroethene, 1,2-trans	8.40E-02	1.46E+03	1.46E+03	1.50E-04	3.34E-05
Dinitrotoluene, 2,4- ^c	2.20E-02	1.00E+05	7.46E+01	2.82E-09	1.38E-11
Dioxin/Furan (Total) ^e	5.00E-06	1.00E+05	2.64E+01	0.00E+00	0.00E+00
Ethylbenzene	4.30E-03	6.15E+01	6.15E+01	1.50E-09	2.47E-12
Fluoranthene ^c	1.52E-01	1.00E+05	8.14E+00	8.88E-11	2.24E-14
Fluorene ^c	5.50E-02	1.00E+05	1.26E+01	8.77E-10	2.21E-13
Heptachlor epoxide ^c	2.00E-04	1.00E+05	1.34E+01	1.40E-25	0.00E+00
Hexachlorobenzene ^c	2.20E-02	1.00E+05	3.98E+02	1.72E-11	1.94E-16
Hexachlorobutadiene	2.30E-02	1.39E+02	1.39E+02	1.41E-09	3.56E-13
Hexachloroethane ^c	3.50E-02	1.00E+05	8.12E+01	2.48E-08	6.26E-12
Methoxychlor ^c	4.66E-02	1.00E+05	2.89E+00	3.83E-26	0.00E+00
Methylphenol, 2-	4.92E-01	4.32E+03	4.32E+03	7.95E-07	3.90E-09
Methylphenol, 3-	4.71E-01	4.91E+03	4.91E+03	3.17E-07	1.56E-09
Methylphenol, 4-	4.90E-01	5.03E+03	5.03E+03	5.14E-07	2.52E-09
Naphthalene ^c	5.60E-02	1.00E+05	3.57E+01	1.61E-08	4.06E-12
Nitrobenzene	3.10E-02	6.17E+02	6.17E+02	1.89E-08	9.28E-11
Pentachlorophenol ^c	2.28E-01	1.00E+05	1.31E+03	1.19E-06	3.00E-10

Table 5.21. Concentrations in RGA groundwater at the DOE property boundary and Ohio River calculated from CERCLA-derived waste disposal criteria

Constituent	Concentration in Waste (mg/kg or pCi/g)			Maximum Concentration in RGA Groundwater (mg/L or pCi/L) ^d	
	Waste Characterization Concentration ^a	Disposal Criteria ^b	Adjusted Disposal Criteria ^c	Property Boundary	Ohio River
Phenanthrene ^e	1.22E-01	1.00E+05	1.37E+01	5.28E-10	1.33E-13
Polychlorinated biphenyls (Total)	8.26E-01	1.73E+02	1.73E+02	4.75E-15	0.00E+00
Polynuclear Aromatic Hydrocarbons (Total) ^e	9.80E-02	1.00E+05	7.75E+00	0.00E+00	0.00E+00
Pyrene ^e	1.43E-01	1.00E+05	7.37E+00	5.82E-11	1.47E-14
Pyridine ^{e,f}	3.10E-02	1.00E+05	1.00E+05	1.74E-04	8.55E-07
Tetrachloroethene	5.30E-03	8.27E+01	8.27E+01	3.65E-07	1.42E-08
Toxaphene ^e	4.60E-03	1.00E+05	5.69E+01	6.37E-25	0.00E+00
Trichloroethene	6.12E-02	3.04E+02	3.04E+02	3.82E-06	1.49E-07
Trichlorophenol, 2,4,5- ^e	9.69E-01	1.00E+05	3.42E+03	3.80E-09	1.86E-11
Trichlorophenol, 2,4,6- ^e	6.80E-02	1.00E+05	2.14E+03	2.55E-09	1.25E-11
Vinyl chloride	6.99E-02	6.00E+02	6.00E+02	1.26E-04	2.80E-05
Xylene	4.60E-03	8.35E+01	8.35E+01	1.55E-09	2.55E-12
Xylene, m-	4.60E-03	5.76E+01	5.76E+01	1.48E-09	2.44E-12
Xylene, o-	4.60E-03	6.89E+01	6.89E+01	1.44E-09	2.37E-12
Xylene, p-	4.60E-03	8.32E+01	8.32E+01	1.35E-09	2.22E-12
		Radionuclides			
Neptunium-237	6.62E-01	2.26E+01	2.26E+01	5.74E+00	4.71E+00
Plutonium-238	3.90E-02	5.66E+03	5.66E+03	2.92E+00	4.31E-01
Plutonium-239	9.20E-02	5.49E+03	5.49E+03	2.85E+00	4.22E-01
Plutonium-240	1.15E-01	5.49E+03	5.49E+03	2.85E+00	4.22E-01
Radium-226	8.99E-01	4.06E+02	4.06E+02	2.33E-01	3.44E-02
Technetium-99	7.04E-01	2.02E+01	2.02E+01	1.40E+02	1.17E+02
Thorium-230	4.54E-01	2.47E+03	2.47E+03	2.21E-01	3.27E-02
Thorium-232	1.00E+00	2.99E+03	2.99E+03	2.68E-01	3.96E-02
Uranium-234	5.58E+00	1.27E+03	1.27E+03	5.44E+00	8.04E-01
Uranium-235	2.76E-01	1.25E+03	1.25E+03	5.37E+00	7.93E-01
Uranium-238	5.62E+00	1.03E+03	1.03E+03	4.42E+00	6.52E-01

^a Concentration of constituent projected for wastes that may be placed in the C-746-U Landfill. These values were used to project constituent concentrations in groundwater that were included in the cumulative risk calculations presented in Sect. 5.1.

^b Final CERCLA-derived waste disposal criteria taken from Table 5.19.

^c CERCLA-derived waste disposal criteria adjusted for solubility in water and soil saturation limit taken from Table 5.4.

^d Estimated concentration of constituents in RGA groundwater at both points of exposure derived from the adjusted disposal criteria.

^e The final criterion was reduced to 100,000 mg/kg based upon guidance in DOE 2001b.

^f The adjusted disposal criterion was reduced to 100,000 mg/kg based upon guidance in DOE 2001b.

In order to estimate the year when the steady-state condition ends, the period of the steady-state condition (T) was added to the estimated year when the peak constituent concentration was attained at the point of exposure. In this calculation, the peak concentration was derived using the solubility corrected disposal criteria shown in Table 5.21. Table 5.22 presents the solubility limits, maximum constituent flux, and the duration of steady-state transport for the inorganic chemicals and organic compounds considered. As shown in Table 5.22, several organic compounds achieve a steady-state concentration within the time period considered (i.e., 10,000 years).

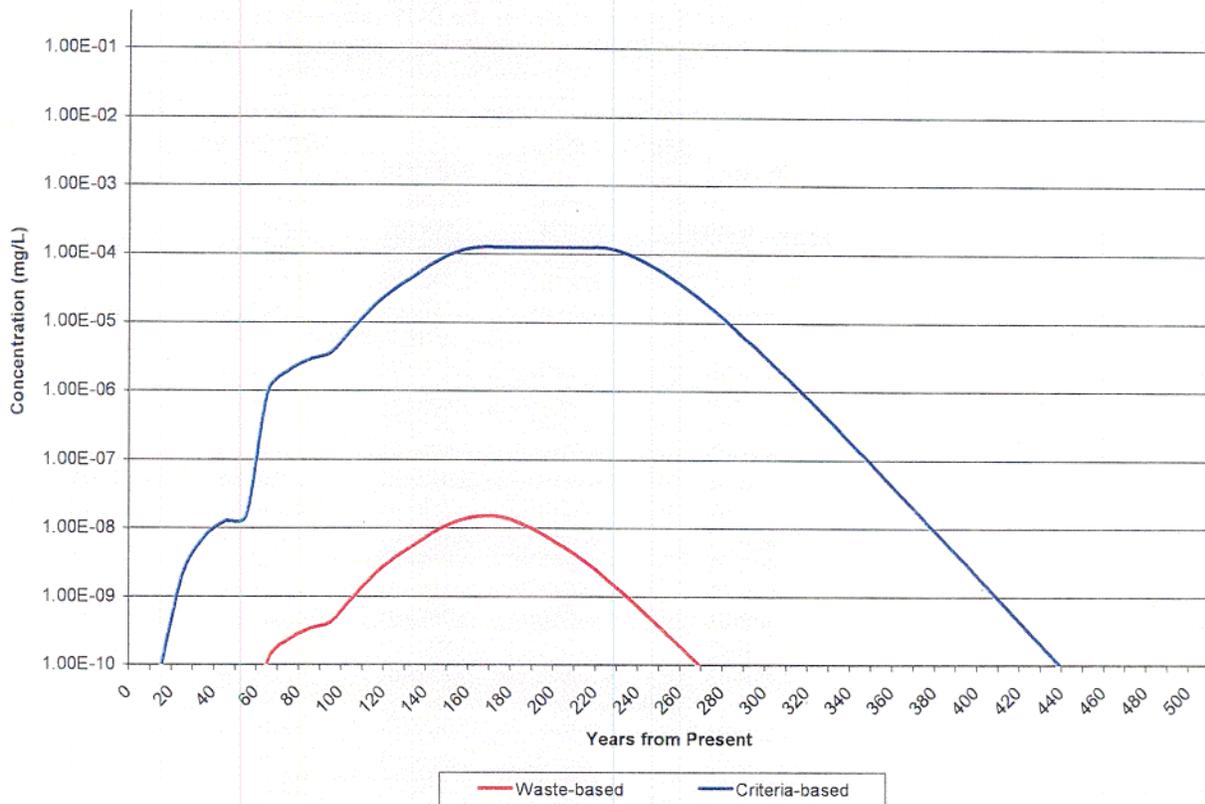


Fig. 5.10. Concentration of vinyl chloride in a well completed in the RGA at the DOE property boundary – comparison between expected waste-based and disposal criteria-based source terms.

Cumulative cancer risks from chemicals and radionuclides for the resident at both points of exposure are shown in Figs. 5.11 and 5.12, respectively. Cumulative hazard and dose for the resident are shown in Figs. 5.13 and 5.14, respectively. Cumulative cancer risks and hazard for the recreational user are shown in Figs. 5.15 and 5.16. Note that cancer risk results are based upon a lifetime exposure, hazard results are based upon exposure by a child, and dose results are based upon exposure by an adult. Hazard results for the adult and teen are not shown because these hazards are less than those for the child. Similarly, dose results for the child are not shown because these are less than those for the adult. Additionally, as discussed in Sect. 5.1.1, radionuclides do not pose a cancer risk or dose to the recreational user under the wading exposure scenario; therefore, no cancer risk or dose results from exposure to radionuclides are shown for this receptor.

As shown in Fig. 5.11, the cumulative cancer risk from chemicals posed to a resident using water drawn from a well completed in the RGA at the DOE property boundary peaks three times. These are at 7×10^{-6} in year 20, 6×10^{-6} in year 170, and 1×10^{-5} in year 10,000. However, the cumulative risk from chemicals posed to a resident using water drawn from a well completed in the RGA at the Ohio River peaks a single time (i.e., at 1×10^{-6} in year 180). [Note that all peaks are below the upper end of the EPA acceptable risk range for site-related exposure (i.e., 10^{-4} .)] The primary constituent driving peak cancer risk to the resident at the first peak seen at the property boundary point of exposure is acrylonitrile, which contributes approximately 99% of the cumulative cancer risk. The primary constituents driving peak cancer risk at the second peak at the property boundary and at the single peak at the Ohio River are vinyl

Table 5.22. Solubility limits, maximum constituent flux, and steady-state transport duration for inorganic chemicals and organic compounds

Chemical ^a	Solubility Limit (kg/L)	Inventory Limit (kg) ^b	Yearly Constituent Flux (kg) ^c	Length of Steady State Period (Years) ^d	Groundwater at the Property Boundary			Groundwater at the Ohio River		
					Year of Peak Concentration in Water ^e	Start of Steady State Period (Year) ^f	End of Steady State (Year) ^g	Year of Peak Concentration in Water ^e	Start of Steady State Period (Year) ^f	End of Steady State (Year) ^g
<i>Inorganic Chemicals</i>										
Antimony	3.85E-02	1.215E+05	3.20E+05	0	10,000	None	None	10,000	None	None
Arsenic	3.02E-02	5.153E+04	2.51E+05	0	10,000	None	None	10,000	None	None
Barium	4.10E-02	2.040E+07	3.41E+05	60	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Beryllium	5.67E-02	4.294E+07	4.72E+05	91	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Cadmium	2.98E-02	1.020E+06	2.48E+05	4	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Chromium	1.20E-02	7.818E+06	9.98E+04	78	3,800	3,800	3,880	5,400	5,400	5,500
Copper	2.44E-02	9.339E+06	2.03E+05	46	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Iron	1.60E-02	1.789E+08	1.33E+05	1,344	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Lead	5.00E-02	1.390E+08	4.16E+05	334	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Manganese	4.26E-02	8.373E+06	3.54E+05	24	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Mercury	6.00E-08	5.600E+03	4.99E-01	11,221	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Molybdenum	2.92E+00	6.924E+04	2.43E+07	0	3,800	None	None	5,400	None	None
Nickel	2.54E-02	1.789E+08	2.11E+05	847	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Selenium	1.30E-02	1.390E+05	1.08E+05	1	2,200	None	None	2,600	None	None
Silver	5.57E-02	1.390E+07	4.63E+05	30	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Thallium	5.00E-02	1.753E+05	4.16E+05	0	10,000	None	None	10,000	None	None
Uranium	4.26E-02	1.394E+06	3.54E+05	4	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Vanadium	5.67E-02	1.789E+08	4.72E+05	379	10,000	>10,000	>10,000	10,000	>10,000	>10,000
Zinc	4.32E-02	1.336E+08	3.59E+05	372	10,000	>10,000	>10,000	10,000	>10,000	>10,000
<i>Organic Compounds</i>										
Acenaphthene	4.24E-06	3.131E+04	3.53E+01	888	130	130	1,100	180	180	1,100
Acenaphthylene	1.61E-05	1.762E+05	1.34E+02	1,316	130	130	1,500	180	180	1,700
Acrylonitrile	7.40E-02	2.630E+07	6.15E+05	43	20	20	70	30	30	80
Anthracene	4.00E-08	1.476E+03	3.33E-01	4,436	130	130	4,600	180	180	4,700
Benzene	1.75E-03	7.836E+05	1.46E+04	54	20	20	80	30	30	90
Butanone, 2-	2.23E-01	9.894E+07	1.85E+06	53	20	20	80	30	30	90
Carbon tetrachloride	7.93E-04	4.598E+05	6.60E+03	70	70	70	140	90	90	160
Chlordane, alpha-	6.00E-08	4.741E+03	4.99E-01	9,500	380	380	9,900	NA	NA	NA
Chlordane, gamma-	6.00E-08	4.741E+03	4.99E-01	9,500	380	380	9,900	NA	NA	NA
Chlorobenzene	4.72E-04	3.202E+05	3.93E+03	82	80	80	170	100	100	190
Chloroform	7.92E-03	3.435E+06	6.59E+04	52	160	160	220	180	180	240
Dichlorobenzene, 1,4-	7.38E-05	9.142E+04	6.14E+02	149	80	80	230	100	100	250
Dichloroethane, 1,2-	8.52E-03	3.578E+06	7.09E+04	50	160	160	210	180	180	230
Dichloroethene, 1,1-	2.25E-03	1.023E+06	1.87E+04	55	160	160	220	180	180	240
Dichloroethene, 1,2- (Mixed Isomers)	6.30E-03	3.757E+05	5.24E+04	7	160	160	170	180	180	190
Dichloroethene, 1,2-cis-	3.50E-03	1.433E+06	2.91E+04	49	160	160	210	180	180	230
Dichloroethene, 1,2-trans-	6.30E-03	2.612E+06	5.24E+04	50	160	160	210	180	180	230
Dinitrotoluene, 2,4-	2.70E-04	1.335E+05	2.25E+03	59	20	20	80	30	30	90
Dioxin/Furan (Total)	1.90E-11	4.723E+04	1.58E-04	298,870,880	NA	NA	NA	NA	NA	NA
Ethylbenzene	1.69E-04	1.100E+05	1.41E+03	78	20	20	100	30	30	110

Table 5.22. Solubility limits, maximum constituent flux, and steady-state transport duration for inorganic chemicals and organic compounds (continued)

Chemical ^a	Solubility Limit (kg/L)	Inventory Limit (kg) ^b	Yearly Constituent Flux (kg) ^c	Length of Steady State Period (Years) ^d	Groundwater at the Property Boundary			Groundwater at the Ohio River		
					Year of Peak Concentration in Water ^e	Start of Steady State Period (Year) ^f	End of Steady State (Year) ^g	Year of Peak Concentration in Water ^e	Start of Steady State Period (Year) ^f	End of Steady State (Year) ^g
Fluoranthene	2.10E-07	1.456E+04	1.75E+00	8,338	130	130	8,500	180	180	8,600
Fluorene	1.98E-06	2.254E+04	1.65E+01	1,369	130	130	1,500	180	180	1,600
Heptachlor epoxide	2.00E-07	2.397E+04	1.66E+00	14,411	380	380	>10,000	NA	NA	NA
Hexachlorobenzene	6.20E-06	7.120E+05	5.16E+01	13,808	80	80	>10,000	100	100	>10,000
Hexachlorobutadiene	3.23E-06	2.487E+05	2.69E+01	9,256	130	130	9,400	180	180	9,500
Hexachloroethane	5.00E-05	1.453E+05	4.16E+02	349	130	130	480	180	180	530
Methoxychlor	5.00E-08	5.170E+03	4.16E-01	12,433	380	380	>10,000	NA	NA	NA
Methylphenol, 2-	2.27E-02	7.729E+06	1.89E+05	41	20	20	70	30	30	80
Methylphenol, 3-	2.60E-02	8.784E+06	2.16E+05	41	20	20	70	30	30	80
Methylphenol, 4-	2.15E-02	8.999E+06	1.79E+05	50	20	20	70	30	30	80
Naphthalene	3.10E-05	6.387E+04	2.58E+02	248	130	130	380	180	180	430
Nitrobenzene	2.09E-03	1.104E+06	1.74E+04	63	20	20	90	30	30	100
Pentachlorophenol	1.95E-03	2.344E+06	1.62E+04	145	130	130	280	180	180	330
Phenanthrene	1.15E-06	2.451E+04	9.57E+00	2,562	130	130	2,700	180	180	2,800
Polychlorinated biphenyls (Total)	7.00E-07	3.095E+05	5.82E+00	53,160	2,200	2,200	>10,000	NA	NA	NA
Polynuclear Aromatic Hydrocarbon (Total)	1.60E-09	1.387E+04	1.33E-02	1,041,874	NA	NA	NA	NA	NA	NA
Pyrene	1.40E-07	1.319E+04	1.16E+00	11,323	130	130	>10,000	180	180	>10,000
Pyridine	1.00E+00	1.789E+08	8.32E+06	22	20	20	50	30	30	50
Tetrachloroethene	2.00E-04	1.480E+05	1.66E+03	89	70	70	160	90	90	180
Toxaphene	7.40E-07	1.018E+05	6.15E+00	16,539	380	380	>10,000	NA	NA	NA
Trichloroethene	1.10E-03	5.439E+05	9.15E+03	59	70	70	130	90	90	150
Trichlorophenol, 2,4,5-	1.20E-03	6.119E+06	9.98E+03	613	20	20	640	30	30	650
Trichlorophenol, 2,4,6-	8.00E-04	3.829E+06	6.65E+03	575	20	20	600	30	30	610
Vinyl chloride	2.76E-03	1.073E+06	2.30E+04	47	160	160	210	180	180	230
Xylene	1.85E-04	1.494E+05	1.54E+03	97	20	20	120	30	30	130
Xylene, m-	1.61E-04	1.031E+05	1.34E+03	77	20	20	100	30	30	110
Xylene, o-	1.78E-04	1.233E+05	1.48E+03	83	20	20	110	30	30	120
Xylene, p-	1.85E-04	1.489E+05	1.54E+03	97	20	20	120	30	30	130

NA = the parameter was not available.

^a Radionuclides are not included because the disposal criteria for these do not approach a concentration that would result in modeled concentrations in water greater than the solubility limit.

^b The maximum amount of constituent that may be placed in the landfill given the constituent's disposal criteria, a maximum landfill volume of 1.56 million cubic yards, and an average waste density of 1.5 g per cubic centimeter.

^c Calculated using the constituent's solubility limit and assuming a groundwater flux through the landfill during the post-institutional control period of 8,317,500 liters per year.

^d The length of time a steady-state transport condition could exist assuming that solubility in water was the only limiting factor. Because the calculation used to derive this period ignores source depletion prior to the time the solubility limit is attained, the length of the period is a conservative estimate.

^e Year in which the peak concentration in groundwater occurs in a well at the DOE property boundary. This value was taken from the modeling performed Chap. 4. A value of 10,000 indicates that the peak concentration was at the end of the modeling period.

^f The time when a steady-state condition begins. "None" indicates that a steady-state condition is not attained. ">10,000" indicates that the steady-state condition would occur after the end of the modeling period.

^g The time when the steady-state condition ends. This time was estimated by adding the length of the steady-state period to the start time in the previous column and rounding to a year used in the modeling. "None" and ">10,000" are defined as in footnote f.

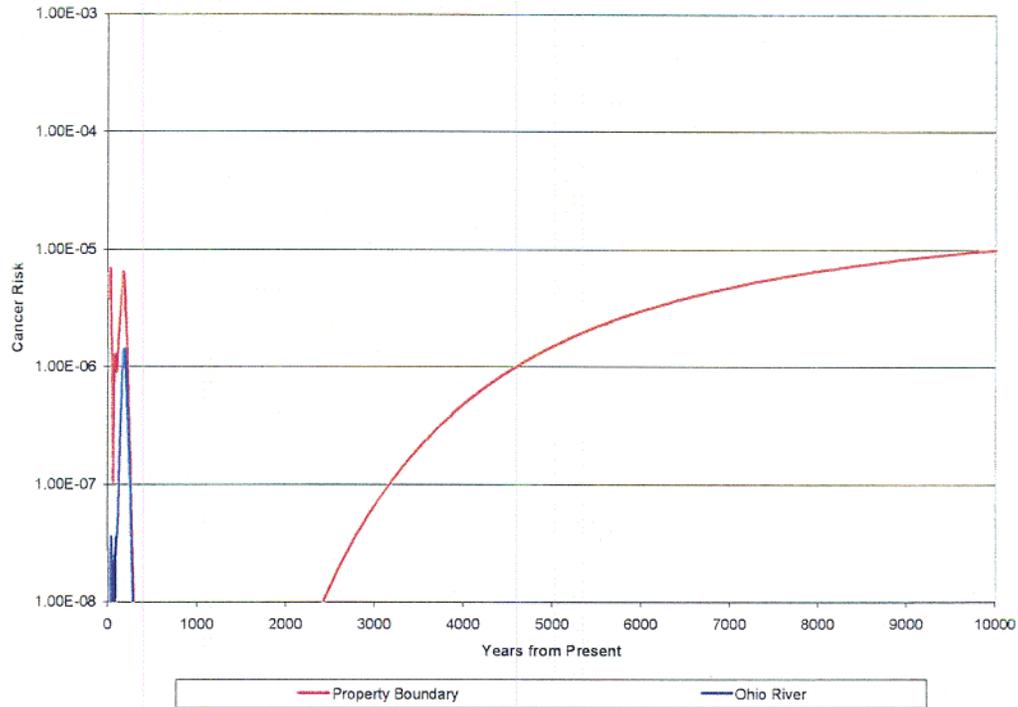


Fig. 5.11. Cancer risk posed by chemicals to a resident using groundwater withdrawn from the RGA at the DOE property boundary and Ohio River points of exposure – CERCLA-derived waste disposal criteria used as a source term for the C-746-U Landfill.

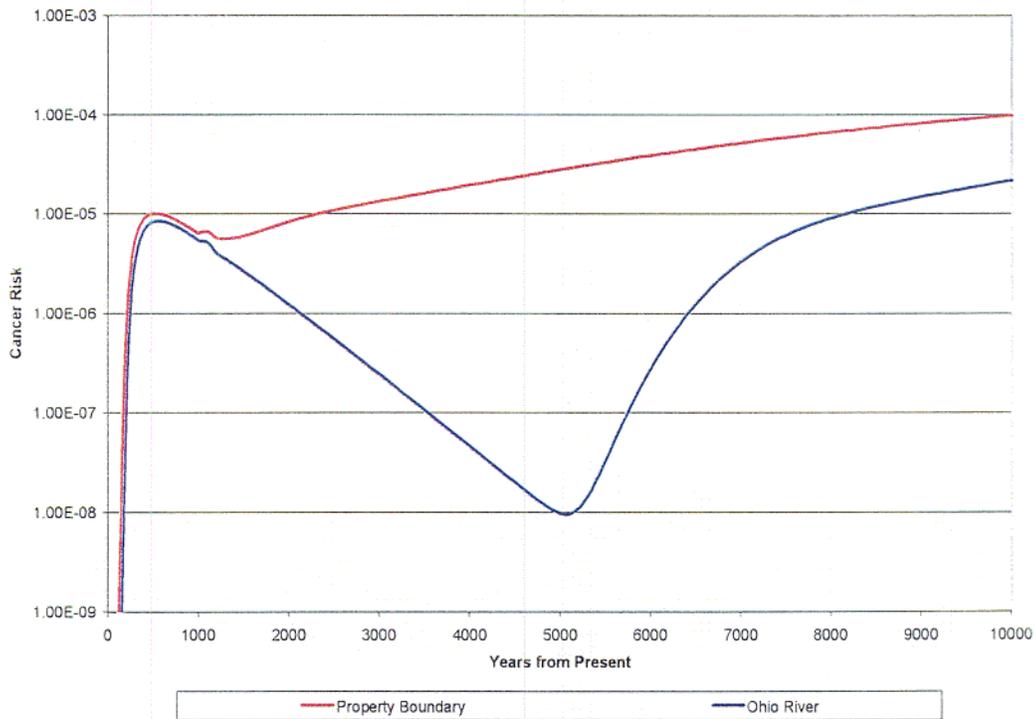


Fig. 5.12. Cancer risk posed by radionuclides to a resident using groundwater withdrawn from the RGA at the DOE property boundary and Ohio River points of exposure – CERCLA-derived waste disposal criteria used as a source term for the C-746-U Landfill.

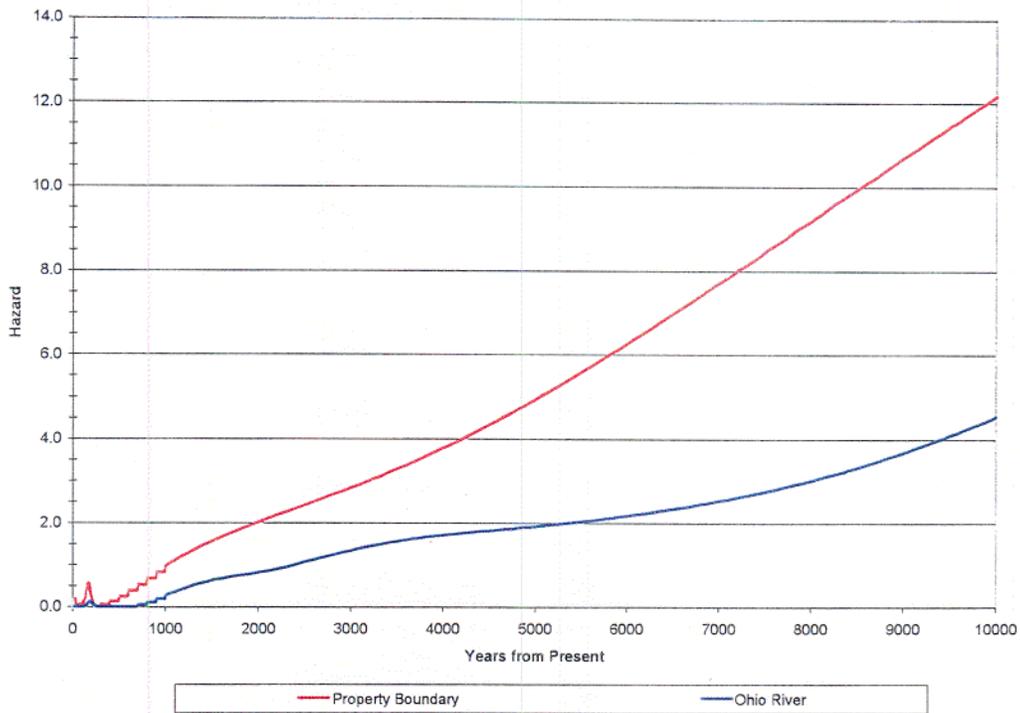


Fig. 5.13. Hazard posed to a resident using groundwater withdrawn from the RGA at the DOE property boundary and Ohio River points of exposure – CERCLA-derived waste disposal criteria used as a source term for the C-746-U Landfill.

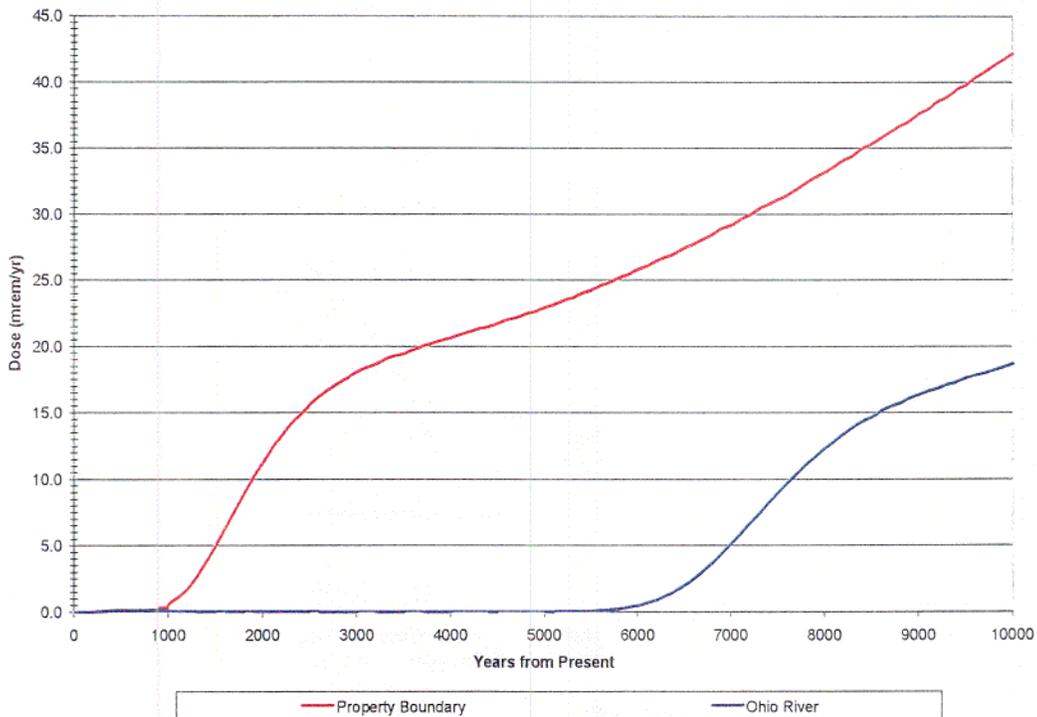


Fig. 5.14. Dose posed to a resident using groundwater withdrawn from the RGA at the DOE property boundary and Ohio River points of exposure – CERCLA-derived waste disposal criteria used as a source term for the C-746-U Landfill.

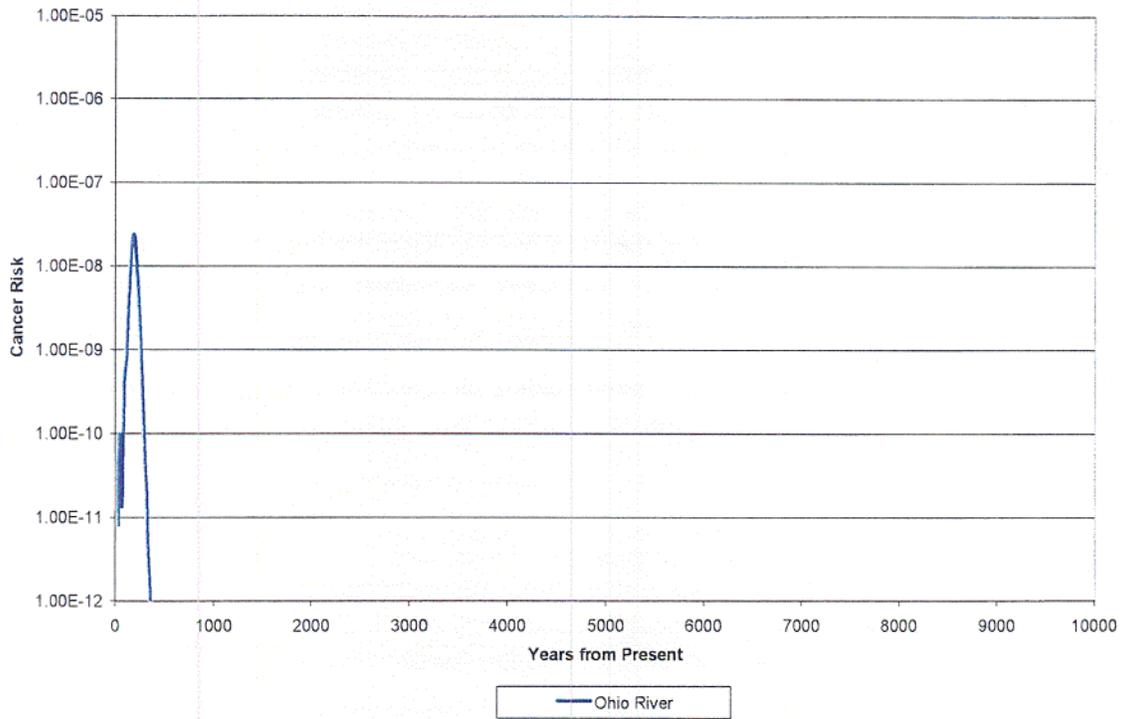


Fig. 5.15. Cancer risk posed by chemicals to a recreational user wading in groundwater discharged to springs at the Ohio River point of exposure – CERCLA-derived waste disposal criteria used as a source term for the C-746-U Landfill.

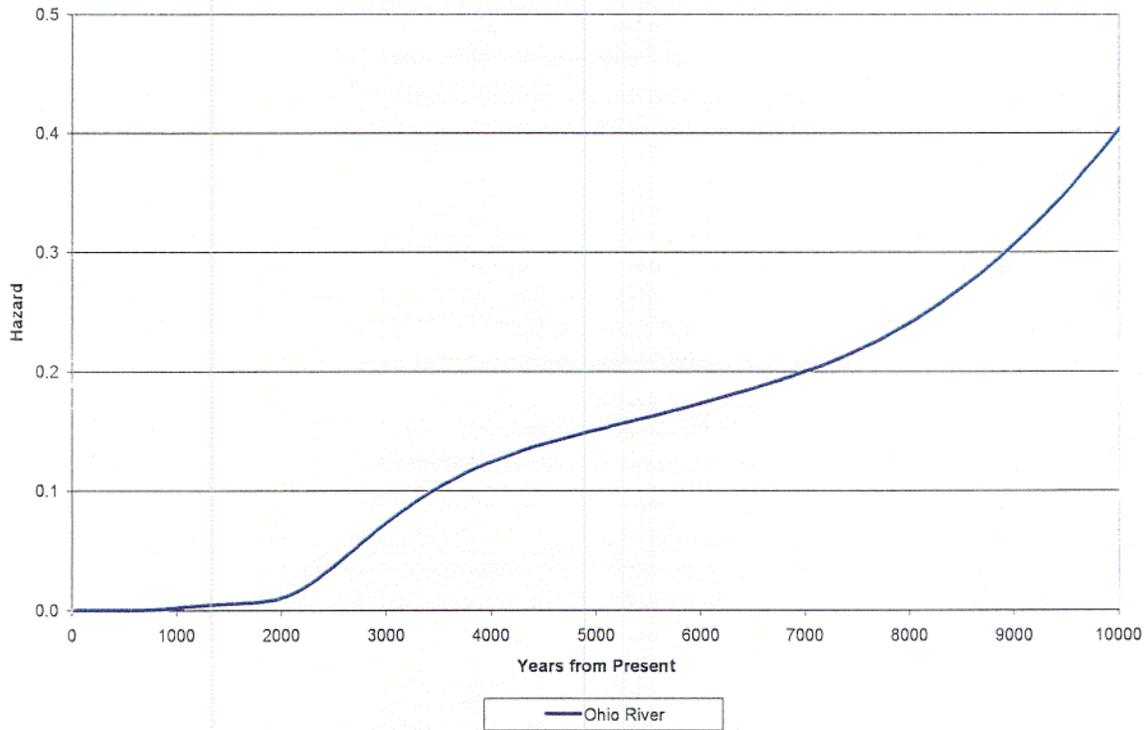


Fig. 5.16. Hazard posed to a recreational user wading in groundwater discharged to springs at the Ohio River point of exposure – CERCLA-derived waste disposal criteria used as a source term for the C-746-U Landfill.

chloride and 1,2-dichloroethane, which contribute approximately 78% of cumulative cancer risk at both the property boundary and Ohio River. Finally, the primary constituent driving cancer risk from chemicals at the third, and highest, peak at the property boundary is arsenic, which contributes virtually all of cumulative cancer risk.

As shown in Fig. 5.12, the cumulative cancer risks from radionuclides posed to a resident using groundwater drawn from a well completed in the RGA or Ohio River are higher than those for chemicals. For both locations, the cumulative cancer risk reaches an early peak near 1×10^{-5} at about year 500 followed by a decrease and subsequent increase to a peak risk near 1×10^{-4} at year 10,000. [Note that results are similar to those for chemicals in that all peaks are at or below the upper end of the EPA risk range for site-related exposures.] The primary radionuclide driving peak cancer risk at the earlier time at both locations is ^{99}Tc . The primary radionuclides driving peak cancer risk at the later times at both locations are ^{238}U , ^{234}U , ^{235}U , ^{226}Ra , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{230}Th , ^{232}Th , and ^{237}Np .

As shown in Fig. 5.13, the cumulative hazard posed to a resident drawing water at either location peaks once near year 200, then decreases, and then shows a continual increase until year 10,000 (i.e., peak hazard at year 10,000 of 12.2 and 4.6 for the property boundary and Ohio River, respectively). Cumulative hazard is consistently above 1 starting at year 1,100 and 2,500 for the property boundary and Ohio River points of exposure, respectively. At both locations, hazard is driven by the inorganic chemical COPCs.

As shown in Fig. 5.14, the cumulative dose from radionuclides posed to a resident shows a continual increase over years to peak doses of 42 and 19 mrem/year at year 10,000 for the property boundary and Ohio River points of exposure, respectively. At both points of exposure, the radionuclides contributing most to dose at year 10,000 are ^{237}Np and the plutonium isotopes.

As shown in Figs. 5.15 and 5.16, cumulative cancer risk to a recreational user and cumulative hazard to a child recreational user exposed to groundwater in springs at the Ohio River peaks a single time. The peak cumulative cancer risk is below 1×10^{-6} and occurs near year 180. This peak is driven by vinyl chloride and 1,2-dichloroethane. The peak cumulative hazard is below 1 and occurs at year 10,000. This peak is driven by chromium (32% of total) and other inorganic chemicals.

5.4.2 Discussion

As would be expected when using a source term which has higher concentrations for most COPCs, the peak cumulative cancer risks, hazards, and doses for the resident estimated using the disposal criteria as the waste source term are greater than those estimated in Sect. 5.1.1. However, like the results in Sect. 5.1.1, where peak cumulative cancer risk remained below the upper end of the EPA risk range for site-related exposures (i.e., 10^{-4}) at both residential use locations (see Fig. 5.1), the peak cumulative cancer risks estimated from modeling based upon the disposal criteria were near the upper end of the EPA risk range. However, unlike the earlier results, the cumulative hazard estimates for the resident derived using the disposal criteria as the source term reached peaks that were greater than 1 (i.e., the EPA benchmark value for hazard) and attained cumulative doses greater than the 15 mrem/year guidance value (EPA 1997) and the 25 mrem/year rule value (NRC 1997). However, all cumulative hazards greater than 1 occurred after year 1,000, and the cumulative dose that exceeded or approached the guidance value or rule value occurred after year 1,000.

These results indicate that cumulative hazards and doses to the resident exposed to groundwater contaminated by constituents migrating from the landfill may be unacceptable if waste placed in the landfill contains COPCs at concentrations equal to the disposal criteria. The limiting COPCs (i.e., the risk drivers) when the disposal criteria are used as the source term are inorganic chemicals and radionuclides, respectively. However, because the hazard and dose estimates are based upon three important

assumptions that are conservative, the results are undoubtedly biased high. These assumptions are that the landfill will actually release contaminants in a manner similar to the gradual failure scenario, that the wells supplying groundwater to the resident will be located in the hypothetical contaminant plume originating at the landfill, and that all constituents will be placed in the landfill at their maximum disposal criteria.

In any case, the calculation of peak hazards and doses greater than "acceptable" levels indicates that the CERCLA-derived waste disposal criteria may need to be adjusted downward if the C-746-U Landfill is truly expected to receive wastes that have average COPC concentrations that attain each criteria and if the gradual failure scenario is deemed reasonable. However, because attainment of all criteria in disposed waste is unlikely, as indicated by the comparison between the criteria and expected waste concentrations discussed in Chap. 7, such an adjustment is not necessary at this time. A more logical approach would be to institute a "sum-of-fractions" approach, which evaluates waste streams on a cumulative risk basis as they are placed in the landfill, when deriving the operational limits for the C-746-U Landfill.

6. UNCERTAINTIES

Several uncertainties affect the fate and transport modeling and the risk evaluations performed in earlier chapters. Each of these uncertainties, which have to do with waste characterization, modeling assumptions, and risk calculations, in turn affect the CERCLA-derived waste disposal criteria and contaminant inventory limits derived in this report. These uncertainties and their ultimate effect upon the CERCLA-derived waste disposal criteria and contaminant inventory limits are discussed in this section.

6.1 UNCERTAINTIES IN WASTE CHARACTERIZATION AND SOURCE TERM

The final CERCLA-derived waste disposal criteria and the contaminant inventory limits derived in this report are not affected greatly by the uncertainties in waste characterization and source term development (i.e., contaminant concentrations in the various waste forms). These results are not greatly affected because the criteria and limits are ultimately back-calculated from "acceptable concentrations" for a set of common PGDP COPCs. However, because this back-calculation relies on DAFs derived for analytes within surrogate groups derived from the waste inventory, it is possible that the use of the CERCLA-derived waste inventory to target indicator chemicals within surrogate groups may have led to the selection of the wrong indicator chemicals. In an attempt to prevent this uncertainty from greatly affecting the derivation of the DAFs, professional judgment, process knowledge, and preliminary results were used to select additional chemicals for refined modeling within some surrogate groups. For example, both TCE and vinyl chloride were modeled even though both are non-aromatic, straight-chain, halogenated hydrocarbons, and both pentachlorophenol and benzo(a)pyrene were modeled even though both are heavy SVOCs. Additionally, some compounds [e.g., PCBs and benzo(a)pyrene] were modeled even though previous work at the PGDP has shown that significant migration of these chemicals to, and through, groundwater at PGDP is unlikely. It should be noted that the risk calculations presented in Sect. 5.1, which were based upon the estimated waste inventory, were highly dependent upon the waste characterization because all exposure point concentrations were directly related to the initial concentrations in waste. As discussed in Chap. 3, only the characteristics of the soil waste form were derived empirically using sampling results. The characteristics of all other waste forms were derived using process knowledge and professional judgment. Therefore, concentrations of contaminants within these waste forms and the risk estimates derived from the results of the initial forward modeling run carry significant uncertainty.

While the contaminant characterization of the waste did not affect the ultimate product of this report to any great extent because the CERCLA-derived waste disposal criteria and the resulting contaminant inventory limits are ultimately back-calculated from acceptable concentrations in exposure media, the characterization of the physical and geochemical parameters of the source term may have a significant affect upon the criteria and limits. While these physical and geochemical parameters were selected from recognized sources (see Chaps. 3 and 4), the uncertainty in some parameters, such as the effect upon migration of varying pH within the source due to the generation of organic acids, could lead to faster migration of some chemicals and compounds and slower migration for others. Please see Sect. 6.2 for additional discussion of this uncertainty and its effects.

6.2 UNCERTAINTIES ASSOCIATED WITH TRANSPORT MODELING

A primary uncertainty associated with the transport modeling approach supporting the development of the CERCLA-derived waste disposal criteria and the contaminant inventory limits is the simplifying assumptions concerning the hydrogeology, soil properties and geochemistry, and distribution coefficients of contaminants in various media within the solid waste landfill facility. Generally, these assumptions let the

material in waste be considered a homogenized mass. Similarly, the modeling of infiltration into the solid waste landfill and contaminant migration out of the waste was simplified by assuming vertical movement only; transverse movement of the contaminants within the landfill was ignored. Also, the models accounted for flow through porous media only; no fracture flow was considered. Finally, as noted earlier, the modeling approach is limited by uncertainties in landfill design and waste composition.

In an attempt to understand some of these modeling uncertainties, a sensitivity analysis was performed using a hypothetical site at PGDP and ^{99}Tc . In this sensitivity analysis, various parameters were changed in the DUST model, and results from each DUST modeling run were put into AT123D to determine concentrations at hypothetical exposure points located at multiple distances.

The following parameters were constant in each simulation:

- Contaminant characteristics: ^{99}Tc
- Half-life = $2.13\text{E} \times 10^5$ years
- Solubility limit = 10 g/cm^3
- Molecular weight = 99 g/mol
- Simulation length = 1000 years
- Simulation time step = 2 years
- Spatial area of the facility = 3 acres
- Total depth modeled = 145 ft
- Total volume of waste soil = $257,383 \text{ yd}^3$
- Thickness of waste soil = 68 ft
- Exposure points (Site 9):
- Exposure point 1, 100 m from source
- Exposure point 2, at DOE Property Boundary Line (640 m from source)
- Exposure point 3, nearest surface water discharge point (Little Bayou Creek, 884 m from source)

The following parameters were varied in each simulation:

- Bulk density within wasteforms
 - Baseline: 1.5 g/cm^3
 - Tested: 1.2, 1.76 g/cm^3
- Moisture content within wasteforms
 - Baseline: 0.30
 - Tested: 0.2, 0.25, 0.40
- Waste type
 - Baseline: Soil waste only ($K_d = 0.10$ everywhere)
 - Tested: Five waste types in one cell [debris ($K_d=1.0$), metal ($K_d=1.0$), concrete ($K_d=1.5$), soil ($K_d=0.1$), and stabilized soil ($K_d=1.0$)]
- Number of waste layers
 - Baseline: 5
 - Tested: 1 (all soil waste in one large layer)
- Percolation rate
 - Baseline: 9.22 cm/year
 - Tested: 12.0, 2.0 cm/year

- Dispersivity
 - Baseline: 394 cm in each layer
 - Tested: $0.1 \times$ thickness of each layer, each layer has unique dispersivity
- Distribution coefficient (K_d) of waste
 - Baseline: $0.1 \text{ cm}^3/\text{g}$
 - Tested: 1.5, $1.0 \text{ cm}^3/\text{g}$
- Distribution coefficient (K_d) of clay barriers
 - Baseline: $0.1 \text{ cm}^3/\text{g}$
 - Tested: $1.3 \text{ cm}^3/\text{g}$
- Diffusion coefficient (D^*) of all soil layers
 - Baseline: $1.00 \times 10^{-6} \text{ cm}^2/\text{sec}$
 - Tested: $1.00 \times 10^{-8} \text{ cm}^2/\text{sec}$
- Combination runs
 - Wastefrom moisture content = 0.4, wastefrom bulk density = 1.2 g/cm^3
 - Wastefrom bulk density = 1.2 g/cm^3 , clay barrier $K_d = 1.3 \text{ cm}^3/\text{g}$
 - $K_d = 1.0 \text{ cm}^3/\text{g}$ in waste, $1.3 \text{ cm}^3/\text{g}$ in clay, $1.0 \text{ cm}^3/\text{g}$ in native soil

The results of these sensitivity analyses, in comparison with the baseline simulation for ^{99}Tc , are presented in Table 6.1 and Fig. 6.1. In general, increasing bulk density of the waste increased contaminant concentrations at the exposure points. Run #4 shows that an increase in bulk density from 1.5 g/cc to 2.0 g/cc (i.e., 33% increase) produced a 27% increase in exposure point concentrations. Similarly, Run #5 shows that a decrease in bulk density from 1.5 g/cc to 1.2 g/cc (i.e., 33% decrease) produced a 17 to 18% decrease in exposure point concentrations. Therefore, the ultimate effect of a higher bulk density would be smaller CERCLA-derived waste disposal criteria.

Runs #6 through #8 show sensitivity with respect to moisture content. Increasing the moisture content from 0.3 to 0.4 decreased concentrations at the receptor by 10 to 11%, and decreasing the moisture content from 0.3 to 0.25 and 0.2 increased concentrations by 5 and 12%, respectively. Therefore, the ultimate effect of a higher moisture content would be larger CERCLA-derived waste disposal criteria.

The percolation rate is one of the most sensitive parameters; increasing the percolation by 30% (Run #9) resulted in a 29% increase in concentration and decreasing the percolation by 78% (Run #10) resulted in a 78% decrease in concentration. Therefore, increasing the percolation rate increased concentrations at the exposure points, because more contaminants are released from the soil through the surface rinse mechanism. This would ultimately lead to smaller CERCLA-derived waste disposal criteria.

The distribution coefficient, K_d , is also a very sensitive parameter. Increasing the K_d of any layer decreased contaminant concentrations at exposure points. Therefore, CERCLA-derived waste disposal criteria would be larger.

Changing the diffusion coefficient in the DUST model had no effect on concentrations at the exposure points because contaminants are released by a surface rinse mechanism and not diffusion. Therefore, changing diffusion coefficient would not affect the CERCLA-derived waste disposal criteria.

Uncertainties with respect to the use of K_d values for ^{238}U were also evaluated. Three simulations were performed by varying the ^{238}U K_d values. The baseline run (Run #1) used K_d values of 1600 L/kg for 3-ft clay liner beneath the waste, 410 L/kg for organic materials in the waste, and 35 L/kg for all remaining

Table 6.1. Comparison of results of sensitivity analysis using ⁹⁹Tc as a test contaminant

Trial #	Waste Type	# Waste Layers	Moisture Content	Bulk Density	Dispersivity (cm)	Percolation Rate (cm/year)	K _d in Waste (cm ³ /g)	K _d in Clay (cm ³ /g)	K _d in Native Soil (cm ³ /g)	D* in Soils	⁹⁹ Tc Initial Mass (Ci)	Maximum Concentration (Ci/L) ^a			% Change		
												Receptor x	Receptor y	Receptor z	Receptor x	Receptor y	Receptor z
1 (Baseline)	Soil Only	4	0.3	1.5	394	9.22	0.1	0.1	0.1	1.00E-06	20.58	5.77E-09	2.31E-09	1.84E-09			
2	All Types	4	0.3	Varies	394	9.22	Varies	0.1	0.1	1.00E-06	23.72	5.37E-09	2.16E-09	1.71E-09	-7%	-6%	-7%
3	Soil Only	1	0.3	1.5	394	9.22	0.1	0.1	0.1	1.00E-06	20.58	6.09E-09	2.45E-09	1.94E-09	6%	6%	5%
4	Soil Only	4	0.3	2.0	394	9.22	0.1	0.1	0.1	1.00E-06	24.14	7.33E-09	2.94E-09	2.34E-09	27%	27%	27%
5	Soil Only	4	0.3	1.2	394	9.22	0.1	0.1	0.1	1.00E-06	16.46	4.78E-09	1.9E-09	1.52E-09	-17%	-18%	-17%
6	Soil Only	4	0.25	1.5	394	9.22	0.1	0.1	0.1	1.00E-06	20.58	6.1E-09	2.43E-09	1.94E-09	6%	5%	5%
7	Soil-Only	4	0.4	1.5	394	9.22	0.1	0.1	0.1	1.00E-06	20.58	5.18E-09	2.08E-09	1.64E-09	-10%	-10%	-11%
8	Soil Only	4	0.2	1.5	394	9.22	0.1	0.1	0.1	1.00E-06	20.58	6.44E-09	2.56E-09	2.06E-09	12%	11%	12%
9	Soil Only	4	0.3	1.5	394	12	0.1	0.1	0.1	1.00E-06	20.58	7.47E-09	2.98E-09	2.36E-09	29%	29%	28%
10	Soil Only	4	0.3	1.5	394	2	0.1	0.1	0.1	1.00E-06	20.58	1.22E-09	5.14E-10	4.08E-10	-79%	-78%	-78%
11	Soil Only	4	0.3	1.5	Varies	9.22	0.1	0.1	0.1	1.00E-06	20.58	6.34E-09	2.54E-09	2.01E-09	10%	10%	9%
12	Soil Only	4	0.3	1.5	394	9.22	1.5	0.1	0.1	1.00E-06	20.58	1.68E-09	6.72E-10	5.36E-10	-71%	-71%	-71%
13	Soil Only	4	0.3	1.5	394	9.22	0.1	1.3	0.1	1.00E-06	20.58	4.39E-09	1.75E-09	1.4E-09	-24%	-24%	-24%
14	Soil Only	4	0.3	1.5	394	9.22	0.1	0.1	0.1	1.00E-08	20.58	5.77E-09	2.31E-09	1.84E-09	0%	0%	0%
15	Soil Only	4	0.3	1.2	394	9.22	0.1	1.3	0.1	1.00E-06	16.46	3.59E-09	1.43E-09	1.14E-09	-38%	-38%	-38%
16	Soil Only	4	0.3	1.5	394	9.22	1.0	1.3	1.0	1.00E-06	20.58	1.46E-09	5.85E-10	4.65E-10	-75%	-75%	-75%

Notes:

^a Arbitrary distances for exposure points from the source for this sensitivity analysis:

Receptor x = 500 ft

Receptor y = 2000 ft

Receptor z = 3000 ft

Shaded cells indicate changed parameters.

D* = diffusion coefficient.

K_d = distribution coefficient.

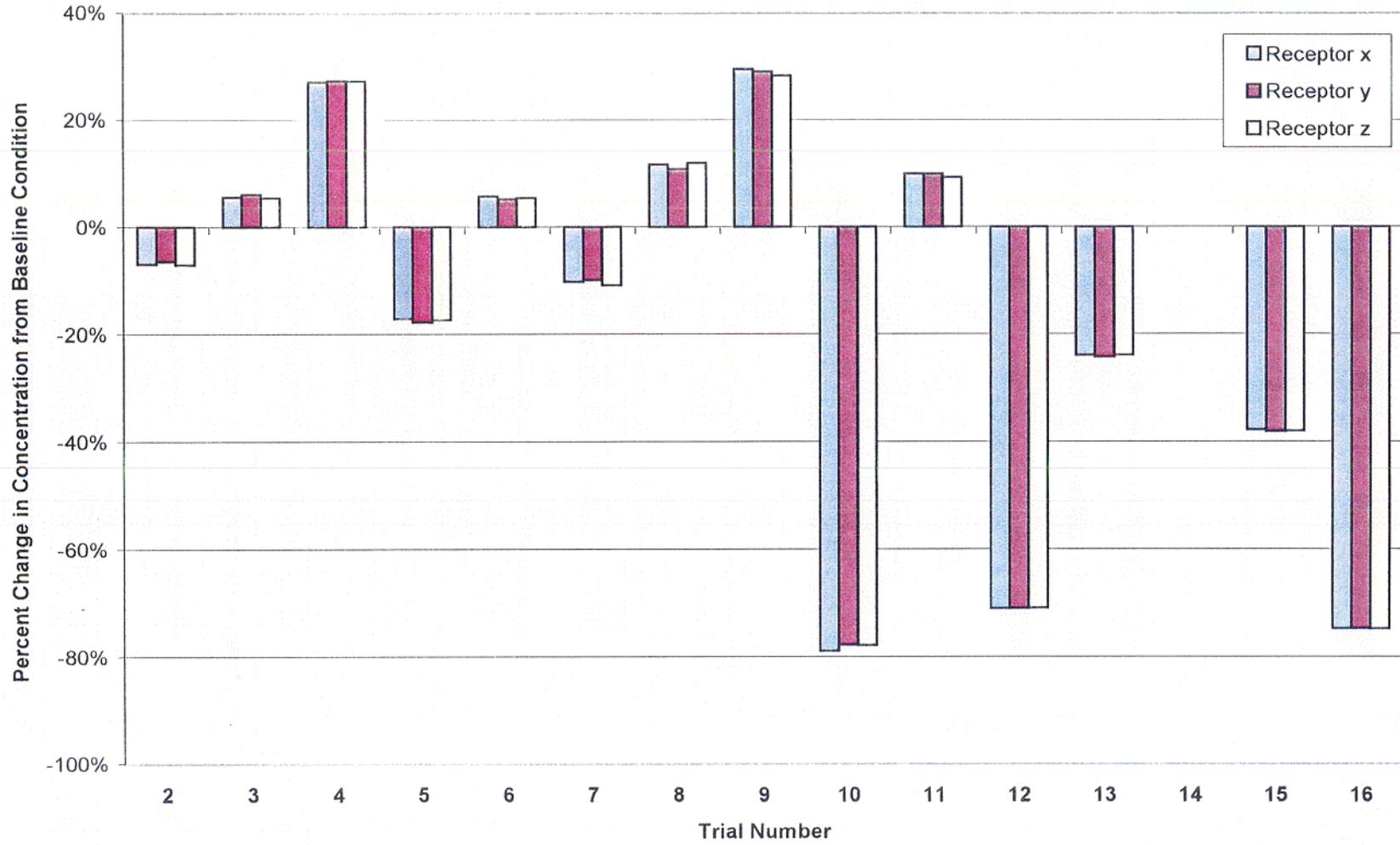


Fig. 6.1. Graphical comparison of results of sensitivity analysis using ⁹⁹Tc as a test contaminant.

materials within the model domain. Simulation Run #2 used K_d values of 35 L/kg for all materials within the model domain, and Simulation Run #3 used the same K_d values as Run #1 except a K_d value of 1600 was used for the 14.5-ft clay layer above the water table. The results of this analysis are shown in Figs. 6.2 and 6.3. The predicted concentrations of ^{238}U at the receptor locations increase significantly (greater than an order of magnitude) in Run #2 from Run #1, while maximum predicted concentration decreases approximately 30% for Run #3 from Run #1. Because the disposal criteria for all metals and radionuclides are calculated based on lower K_d values, the criteria are expected to be highly conservative if the K_d values of a constituent vary by orders of magnitude between clay and sand.

Other modeling uncertainties and their explanation are as follows.

- **Degradation of Organic COPCs**—The most conservative degradation half-life (i.e., the slowest degradation) found in literature was used for all the organic COPCs except for PCB. A value of 100 years was used for PCB as its half-life could not be found in literature. The use of this half-life may have led to an overestimation of the concentrations of some organic COCs at the exposure points. This would lead to smaller CERCLA-derived waste disposal criteria.
- **Ingrowth of Organic COPCs**—The modeling did not consider the ingrowth of degradation products of organic COPCs. This is most important for vinyl chloride, a degradation product of TCE. The effect of this uncertainty may be an underestimation of the concentrations for some organic COPCs. However, the transit time for most of the organic COPCs of importance is short enough that the importance of this uncertainty is minimal because transit times are much shorter than the half-lives. Therefore, this uncertainty is not expected to impact the CERCLA-derived waste disposal criteria.
- **Ingrowth of Radiological Constituents**—Neither the DUST nor AT123D models account for the ingrowth of radionuclide decay products. This may have resulted in an underestimation of exposure point concentrations of decay products with mobility higher than the starting radionuclide, and an overestimation of exposure point concentrations of decay products with mobility lower than the starting radionuclide. Similarly, because decay will reduce the concentration of the starting radionuclide in the waste, the exposure point concentrations of the starting radionuclide may be overestimated. Fortunately, most of the radionuclides identified by waste characterization either have very short half-lives relative to the time modeled (i.e., ^{137}Cs and ^{60}Co) or very long half-lives relative to the time modeled (i.e., ^{99}Tc , ^{238}U , etc.). Therefore, in general, the decay and ingrowth of radiological constituents should have very little effect on the final risk calculations and the identification of the major COPCs. However, it appears that the criteria derived for some radionuclides (e.g., $^{232/228}\text{Th}$, ^{241}Am) may not adequately account for all radioactive decay products, which would be more limiting (i.e., result in lower criteria values) than the parent radionuclide. For example, with the very long period of compliance considered in this analysis, the criterion for ^{241}Am would be constrained by the much lower value for ^{237}Np , the values for $^{232/228}\text{Th}$ could be constrained by $^{226/228}\text{Ra}$, etc. Therefore, RESRAD modeling was performed for these radionuclides. The results of this modeling are presented in the attachment to Appendix C.3 and indicate that this uncertainty is not important.
- **Gradual Failure versus Immediate Failure**—The analysis presented in Chap. 4 indicates that contaminants with high mobility (i.e., arrival time to receptor locations less than 200 years) are expected to be at higher concentrations at the receptor locations under an immediate failure scenario as compared to a gradual failure scenario. However, the impact is minimal with respect to less mobile COPCs. The modeled gradual failure assumed approximately 200 years to reach the steady-state failure condition from closure of the cap. However, in reality, degradation of the liner system may take much longer than 200 years. In which case, this modeling has over predicted the receptor concentrations, concentrations, thereby producing more stringent numbers for the CERCLA-derived waste disposal

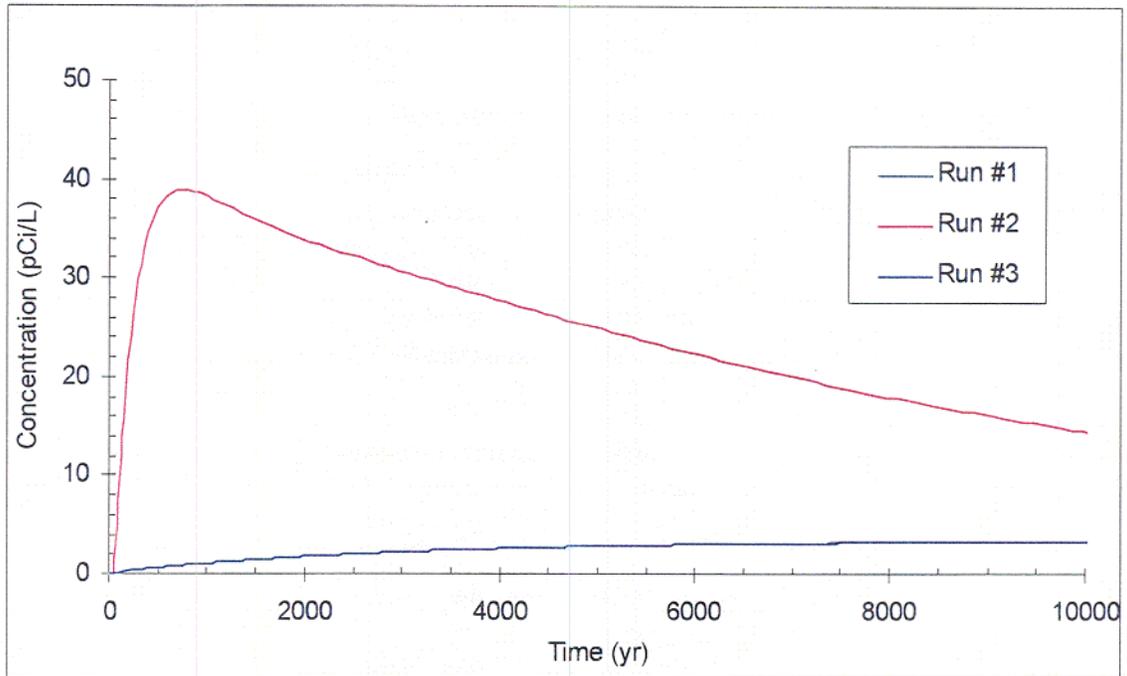


Fig. 6.2. Predicted leachate concentration of ^{238}U to top of landfill liner system by DUST.

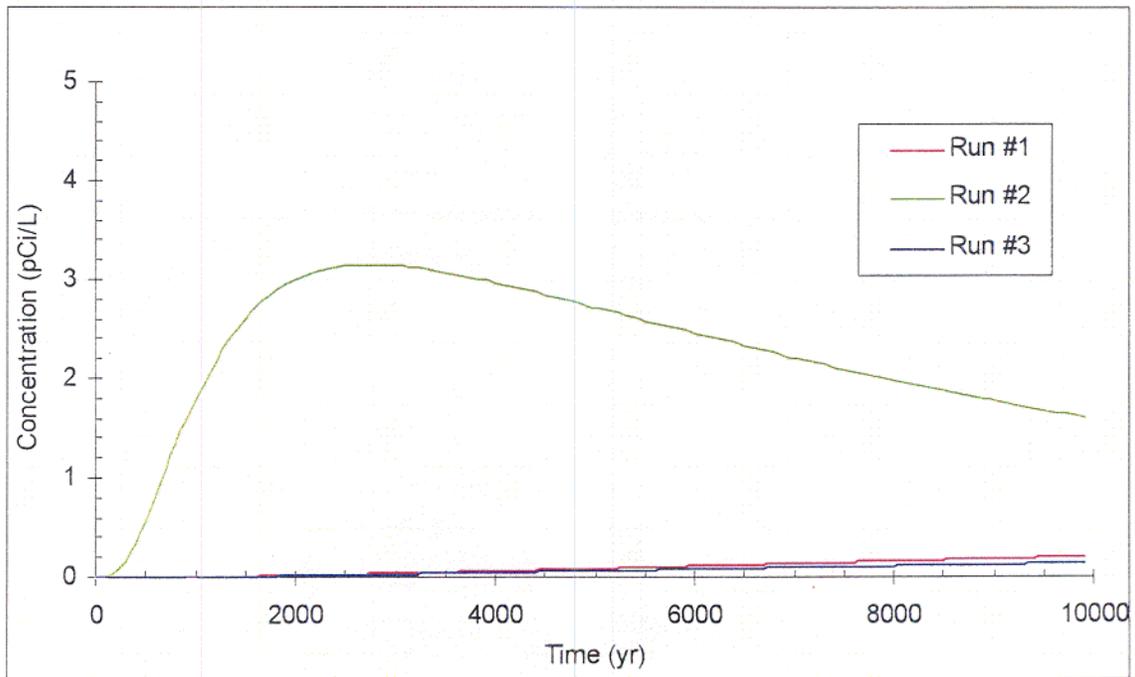


Fig. 6.3. Model-predicted groundwater concentration at the DOE property boundary.

criteria. On the other hand, if failure occurs due to some catastrophic event, then the predicted concentrations at the receptor locations for highly mobile COPCs can be expected to be much higher.

- **Gradual Failure versus No Failure**—Previously it was observed that COPCs with high mobility (i.e., those with arrival time at receptor locations that are less than 200 years under the gradual failure scenario) are predicted to be at higher concentrations at receptor locations under the immediate failure scenario when compared to the gradual failure scenario. However, the analysis presented in Chap. 4 indicates that the opposite is true under the no failure scenario. Under the no failure scenario, the predicted concentrations for all COPCs, except those in the highly mobile organic compound group (i.e., the vinyl chloride group), are zero over the 10,000 years of simulation time. Additionally, for the highly mobile organic compound COPCs, the predicted concentrations under the no failure scenario are well below those predicted under the gradual failure scenario and are below detection limits in all cases. The very small concentrations seen under the no failure scenario are the result of limited COPC flux to the environment and, for organic compounds, inventory reduction through biodegradation. These results indicate that the gradual failure scenario, which assumes that a steady-state failure condition would be conservatively reached approximately 200 years after closure of the landfill, probably overestimates the “real” potential for COPCs to migrate from the landfill to the points of exposure. Therefore, it can be concluded that the gradual failure scenario over-predicts the concentrations that may be attained at the points of exposure over the 10,000 years modeled, thereby leading to the derivation of CERCLA-derived waste disposal criteria that are conservative.
- **Use of Crushed Scrap Iron/Change of Soil Geochemistry**—A large portion of the C-746-U Landfill consists of scrap metal, which is estimated to occupy a volume of 368,118 cubic yards. This volume translates to a normalized thickness of 12 ft for the metal-waste. This form of waste will be crushed and mixed with native soil before being disposed into the landfill. The inventory of the metals reveals that the majority of the mass is due to iron alone (72% by mass), followed by nickel (26.5% by mass), leaving 1.5% of total mass for the rest of the metals combined. So the chemical characteristics of iron are significant to the leachate generation mechanism in the landfill. In the recent days, a geochemical barrier has been successfully applied in groundwater treatment processes. This process involves installation of a reactive wall filled with chemical media, perpendicular to a groundwater plume. The chemicals in the media effect the migration of the contaminant through one of three mechanisms – sorption, degradation (chemically or biologically), or reductive-precipitation. Zero Valent Iron (ZVI) in granular form has been used as the chemical media in the geochemical barrier and has been seen to retard the migration of radionuclides (mostly uranium) and reduce chlorinated hydrocarbon compounds (TCE, tetrachloroethene, etc.) to relatively harmless compounds. As iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The process dissolves the iron granules, but the dissolution rate is slow, and the barrier can be expected to remain active for years, even decades. Naturally found iron in the soil media – known as ferric oxyhydroxide – has been used successfully to adsorb radioactive elements (i.e., U, Cs, Ra, Sr, and Tc) as well as heavy metals (i.e., Ni, Pb, Cd, Cr, V, and Hg). Several laboratory-scale and pilot plant studies on the effectiveness of ZVI on reducing halogenated VOCs revealed that the concentration of dissolved iron increased as the result of the reactions, keeping pH of the solutions fairly similar, decreasing dissolved oxygen of the water, and slightly increasing alkalinity (Vidic and Pohland 1996). Chemical barriers installed in the groundwater pathway in the DOE-owned Y-12 plant in Oak Ridge, Tennessee, has significantly removed uranium, nitrate, and technetium from groundwater. Therefore, it may be concluded that the crushed scrap metals to be disposed of at C-746-U Landfill may inhibit the migration of the radioactive elements as well as heavy metals and facilitate the degradation of chlorinated solvents (e.g., TCE). Therefore, if the geochemical effects of ZVI were completely integrated into the derivation of the CERCLA-derived waste disposal criteria, then some criteria would have been larger.

- **Importance of Solubility**—A primary factor that can affect concentrations of contaminants in leachate and groundwater is the solubility of the particular chemical form of the contaminant when it comes into contact with water. In general, soluble chemical forms include the electrically-neutral elemental form of the contaminant, also known as the metal, and stable chemical compounds, of which there can be many for a given contaminant. For the purposes of contaminant leaching, solubility of a chemical form is defined as *the maximum amount of a contaminant that will be released in a given volume of water at a specified temperature as the result of dissolution of the original chemical form.*

Whereas solubility describes the equilibrium mass relationship between the chemical form and water, chemical stability describes the conditions under which particular chemical forms can exist. Many physical/chemical parameters influence stability of a chemical form within a system (i.e., generally, and in the case of the U Landfill, water-bearing systems). Chief among these factors are reduction-oxidation potential (Eh), pH, and the presence of ions. Chemical stability is important to the discussion of solubility because changes in physical/chemical parameters of a system can create a new chemical form of a contaminant that has a different solubility from the original form.

Four key potential contaminants at the C-746-U Landfill that will be emphasized in this discussion are arsenic (As), technetium (Tc), neptunium (Np), and uranium (U). These elements are key because they are prevalent across the PGDP and because they drive most of the risk to human health that results from exposure to soils and other solid materials at the plant. All four elements can exist either as metals or in several different chemical compounds. The particular isotope of the element is of no concern here as the mass number of an element has no effect on the chemical behavior of the element.

Key to understanding solubility-related uncertainties in the risk calculations for the C-746-U Landfill is an understanding of the chemical form of each of the four key potential contaminants when they were placed in the landfill.

It can be assumed that none of these contaminants was placed in the landfill in liquid form because liquids are excluded from disposal at the C-746-U Landfill. Additionally, the nature of the landfill precludes the deposition of any quantities of the four contaminants either as metals or in the form of chemical compounds, and the waste inventory in Section 3.1 does not specifically mention placement of As, Tc, Np, or U in the landfill. Therefore, the possible presence of the four contaminants in the landfill must occur as the result of contamination of other media that were placed in the landfill. Among the media listed in Section 3.1, the most likely to have been contaminated by As, Tc, Np, or U are soils from PGDP site characterization studies, D&D materials (e.g., concrete and other building materials), and scrap metal. D&D materials and scrap metal would have become contaminated by adherence of charged ionic forms of the contaminants to oppositely charged sites on the materials constituting the media. Presumably, under atmospheric conditions the contaminant ions would be positively charged, i.e., oxidized. For example, the ionic form of uranium under these conditions might be the uranyl ion, UO_2^{2+} . Similarly, soils would also contain a substantial proportion of their contaminants in the ionic form by adherence to charged sites on soil particles. Soils may also have contained any of the four key potential contaminants in their electrically-neutral elemental forms as metals or in the form of stable chemical compounds, but amounts of these chemicals would have been negligible in order for the soils to meet the landfill's waste acceptance criteria.

In order for solubility to be a significant limiting factor in transport of As, Tc, Np, and U out of the C-746-U Landfill, it would be necessary that substantial growth of metals or stable chemical

compounds of the four contaminants occur inside the landfill following disposal and burial of the various media. Such an event could conceivably occur as the result of mobilization of the contaminants by water percolating through the landfill and subsequent formation of stable compounds under new physical/chemical conditions in the landfill environment. Probably the most significant potential effect on the physical/chemical conditions in the landfill would be a movement toward more reducing conditions (lowering Eh) as buried iron is oxidized (i.e., as it rusts). These conditions (please see preceding subsection for additional information) would tend to create an environment in which relatively insoluble oxides become the stable forms of the contaminants as opposed to the original ionic forms that exist under more oxidizing conditions. An additional effect of oxidation of buried iron would be that as metallic iron is oxidized during rusting it will release the contaminant ions that were originally bound to the charged sites on the metallic iron.

Therefore, it is concluded that any As, Tc, Np, or U to have been placed in the C-746-U Landfill would initially have been predominantly the ionic forms of these elements adhering to oppositely charged sites on surfaces of materials disposed in the landfill. Because of this, solubility would not play a role in the transport of these contaminants out of the landfill if they remain in that form. However, under a reducing environment, solubility could play a greater role as more stable chemical forms become more prevalent. Therefore, the factor controlling migration under current chemical forms would be the relationship between each particular ion and the material to which it was adhered (i.e., the distribution coefficient, K_d).

6.3 UNCERTAINTIES IN RISK CALCULATIONS

6.3.1 Human Health

The primary uncertainties in the risk calculations are the selection of the receptor used for the identification of the significant COPCs as part of the risk evaluation and the validity of the receptors selected to help refine the CERCLA-derived waste disposal criteria as part of the performance evaluation. The first uncertainty (i.e., the selection of the groundwater user as the most sensitive receptor) had only a small impact on the disposal criteria because the majority of the disposal criteria derived from exposure concentrations protective of this receptor were shown to be protective of other receptors as well. Additionally, because the disposal criteria were modified after considering other receptors, potential risks to other receptors and the uncertainty in the criteria were minimized.

Similarly, the selection of other receptors used to refine the disposal criteria is assumed to contain little uncertainty because these receptors were selected using an exposure assessment based upon the realistic future land use of the landfill site and areas downgradient. (Please see land use map and discussion in Sect. 2.2.1.) Additionally, the exposure assessment was consistent with DOE orders that require control and maintenance of the landfill as long as the material in the landfill and the landfill itself could pose a hazard to human health and the environment. Because the landfill will contain at least trace amounts of long-lived radionuclides (as allowed under the authorized limits process contained in DOE orders) and organic compounds (as allowed under TSCA), this means that DOE will be required to control and maintain the landfill well beyond the 30 years assumed in the CSM. (Additionally, Commonwealth of Kentucky regulation allows for the extension of the post-closure care period of the landfill beyond 30 years if this is deemed necessary.) This requirement for continued control and maintenance makes it very unlikely that the landfill's structure and systems will begin to fail after 30 years, that casual access to the landfill will be possible, and that excavation at the landfill will occur. It should be noted that the use of a groundwater well located in the RGA at the DOE property boundary is a very conservative assumption given the industrial nature of the PGDP site, which makes the area immediately adjacent to it unattractive for

homes under current social norms. If a location further downgradient is used, then the CERCLA-derived waste disposal criteria would be markedly higher for COPCs with larger K_{ds} .

Another uncertainty that deserves some attention concerns the exposure routes considered for the groundwater user. If additional routes had been included, such as the consumption of irrigated produce, then lower criteria and limits may have resulted. However, the uncertainty in biota transfer modeling for organic compounds would be marked due to the use of modeled water concentrations as inputs to highly conservative biota contaminant transfer models. Additionally, note that in western Kentucky, surface water is used most often in crop irrigation. Therefore, the use of groundwater concentrations would have led to gross overestimates of contaminant concentrations in biota. While the exclusion of the biota pathways did result in higher criteria, this made the criteria more certain.

6.3.2 Uncertainties in Ecological Risk

This section discusses the uncertainties associated with the ecological risk calculations. The uncertainties are discussed in terms of the CSM (Sect. 6.3.2.1), exposures (Sect. 6.3.2.2), and effects (Sect. 6.3.2.3).

6.3.2.1 Uncertainties in the conceptual site model

There are three potential sources of uncertainty in the conceptual site model for ecological receptors: receptor selection, exposure pathways, and immediate failure of the clay liner. The ecological receptors selected for this risk evaluation represent those that should be most at risk if releases occur because they are the receptors likely to be exposed to the released materials in the affected medium, and they are the receptors known to be sensitive to many of the materials. Thus, the uncertainty associated with selecting these receptors for risk evaluation is estimated to be low.

The uncertainties associated with the ecological exposure pathways that were selected for development of CERCLA-derived waste disposal criteria are also estimated to be low because the pathways selected are judged most likely to occur and produce the highest potential exposures to the ecological receptors.

The conceptual model assumes there is no immediate failure of the clay liner. A model of immediate failure of the clay liner of the C-746-U-Landfill produced revised concentrations for seven halogenated hydrocarbons (vinyl chloride; cis-1,2-dichloroethene; trans-1,2-dichloroethene; chloroform; 1,1-dichloroethene; 1,2-dichloroethane; and 1,2-dichloroethene), mixed isomers, and one highly mobile radionuclide (^{99}Tc) in the groundwater plume at the Ohio River. The modeled concentrations of five of the seven halogenated hydrocarbons following immediate failure of the clay liner are predicted to increase by 282-fold, resulting in a corresponding increase of the hazard quotients (HQs) for those chemicals for aquatic biota. The modeled concentrations for the other two halogenated hydrocarbons (vinyl chloride and 1,2-dichloroethane) are predicted to increase by 163-fold and 129-fold, respectively. The largest HQ for aquatic biota exposed to groundwater at the Ohio River without an immediate failure of the clay liner is five orders of magnitude below 1 for chloroform. With an immediate failure of the clay liner, that HQ is predicted to increase by 282-fold but would still be far below 1. The modeled concentrations of the radionuclide do not change under the immediate failure scenario, and the HQs were much less than 1 under a gradual failure. Therefore, immediate failure of the clay liner should cause negligible risk to aquatic biota because even the largest HQ is predicted to be much less than 1.

Immediate failure of the clay liner at the C-746-U-Landfill should cause negligible risk to sediment-dwelling biota in the Ohio River and to small mammals or birds that ingest groundwater at springs because even the largest HQ under gradual failure is far below 1. In addition, only one of the seven halogenated hydrocarbons (i.e., 1,2-dichloroethane) had a dietary NOAEL for birds, so HQs could not be calculated for the other six chemicals. In summary, the modeled concentrations of seven halogenated hydrocarbons and a highly mobile radionuclide in groundwater at the Ohio River are low enough such

that the risks to aquatic biota, sediment-dwelling biota, small mammals, and birds are predicted to be negligible because the HQs are all much less than 1.

6.3.2.2 Uncertainties in ecological risk exposures

One assumption for all of the ecological receptor exposures was that the receptors receive 100% exposure to the applicable media. For example, aquatic and sediment-dwelling biota are assumed to spend 100% of their time living in the media containing the predicted concentrations of chemicals and radionuclides. The shrews and wrens are assumed to obtain 100% of their drinking water from affected springs. The home ranges of these two receptors are small enough that the receptors could obtain all their drinking water from a single source such as the spring, especially if no other water sources were available. However, there probably are multiple sources of drinking water within the home ranges of these two receptors so the reported exposure doses likely overestimate the actual exposures to chemicals in the groundwater discharging at springs.

Another environmental factor that could affect exposures of aquatic, sediment-dwelling, and terrestrial insectivore biota to chemicals in the groundwater from the C-746-U Landfill is the failure of the leachate to reach the groundwater and discharge to the soil surface or surface water. If the plume of leachate from the C-746-U Landfill does not discharge or otherwise have an opportunity to mix with the Ohio River, the predicted concentrations of analytes in the leachate and groundwater are moot because there would be no exposure pathway for ecological receptors.

Default K_{ds} , based on studies using sand, were used in the model to predict concentrations of chemicals in the groundwater. There is uncertainty as to whether the default K_{ds} are representative of the site-specific K_{ds} for the sediments in the Ohio River. If site-specific K_{ds} for sediment are lower than the default K_{ds} , the predicted sediment concentrations would be overestimated, meaning that HQs overestimated potential risk. In contrast, if the site-specific K_{ds} for sediment are higher than the default K_{ds} , the sediment concentrations of analytes are underestimated, meaning that the observed HQs actually underestimated risk.

6.3.2.3 Uncertainties in ecological risk effects

The PGDP NFA concentrations for surface water and sediment have been approved by the Ecological Risk Assessment Working Group for the Paducah Site (DOE 2001b), so they are acceptably uncertain. There is some uncertainty whether the NFAs are overly conservative for setting disposal criteria. However, this uncertainty was addressed in part by examining NFAs of chemicals that could potentially affect ecological receptors. Because alternative NFAs were derived in some cases, there is some uncertainty in the protectiveness of the alternative NFAs.

Some chemicals lacked a PGDP NFA concentration for surface water or sediment, or a dietary NOAEL, so an alternative toxicity benchmark was used for them. Some alternatives for surface water and sediment were PGDP NFAs for chemicals that had a very similar, or identical, molecular composition and very similar molecular structures as the chemical that lacked the NFA. For example, the surface water NFA for m-xylene was used as an alternative toxicity benchmark for o-xylene and p-xylene. The only difference between the three xylene isomers is the location of the second methyl group relative to the first methyl group on the "benzene ring" that comprised the foundation of the xylene molecule. The location of the methyl groups will change the shape of the xylene molecule, which potentially could effect its toxicity. However, the alternatives were used with the assumption that the isomers are structurally similar enough to minimize differences in toxicity between the isomers. The same rationale was used for 1,2-dichloroethylene and its isomers. Other alternatives were based on toxicity benchmarks for chemicals that did not have PGDP NFAs. For example, the surrogate toxicity benchmark for 2-butanone, chlorobenzene, and 2-methylphenol were based on equilibrium partitioning-derived sediment quality benchmarks for nonionic organic chemicals

corresponding to aqueous benchmarks. There is uncertainty whether the alternative benchmarks are as conservative as NFAs. The alternative values are assumed to have low uncertainty because they are published benchmarks based on effects data.

The sediment NFA for silver, 3.8E-04 mg/kg, is several orders of magnitude lower than other published NOAEL-based toxicity benchmarks. The alternative benchmarks used here are the National Oceanic and Atmospheric Administration ER-L for silver, 1.00E+00 mg/kg, and the FDEP TEL value, 0.73 mg/kg. The ER-Ls are the 10th percentile of the range of concentrations of chemicals associated with biological effects, as documented by Long and Morgan (1991). The FDEP TELs are calculated using an approach similar to that used for the ER-Ls, but also incorporate chemical concentrations observed, or predicted to be associated, with no adverse biological effects. The TEL represents the upper limit of the range of sediment chemical concentrations dominated by "no effects" data. Thus, the PGDP NFA value appears to be extremely conservative relative to other screening benchmarks and was replaced with an alternative value.

6.4 SUMMARY OF UNCERTAINTIES

This section presents Table 6.2 listing the uncertainties discussed earlier in this chapter, including qualitative estimates of importance of each uncertainty to the derivation of the CERCLA-derived waste disposal criteria and contaminant inventory limits.

Table 6.2. Summary of uncertainties that may affect derivation of final CERCLA-derived waste disposal criteria and contaminant inventory limits

Group	Uncertainty Description	Potential Effect on Final Criteria and Inventory Limits
Waste characterization and source term	Projecting future CERCLA-derived waste volumes from current baseline projections.	Minor because estimates are ultimately derived from "acceptable" concentrations in exposure media.
	Estimating characteristics of future CERCLA-derived waste from current data.	Minor because estimates are ultimately derived from "acceptable" concentrations in exposure media.
	Selection of incorrect indicator chemical for a surrogate group.	Minor because chemicals that were not selected as indicator chemicals but were determined to drive risk were modeled as part of the iterative methodology.
Transport Modeling	Use of simplifying assumptions concerning hydrogeology, soil properties and geochemistry, and waste geochemistry.	Varying effects as shown in the sensitivity analysis presented in Sect. 6.2. Larger criteria and inventory limits would result if bulk density and percolation rate were set at smaller values, or if moisture content and distribution coefficient (K_d) were set at greater values.
	Degradation of organic COPCs.	Increasing degradation rates would result in larger criteria and inventory limits.
	Ingrowth of organic COPCs.	Accounting for ingrowth would have no effect on criteria or inventory limits unless half-lives of organic chemicals were longer than expected transit times and if decay products were transported at a significantly greater rate. If either of these factors are true then criteria and inventory limits would be smaller.

Table 6.2. Summary of uncertainties that may affect derivation of final CERCLA-derived waste disposal criteria and contaminant inventory limits

Group	Uncertainty Description	Potential Effect on Final Criteria and Inventory Limits
	Ingrowth of radiological constituents.	Accounting for ingrowth would have a minimal effect because this effect was accounted for as part of the risk evaluation used to derive the criteria and limits.
	Rate of landfill failure.	Using a higher rate of failure would lead to smaller criteria for those COPCs with short transit times. Assuming no failure would lead to larger criteria and limits for all COPCs.
	Effect of scrap metal upon other COPCs.	Reducing environment from scrap oxidation could lead to increased degradation of chlorinated solvents and reduced transport of metal. These would lead to larger criteria and limits.
	Solubility of inorganic COPCs in water.	Low solubility of waste forms that are solid pieces of metal would lead to larger criteria and limits. However, most inorganic COPCs are not deposited in environment in that form. Therefore, expected effect in minimal.
Human Health Risk Calculations	Selection of receptors – no exposure to waste	Selecting receptors directly exposed to waste would lead to smaller criteria and limits for COPCs presenting a high direct exposure risk.
	Selection of receptors – selection of groundwater user point of exposure.	Selecting locations farther from the hypothetical release point would lead to larger criteria and limits.
	Routes of exposure for groundwater user.	Including more routes of exposure (e.g., the farm produce consumption pathways) could lead to smaller criteria and limits for COPCs that translocate or bioaccumulate.
Ecological Risk Calculations	Selection of receptors – additional receptors.	Including additional receptors under the failure scenario used would have no effect on criteria because the most sensitive ecological receptors were used in the analysis.
	Selection of receptors – no exposure to waste.	Selecting receptors directly exposed to waste would lead to smaller criteria and limits for COPCs presenting a high direct exposure risk.
	Rates of exposure.	Reducing rate of exposure to groundwater as a drinking water source would reduce dose. This would result in larger criteria and limits.
	Ecological risk effects	Considering uncertainties in screening value selection led to use of larger benchmarks for some COPCs. Using default benchmarks would have led to smaller criteria and limits for some COPCs.

7. CONCLUSIONS AND OBSERVATIONS

This chapter presents the conclusions and observations regarding the modeling effort. Observations include comparisons between the final CERCLA-derived waste disposal criteria and the Toxicity Characteristic Leaching Procedure (TCLP)- and TSCA-based values for PGDP DOE waste disposal units and between the criteria and concentrations in the expected CERCLA-derived waste expected to be placed in the C-746-U Landfill.

7.1 COMPARISON OF FINAL CERCLA-DERIVED WASTE DISPOSAL CRITERIA TO TCLP- AND TSCA-BASED VALUES AND EXPECTED WASTE CONCENTRATIONS

In order to develop operating limits for the C-746-U Landfill, applicable regulations from multiple programs will need to be integrated. Table 7.1 begins this integration by showing a comparison between the final CERCLA-derived waste disposal criteria and the TCLP- and TSCA-based values for PGDP DOE waste disposal units. TCLP-based values were taken from Table 3.3, and the TSCA-based value was taken from regulations.

As shown in Table 7.1, only two inorganic chemicals and one organic compound have CERCLA-derived waste disposal criteria less than their TCLP-based values. These are:

- arsenic with a criterion of 28.8 mg/kg versus a TCLP-based value of 100 mg/kg,
- mercury with a criterion of 3.13 mg/kg versus a TCLP-based value of 4.00 mg/kg, and
- chlorobenzene with a criterion of 179 mg/kg versus a TCLP-based value of 2,000 mg/kg.

While these results appear to be of note because it appears that the CERCLA-derived waste disposal criteria may be more limiting for these chemicals when placing waste in the landfill than the RCRA TSCA-based values, a closer examination reveals that these results are probably of little significance. For mercury and chlorobenzene, the results have little significance because their disposal criteria are limited by their soil saturation limit and not by their migration potential as shown in Table 5.18. (That is, the disposal criteria calculated ignoring the soil saturation limit for these chemicals are 61.8 mg/kg and greater than unity, respectively.) Therefore, it appears that for mercury and chlorobenzene the disposal criteria are less than their TCLP-based values not because of restrictions due to migration but due to the lack of the consideration of soil saturation in the derivation of the TCLP-based values. (For a discussion of the derivation of the TCLP-based values, please see DOE 1999b.) For arsenic, the results probably have little significance for two reasons. First, the TCLP-based value, which is based on the current maximum contaminant level (MCL) of 50 µg/L, may be reduced by one-fifth once the revised MCL of 10 µg/L is used to regulate Subtitle D landfills. This will result in a TCLP-based value of 20 mg/kg, a value less than the disposal criteria. Second, as discussed next in this section, the disposal criteria for arsenic is approximately seven times greater than the projected concentration in CERCLA-derived waste expected to be placed in the C-746-U Landfill (i.e., 4.22 mg/kg). Therefore, it is unlikely that arsenic will limit the placement of any waste package in the landfill.

Table 7.1 also contains a comparison between the disposal criteria and the expected volume-weighted average concentrations for CERCLA-derived waste projected to be placed in the C-746-U Landfill. As shown in Table 7.1, one inorganic chemical, but no organic compound or radionuclide, has a CERCLA-derived waste disposal criterion less than its expected volume-weighted average CERCLA-derived waste concentration. The inorganic chemical is:

- iron with a criterion of 100,000 mg/kg versus a projected waste concentration of 192,000 mg/kg.

Table 7.1. Comparison between CERCLA-derived waste disposal criteria and TCLP values for PGDP DOE waste disposal units and concentrations reported for CERCLA-derived waste projected to be acceptable for placement in the C-746-U Landfill

Chemical	CERCLA-derived waste disposal criteria ^a	TCLP or TSCA concentration ^b	CERCLA-derived waste concentration ^c	Comparison versus TCLP and TSCA ^d	Comparison versus CERCLA-derived waste concentration ^e
<i>Inorganic Chemicals (mg/kg)</i>					
Antimony	6.79E+01		1.24E+00	No Value	Criterion > Waste Value
Arsenic	2.88E+01	1.00E+02	4.22E+00	Criterion < TCLP	Criterion > Waste Value
Barium	1.14E+04	2.00E+03	2.82E+02	Criterion > TCLP	Criterion > Waste Value
Beryllium	2.40E+04		5.59E-01	No Value	Criterion > Waste Value
Cadmium	5.70E+02	2.00E+01	6.23E-01	Criterion > TCLP	Criterion > Waste Value
Chromium	4.37E+03	1.00E+02	7.07E+01	Criterion > TCLP	Criterion > Waste Value
Copper	5.22E+03		3.19E+02	No Value	Criterion > Waste Value
Iron	1.00E+05 ^g		1.92E+05	No Value	Criterion < Waste Value
Lead	7.77E+04	1.00E+02	1.66E+01	Criterion > TCLP	Criterion > Waste Value
Manganese	4.68E+03		3.13E+02	No Value	Criterion > Waste Value
Mercury	3.13E+00 ^f	4.00E+00	6.69E-02	Criterion < TCLP	Criterion > Waste Value
Molybdenum	3.87E+01		3.15E+00	No Value	Criterion > Waste Value
Nickel	1.00E+05 ^g		6.90E+04	No Value	Criterion > Waste Value
Selenium	7.77E+01	2.00E+01	2.63E-01	Criterion > TCLP	Criterion > Waste Value
Silver	7.77E+03	1.00E+02	8.85E-01	Criterion > TCLP	Criterion > Waste Value
Thallium	9.80E+01		4.41E-01	No Value	Criterion > Waste Value
Uranium	7.79E+02		1.57E+02	No Value	Criterion > Waste Value
Vanadium	1.00E+05 ^g		4.18E+01	No Value	Criterion > Waste Value
Zinc	7.47E+04		5.16E+01	No Value	Criterion > Waste Value
<i>Organic Compounds (mg/kg)</i>					
Acenaphthene	1.00E+05 ^g		5.58E-02	No Value	Criterion > Waste Value
Acenaphthylene	1.00E+05 ^g		5.77E-02	No Value	Criterion > Waste Value
Acrylonitrile	1.47E+04 ^f		2.43E-03	No Value	Criterion > Waste Value
Anthracene	1.00E+05 ^g		8.63E-02	No Value	Criterion > Waste Value
Benzene	4.38E+02 ^f	1.00E+01	4.06E-03	Criterion > TCLP	Criterion > Waste Value
Butanone, 2-	5.53E+04 ^f	4.00E+03	9.14E-01	Criterion > TCLP	Criterion > Waste Value
Carbon Tetrachloride	2.57E+02 ^f	1.00E+01	3.40E-03	Criterion > TCLP	Criterion > Waste Value
Chlordane, alpha-	1.00E+05 ^g	6.00E-01	1.89E-03	Criterion > TCLP	Criterion > Waste Value
Chlordane, gamma-	1.00E+05 ^g	6.00E-01	1.89E-03	Criterion > TCLP	Criterion > Waste Value
Chlorobenzene	1.79E+02 ^f	2.00E+03	4.56E-01	Criterion < TCLP	Criterion > Waste Value
Chloroform	1.92E+03 ^f	1.20E+02	2.84E-02	Criterion > TCLP	Criterion > Waste Value
Dichlorobenzene, 1,4-	1.00E+05 ^g	1.50E+02	5.71E-02	Criterion > TCLP	Criterion > Waste Value
Dichloroethane, 1,2-	2.00E+03 ^f	1.00E+01	3.40E-03	Criterion > TCLP	Criterion > Waste Value
Dichloroethene, 1,1-	5.72E+02 ^f	1.40E+01	1.40E-02	Criterion > TCLP	Criterion > Waste Value
Dichloroethene, 1,2- (mixed isomers)	2.10E+02 ^f		8.77E-05	No Value	Criterion > Waste Value
Dichloroethene, cis-1,2-	8.01E+02 ^f		2.22E-01	No Value	Criterion > Waste Value
Dichloroethene, trans-1,2-	1.46E+03 ^f		8.41E-02	No Value	Criterion > Waste Value
Dinitrotoluene, 2,4-	1.00E+05 ^g	2.60E+00	2.16E-02	Criterion > TCLP	Criterion > Waste Value
Dioxins/Furan (Total)	1.00E+05 ^g		4.84E-06	No Value	Criterion > Waste Value
Ethylbenzene	6.15E+01 ^f		4.28E-03	No Value	Criterion > Waste Value
Fluoranthene	1.00E+05 ^g		1.52E-01	No Value	Criterion > Waste Value
Fluorene	1.00E+05 ^g		5.50E-02	No Value	Criterion > Waste Value
Heptachlor Epoxide	1.00E+05 ^g	1.60E-01	1.64E-04	Criterion > TCLP	Criterion > Waste Value
Hexachlorobenzene	1.00E+05 ^g	2.60E+00	2.16E-02	Criterion > TCLP	Criterion > Waste Value
Hexachlorobutadine	1.39E+02 ^f	1.00E+01	2.34E-02	Criterion > TCLP	Criterion > Waste Value
Hexachloroethane	1.00E+05 ^g	6.00E+01	3.54E-02	Criterion > TCLP	Criterion > Waste Value
Methoxychlor	1.00E+05 ^g	2.00E+02	4.66E-02	Criterion > TCLP	Criterion > Waste Value
Methylphenol, 2-	4.32E+03 ^f	4.00E+03	4.92E-01	Criterion > TCLP	Criterion > Waste Value
Methylphenol, 3-	4.91E+03 ^f	4.00E+03	4.71E-01	Criterion > TCLP	Criterion > Waste Value
Methylphenol, 4-	5.03E+03 ^f	4.00E+03	4.90E-01	Criterion > TCLP	Criterion > Waste Value
Naphthalene	1.00E+05 ^g		5.58E-02	No Value	Criterion > Waste Value
Nitrobenzene	6.17E+02 ^f	4.00E+01	3.06E-02	Criterion > TCLP	Criterion > Waste Value

Table 7.1. Comparison between CERCLA-derived waste disposal criteria and TCLP values for PGDP DOE waste disposal units and concentrations reported for CERCLA-derived waste projected to be acceptable for placement in the C-746-U Landfill (continued)

Chemical	CERCLA-derived waste disposal criteria ^a	TCLP or TSCA concentration ^b	CERCLA-derived waste concentration ^c	Comparison versus TCLP and TSCA ^d	Comparison versus CERCLA-derived waste concentration ^e
Pentachlorophenol	1.00E+05 ^g	2.00E+03	2.28E-01	Criterion > TCLP	Criterion > Waste Value
Phenanthrene	1.00E+05 ^g		1.22E-01	No Value	Criterion > Waste Value
PCBs (Total)	1.73E+02 ^f	5.00E+01	8.26E-01	Criterion > TSCA	Criterion > Waste Value
PAHs (Total)	1.00E+05 ^g		9.78E-02	No Value	Criterion > Waste Value
Pyrene	1.00E+05 ^g		1.43E-01	No Value	Criterion > Waste Value
Pyridine	1.00E+05 ^{f, g}	1.00E+02	3.15E-02	Criterion > TCLP	Criterion > Waste Value
Tetrachloroethene	8.27E+01 ^f	1.40E+01	5.25E-03	Criterion > TCLP	Criterion > Waste Value
Toxaphene	1.00E+05 ^g	1.00E+01	4.63E-03	Criterion > TCLP	Criterion > Waste Value
Trichloroethene	3.04E+02 ^f	1.00E+01	6.12E-02	Criterion > TCLP	Criterion > Waste Value
Trichlorophenol, 2,4,5-	1.00E+05 ^g	8.00E+03	9.69E-01	Criterion > TCLP	Criterion > Waste Value
Trichlorophenol, 2,4,6-	1.00E+05 ^g	4.00E+01	6.81E-02	Criterion > TCLP	Criterion > Waste Value
Vinyl Chloride	6.00E+02 ^f	4.00E+00	6.99E-02	Criterion > TCLP	Criterion > Waste Value
Xylene (mixture)	8.35E+01 ^f		4.64E-03	No Value	Criterion > Waste Value
Xylene, m-	5.76E+01 ^f		4.64E-03	No Value	Criterion > Waste Value
Xylene, o-	6.89E+01 ^f		4.64E-03	No Value	Criterion > Waste Value
Xylene, p-	8.32E+01 ^f		4.64E-03	No Value	Criterion > Waste Value
Radionuclides					
Neptunium-237	2.26E+01		6.62E-01	No Value	Criterion > Waste Value
Plutonium-238	5.66E+03		3.86E-02	No Value	Criterion > Waste Value
Plutonium-239	5.49E+03		9.18E-02	No Value	Criterion > Waste Value
Plutonium-240	5.49E+03		1.15E-01	No Value	Criterion > Waste Value
Radium-226	4.06E+02		8.99E-01	No Value	Criterion > Waste Value
Technetium-99	2.02E+01		7.04E-01	No Value	Criterion > Waste Value
Thorium-230	2.47E+03		4.54E-01	No Value	Criterion > Waste Value
Thorium-232	2.99E+03		1.00E+00	No Value	Criterion > Waste Value
Uranium-234	1.27E+03		5.58E+00	No Value	Criterion > Waste Value
Uranium-235	1.25E+03		2.76E-01	No Value	Criterion > Waste Value
Uranium-238	1.03E+03		5.61E+00	No Value	Criterion > Waste Value

Notes:

^a Final CERCLA-derived waste disposal criteria taken from Table 5.19.

^b All values taken from Table 3.3, except that for PCBs (Total), which is the Toxicity Substances Control Act of 1976 (TSCA) value.

^c Concentrations taken from Table 3.4.

^d "No value" = a Toxicity Characteristic Leaching Procedure (TCLP)-based screening value was not available; "Criterion > TCLP" = CERCLA-derived waste disposal criterion is greater than the TCLP-based screening value; "Criterion < TCLP" = CERCLA-derived waste disposal criterion is less than the TCLP-based screening value; "Criterion > TSCA" = CERCLA-derived waste disposal criterion is greater than the TSCA limit.

^e "Criterion > Waste Value" = CERCLA-derived waste disposal criterion is greater than the volume weighted-average concentration for CERCLA-derived waste; "Criterion < Waste Value" = CERCLA-derived waste disposal criterion is less than the volume weighted-average concentration for CERCLA-derived waste.

^f The CERCLA-derived waste disposal criterion is the soil saturation limit in sand (0.08% organic content) for the chemical or compound. This value was chosen because liquids can not be disposed of in the C-746-U Landfill. The value may be greater if the chemical or compound is found in a different soil matrix (i.e., with a higher clay or organic carbon content).

^g The final CERCLA-derived waste disposal criterion was reduced to 100,000 mg/kg in order to be consistent with guidance in DOE 2001b concerning back-calculation of risk-based values. The actual back-calculated value is greater than that reported.

DOE = U.S. Department of Energy

PAHs = polycyclic aromatic hydrocarbons

PCBs = polychlorinated biphenyls

PGDP = Paducah Gaseous Diffusion Plant

Like the previous discussion regarding the comparison between the disposal criteria and TCLP-based values, this result appears to be of importance. Additional investigation indicates that it is probably of little significance. The result for iron is of little significance because the disposal criteria is not based upon the migration potential of iron but upon instructions in a PGDP guidance document (DOE 2001b) that limits concentrations back-calculated from risk-based values to 100,000 mg/kg. If this restriction is ignored, then the disposal criteria for iron would equal unity (i.e., 1 kg/kg) as shown in Table 5.18.

7.2 CONCLUSIONS AND OBSERVATIONS

Four major conclusions can be drawn from the results presented in this report. The first is drawn from the risk evaluation performed using the results of the forward modeling run presented in Sect. 5.1.1. This conclusion is that the peak cumulative potential cancer risk, hazard, and dose posed to a rural resident using groundwater drawn from the RGA from a well installed at the DOE property boundary for ingestion and other household purposes is similar to the lower limit of the EPA cancer risk-range, less than the hazard limit for site-related exposures (i.e., 10^{-6} and 1, respectively), and less than the cumulative groundwater dose guidance and rule values (15 and 25 mrem/year, respectively). Because the peak cancer risk and hazard results are less than their limits, and because the screening values used are based upon conservative exposure assumptions, it is likely that the actual risk that would be posed to such a rural resident would actually be below the EPA risk range and hazard limit. Similarly, if the exposure point for the well is moved to a more reasonable location, such as at a point removed from the DOE property boundary, given the proposed future land-use of PGDP and current social norms, the cancer risk can be expected to fall to *de minimis* levels because contaminant concentrations would be lessened due to the greater distance traveled by groundwater from the source to the well.

The second major conclusion that can be taken from the results in this report is that the RCRA-based values (i.e., the TCLP-based values and TSCA limits) can be used as adequate surrogates for the CERCLA-derived waste disposal criteria. The only exceptions to this general conclusion may be the chemicals discussed in Sect. 7.1. However, even the criteria for these can be shown to be similar to their RCRA-based values.

The third conclusion, drawn from the comparison of the CERCLA-derived waste inventory chemical concentrations and the CERCLA-derived waste disposal criteria, where only one analyte was seen to have a projected waste concentration less than its criterion, is that CERCLA-derived waste with concentrations at the disposal criteria should be able to be safely placed in the C-746-U Landfill when evaluated on a chemical-specific basis. Additionally, even placement of this analyte would not be limited because the disposal criteria for this chemical is probably greater than its "real" average concentration in waste.

The fourth conclusion is drawn from the cumulative risk calculation performed assuming disposal of CERCLA-derived waste containing all analytes at concentrations equal to their disposal criteria (Sect. 5.4). When considered on a cumulative risk basis, migration from waste attaining concentrations equal to the CERCLA-derived waste disposal criteria will probably not adversely impact human health of probable receptors. For example, cumulative cancer risks, hazards, and doses for the recreational user (and industrial user) are below all risk benchmarks at all times. Similarly, cumulative cancer risks posed by chemicals and radionuclides to groundwater users are within the EPA risk-range for site-related exposures, cumulative hazard posed by chemicals will only attain levels that may be unacceptable after 1,000 years of uncontrolled releases, and cumulative dose posed by radionuclides will only attain unacceptable levels after 1,000 years of uncontrolled releases. Because uncontrolled releases are unlikely due to the engineering of the C-746-U Landfill and continued maintenance by DOE for the foreseeable future, the potentially unacceptable cumulative hazard and dose are overestimates of the actual hazard and dose that may be posed to the groundwater user. Hence, even if waste placed in the C-746-U Landfill exceeded projections

for this waste stream, and attained the CERCLA-derived waste disposal criteria, it is unlikely that unacceptable cumulative risk, hazard, or dose would be posed to human health or the environment. However, as an added level of protection, it may be appropriate to consider a "sum-of-fraction" approach, which evaluates waste streams on a cumulative risk basis as they are placed in the landfill, when deriving the operational limits for the C-746-U Landfill.

Alternatively, the inventory of the waste can be tracked as it is placed in the landfill. This approach would allow for consideration of mixing ratios and the heterogeneity of waste projected for the CERCLA actions. Examples of considering inventory and mixing ratios are presented in Appendices A and B. In these appendices, the inventory projected to arise from the North-South Diversion Ditch and Scrap Yard response actions are compared to the final contaminant inventory limits. As shown there, wastes from both of these response actions can be placed in the landfill if one is willing to sacrifice a percentage inventory greater than percentage volume for some COPCs.

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