



This produced an estimate of the equilibrium body burden that would have resulted from continued exposure to water at the benchmark concentration. Because the bioconcentration factor is an uncertain estimate, this conversion introduces a moderate to large degree of uncertainty, depending on the contaminant (see ranges of uncertainties in bioconcentration factors in Table 4.30).

To estimate endpoints for terrestrial species, we followed the recommendations of Sample et al. (1996) that mammalian response should be scaled as a three-fourths power function of body weight. Traditional wildlife approaches use a straight function of body weight. The consequences of selecting the Sample et al. (1996) method over the traditional approach is that, where the reference species is smaller than the species to which its endpoint is extrapolated, the resultant endpoint will be below that estimated by the other method. From this standpoint, the method chosen is conservative.

4.2.11 Analysis of Risk

The previous sections have presented the results of the deterministic and stochastic assessments of exposure to contaminants in relation to toxicological endpoints following EPA guidelines (EPA 1996a). To assess the potential risk, however, these results must be evaluated in light of the physical and ecological context of the study area and the data that served as input to the exposure modeling itself. The key questions to be addressed by this risk assessment are as follows:

- ◆ Where within the study area do contaminants of interest currently pose a potential threat to ecological resources?
- ◆ Which contaminant/media combinations contribute to that threat?
- ◆ Which organisms have the greatest likelihood of being adversely affected in those areas?

The primary objective of this analysis is to determine whether Hanford Site-derived contaminants pose a present risk to non-human biota within the study area, and if so, where that risk is, and which ecosystem components are most at risk.

Many of the contaminants of interest for this screening-level risk assessment are elements or isotopes that are relatively pervasive in the environment. They derive from sources in addition to those on the Hanford Site. For example, several metals in the contaminants list occur in relatively high concentrations in sediment and

We sought answers to several key questions in our assessment of risk to the environment:

Question: Which organisms have the greatest likelihood of being adversely affected by which contaminant and media?

Answer: Some herbivores, omnivores, and weasels have the greatest likelihood of being adversely affected by cobalt-60, chromium, cesium-137, mercury, and lead in sediment and pore water.

Aquatic species have the greatest likelihood of being adversely affected by cyanide, chromium, copper, mercury, ammonia, lead, and zinc in pore water and somewhat in sediment.

Question: Where within the study area do contaminants of interest currently pose a potential threat to ecological resources?

Answer: Segments 4, 7-10, 12-14, 17, and 20 contain contaminants that pose a potential risk above reference to terrestrial and aquatic organisms.



water in the Columbia River upstream from any Hanford Site input, including mercury, lead, zinc, copper, and chromium (Munn et al. 1995; Serdar 1993; Johnson et al. 1990). As discussed earlier, many of the contaminant metals are also nutrients or micronutrients for most organisms. Consequently, tissue levels are generally stable over a range of environmental concentrations. For these reasons, the CRCIA Team elected to examine incremental risk from Hanford-derived contaminants, addressing risk that exceeds levels found in Segment 1 of the study area. Contaminants with non-zero risk where simulations showed no exposures above thresholds in Segment 1 for aquatic organisms were copper, lead, and zinc. For terrestrial organisms, these reference contaminants also included cesium-137, chromium, mercury, nickel, and uranium. Consequently, risk for these contaminants within the study area below Segment 1 was evaluated where the estimated risk exceeded the reference level.

Contaminants of interest found to pose no significant risk to non-human biota were organics, nitrate, iodine-129, europium-152, europium-154, and tritium (hydrogen-3) (Figure 4.17). As noted earlier, risk from carbon-14, neptunium-237, and diesel fuel was not evaluated, as recommended by the CRCIA Team because of insufficient media data (see Tables 4.27 and 4.28).

The risks shown in Figure 4.17 include both significant deterministic and significant stochastic risks above those in reference Segment 1. Significant deterministic risks are those for which the EHQ exceeded 1 using maximum observed concentrations. Significant stochastic risks are those for which a greater than 5% chance exists that exposure to the contaminant would exceed the chronic LOEL. As the figure shows, these two measures did not always overlap: some contaminants in some segments presented significant deterministic risks, but did not present significant stochastic risks. These outcomes result from using data sets that have a few high concentrations relative to either a few very low concentrations or a bulk of intermediate concentrations. In such cases, the high concentrations may represent a significant risk, but taken in the context of the bulk of the samples, the chance of exceeding a risk threshold is slight throughout the segment. In other words, these cases present either temporally or spatially limited "hot spots." An example is strontium-90, which was found above risk levels in limited portions of Segments 6 and 7 because of locally high concentrations in seep/springs at the N Springs area. The significant deterministic risk from zinc at Segment 21 for terrestrial species is due to a high pore water/drinking water value represented by groundwater well 699-530-E15A, a potential spatially limited hot spot.

To determine whether the study area segments listed in Figure 4.17 actually contain contaminants at levels that pose a potential threat to biota, the data on which these estimates were based were first evaluated. The primary medium of interest was pore water, which was the primary contributor to risk in most cases. The risk due to pore water contamination arises principally from respiratory (gill or dermal) uptake by aquatic organisms exposed to pore water and the subsequent movement of these contaminants through the food web.

One concern is to what degree does the surrogated pore water used in the exposure estimate reflect actual pore water to which organisms are exposed. As part of a special study by Bechtel Hanford, Inc. in 1995 and 1996, chromium (VI) was measured in pore water at various points within Segments 7, 8 (Hope and Peterson 1996), and 10 (Hope and Peterson 1995). Pore water was collected through a sampling pipe

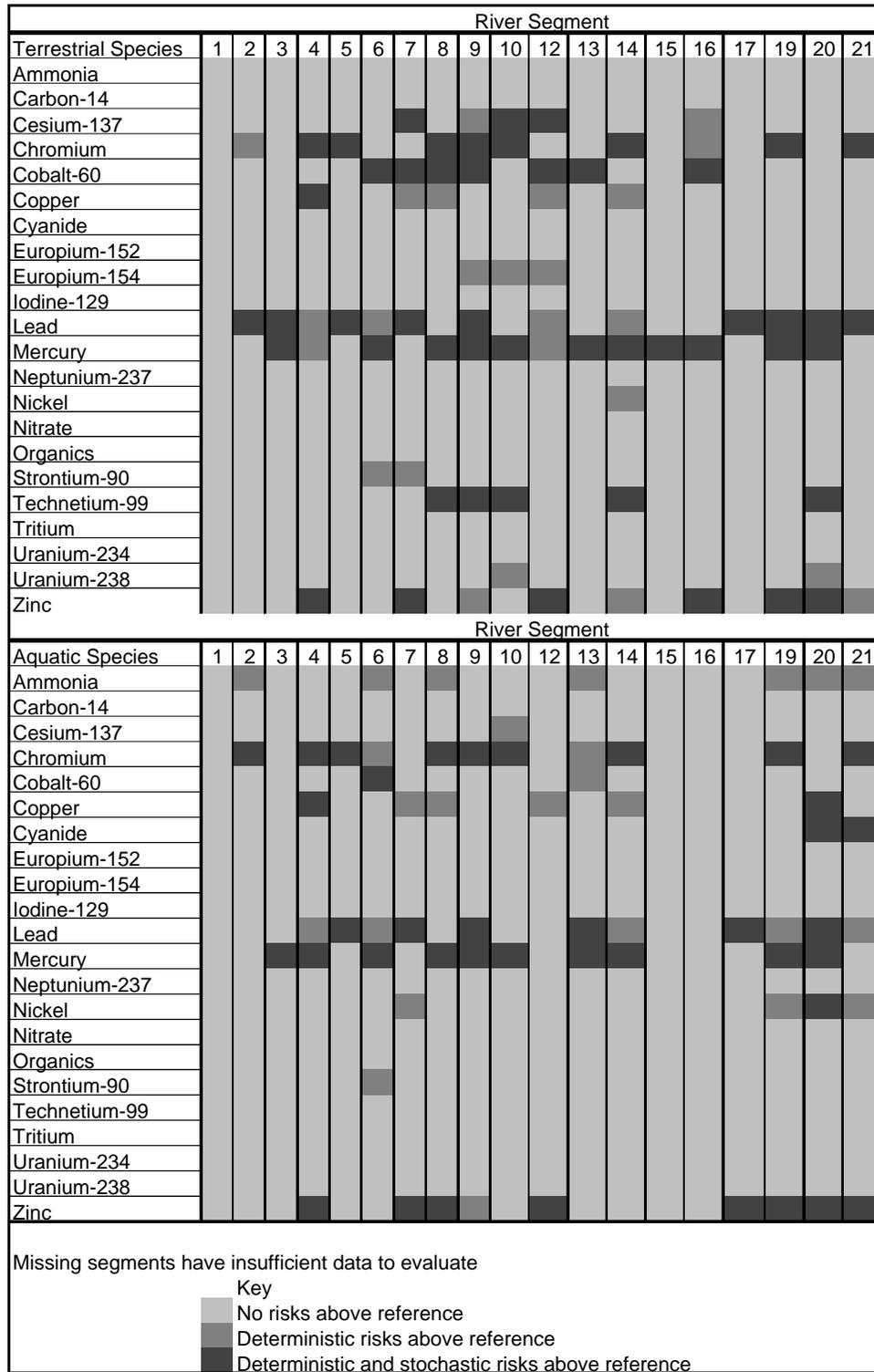


Figure 4.17. Segments and Contaminants Where Deterministic EHQs Exceed or Estimated Exposures Were Above LOEL Endpoints and Were Above Segment 1 Values



driven into the substrate at a number of locations near the 100-D/DR (Segments 7 and 8) and at 100-H (Segment 10) Areas. The CRCIA Team determined that these data would be used for comparison to evaluate the adequacy of the surrogated pore water used in the screening assessment, but the data would not be used in the exposure analyses or in the media summaries presented in Section 3.0.

As shown in Table 4.31, measured pore water maxima exceeded surrogated pore water maxima in Segments 7 and 10. The geometric standard deviations for these segments also showed the same pattern, with measured values exceeding surrogated values (Ln-transformed data, Levene's test for equality of variances [Levene 1960]: $P < 0.001$). Pore water measurements in Segments 7 and 10 identified a narrow band of elevated chromium at the lower end of each segment that was not reflected in the seep/spring data, which was the source for the pore water surrogate data. However, the geometric mean of the surrogated pore water exceeded the measured pore water in all three segments (Ln-transformed data, Welch analysis of variance for unequal variances [Welch 1951]: $P < 0.01$).

Table 4.31. Comparison of Chromium ($\mu\text{g/L}$) in Surrogate Pore Water Versus Measured Pore Water

Contaminant	Segment	Maximum		Geometric Mean		Geometric Standard Deviation	
		Surrogated	Measured	Surrogated	Measured	Surrogated	Measured
Chromium	7	28.0	632.0	3.5	2.4	5.6	11.9
Chromium	8	400.0	84.7	20.4	0.9	6.5	5.7
Chromium	10	84.0	130.0	35.7	1.7	1.6	7.4

Based on this comparison, chromium exposures estimated using surrogated pore water were higher on average than they would have been if measured values had been used. Surrogated pore water maxima in all three segments were high enough that none were screened out in the deterministic analysis. Because the standard deviations and maxima for surrogated pore water in Segments 7 and 10 were less than the measured values, both the range and maximum risk estimates for these segments were lower than would have resulted if measured values had been used. The spatial extent of the higher risk, however, is extremely limited: The high-chromium area in Segment 10 covers no more than 80 meters (263 feet) of shoreline (Hope and Peterson 1995). The area in Segment 7 extends no more than 120 meters (394 feet) (Hope and Peterson 1996). Assuming these trends held for other contaminants of interest in other areas, the average exposure estimates may be biased slightly high. This comparison also supports the decision not to use K_{ds} to estimate pore water concentrations from sediment concentrations: The maximum observed difference between surrogated and measured pore water was 23x—far less than the 1000x that would result from using K_{ds} (see Figure 4.11).

A second consideration in using the surrogated pore water data arises from assuming that the contaminants as measured were all bioavailable via gill uptake. Some of the data contained information on whether the reported water concentrations reflected filtered or unfiltered water samples. Filtered samples are water that has been passed through a 0.45- μ filter, thereby removing particulate metal, which



is unavailable for uptake by aquatic organisms via dermal or respiratory surfaces (Förstner and Wittmann 1981). Although not all metal that passes a 0.45- μ filter is bioavailable (Förstner and Wittmann 1981), the difference between filtered versus unfiltered data indicates where exposures have been overestimated and by how much.

Surrogated pore water data were separated into two sets based on whether the data were from filtered or unfiltered samples. Geometric means for filtered data were then expressed as a percentage of the geometric means of the unfiltered data. These percentages are shown in Table 4.32.

Most contaminant concentrations in pore water were based on unfiltered samples; that is, the concentrations reflect particulate as well as dissolved metal. This was the case in all segments for cesium-137, cobalt-60, europium-154, strontium-90, technetium-99, and uranium. Consequently, the degree of overestimation of exposures for these contaminants cannot be quantified. Concentrations of mercury were generally similar between filtered and unfiltered values. Concentrations for zinc in pore water differed by 2 to 100 times for Segments 5, 6, 9, 12, 14, and 15. Segment 12 was especially in error. Concentrations

Table 4.32. Geometric Mean Concentrations of Filtered Surrogate Pore Water Expressed as a Percentage of the Geometric Mean Concentration of Unfiltered Surrogate Pore Water

Contaminant	Segment																	
	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	19	20	21
Carbon-14	UF ^(a)	UF	UF	36%	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Cesium-137	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Chromium	104% ^(b)	122%	348%	UF	97%	37%	UF	13%	83%	136%	107%	78%	17%	66%	33%	32%	UF	24%
Cobalt-60	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Copper	96%	105%	100%	UF	36%	40%	64%	69%	64%	106%	13%	88%	35%	80%	40%	94%	UF	89%
Europium-152	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	92%	UF
Europium-154	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Lead	68%	UF	120%	95%	UF	65%	96%	UF	UF	UF	UF	UF	UF	UF	UF	59%	89%	86%
Mercury	109%	UF	108%	104%	UF	119%	100%	UF	UF	UF	UF	UF	UF	UF	UF	107%	101%	100%
Nickel	68%	133%	100%	UF	82%	57%	44%	84%	136%	134%	UF	121%	74%	103%	56%	49%	UF	35%
Nitrate	235%	UF	UF	UF	UF	UF	UF	1%	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Strontium-90	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Technetium-99	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Tritium (H-3)	UF	UF	UF	25%	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	65%
Uranium-234	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Uranium-238	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF	UF
Zinc	103%	78%	100%	UF	36%	33%	89%	114%	44%	59%	1%	62%	51%	31%	54%	55%	UF	76%

(a) UF = Only unfiltered data were available.

(b) Values may exceed 100% because filtered and unfiltered values were **not** obtained from the same water sample.



of nickel in pore water differed by two times for Segments 6, 7, 8, 16, 19, 20, and 21. Copper values differed by two to three times for Segments 5, 6, 12, 14, and 16. Finally, chromium concentrations differed by two to five times in Segments 6, 8, 14, 16, 19, and 21.

In each case, if exposures had been estimated using filtered data for in-water respiratory sources, exposures and risk would have been significantly reduced. For example, mean estimated body burdens of chromium for aquatic organisms in Segment 8 were reduced by up to 20 parts per million. Copper in Segment 12 was reduced by up to 40 parts per million, and zinc in Segment 12 was reduced by nearly 80,000 parts per million (Figure 4.18). The greatest decreases in relative risk were found for benthic organisms: periphyton, mayfly, Columbia pebblesnail, crayfish, water milfoil, trout and salmon eggs, and Woodhouse's toad/tadpoles. For air-respiring (or transpiring) species in these segments, chromium exposures decreased by up to 15 parts per million, copper decreased by nearly 25 parts per million, and zinc decreased by 45,000 parts per million (Figure 4.19). The greatest decreases in relative risk when data from filtered samples were used were for American coot, cliff swallow, mallard, bufflehead, common snipe, and Canada goose.

Because both the geometric means and standard deviations were inflated by using all data rather than just filtered data for these contaminant-segment combinations, both mean and maximum risk was overestimated. Based on these considerations, copper presents a potential risk above reference to aquatic organisms in Segments 4 and 20. Risk from zinc above reference is potentially present in Segments 4, 7, 8, 17, and 20 for terrestrial organisms and in Segments 4, 7, 8, 17, and 20 for aquatic organisms. Nickel poses a minor risk in Segment 20. Risk from chromium is greater than reference in Segments 2, 4, 5, 9, and 10.

Taking into account all the areas where filtered concentrations were less than one-third of unfiltered pore water (that is, areas where using all the groundwater data biased the exposure estimates), study area segments were grouped as follows (Figure 4.20): those where contaminants currently pose no significant risk above reference (green in Figure 4.20), those where risk of chronic effects is present above reference (yellow in Figure 4.20), and those where acute effects may be present (red in Figure 4.20). Chronic effects are those that result from exposure to a contaminant in excess of LOELs, with simulated exposures greater than those in Segment 1. Acute effects are those that exceed lethal exposure benchmarks and have an exposure risk greater than those in Segment 1. Chronic effects were considered significantly elevated if they exceeded background by more than 5%. The acute effects were considered significantly elevated if they exceeded background by 50%.

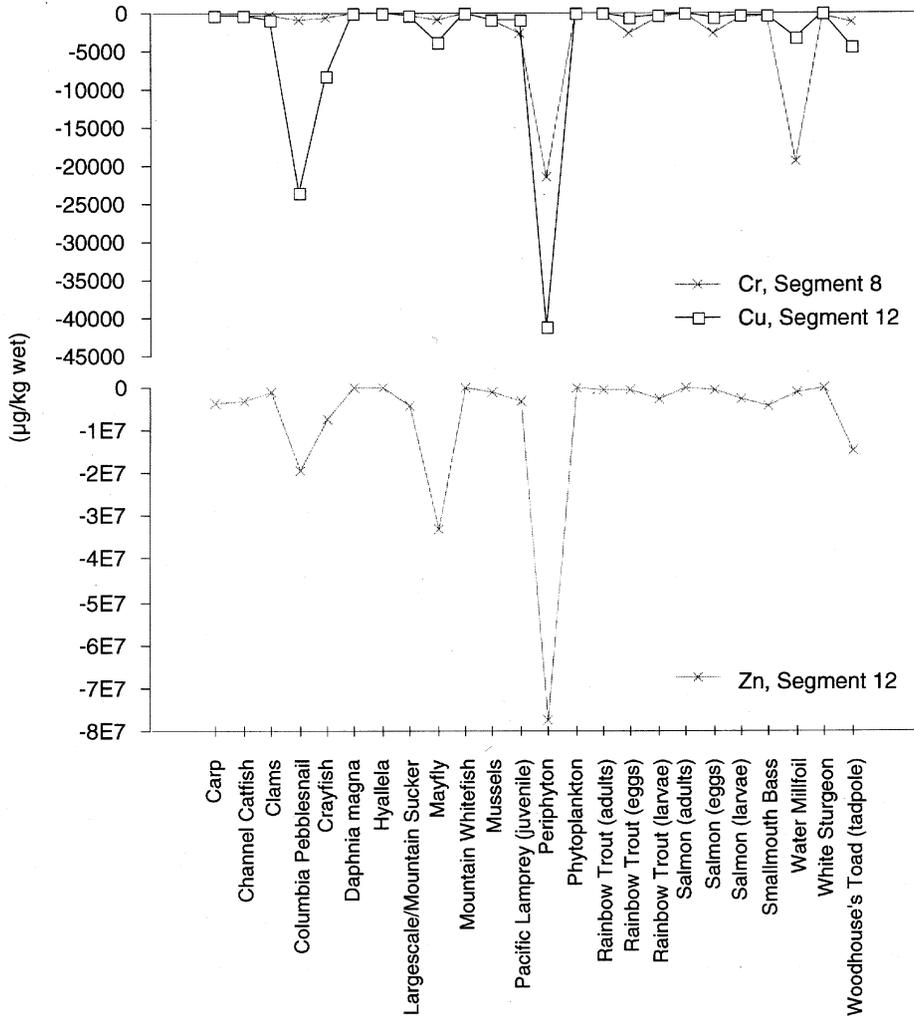
Acute effects on terrestrial systems are potentially present from chromium in Segments 4 (100-K Area) and 9 (downstream from 100-D Area), from lead in Segment 17 (corresponding to the old Hanford townsite), and zinc in Segment 4 (100-K Area).



-



Figure 4.18. Change in Estimated Equilibrium Body Burden of Aquatic Organisms Produced by Using Filtered Versus Total Metal in Surrogated Pore Water

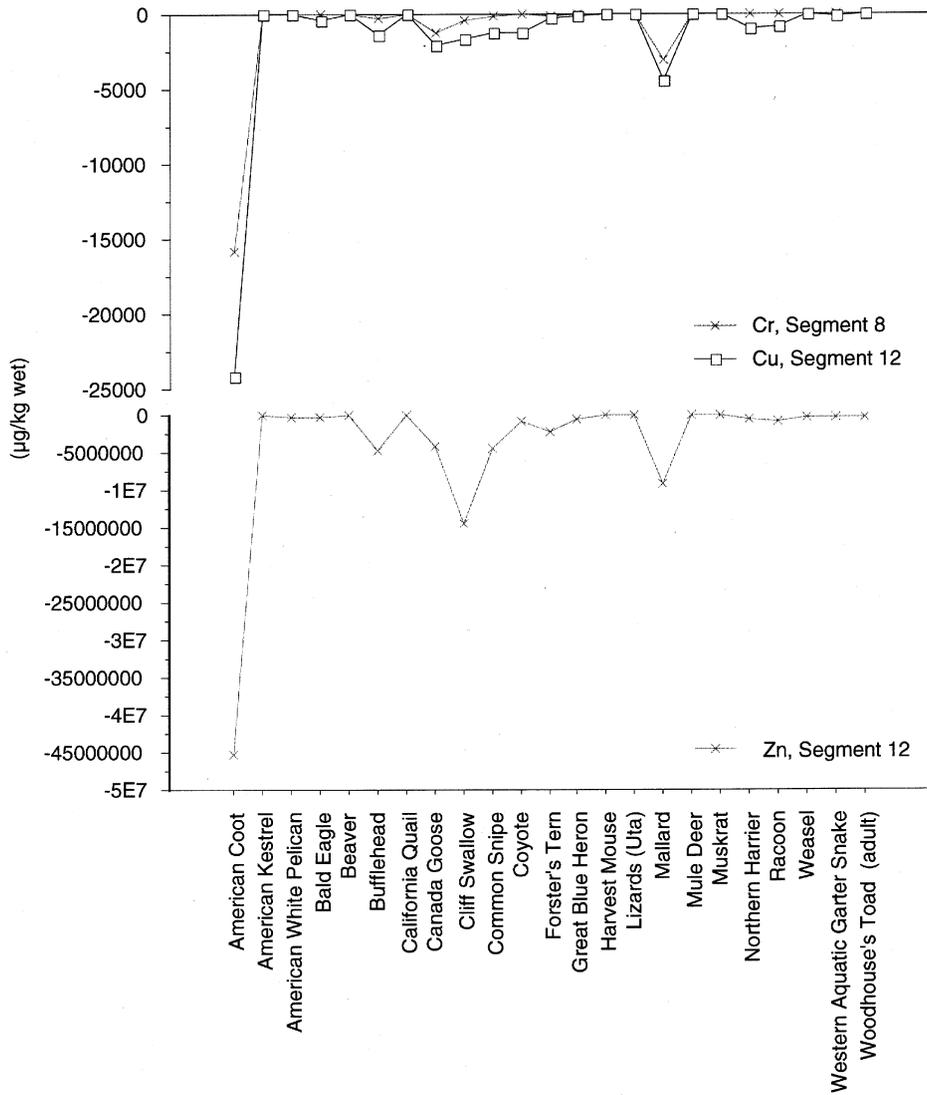




-



Figure 4.19. Change in Estimated Equilibrium Body Burden of Air-Respiring Organisms Produced by Using Filtered Versus Total Metal in Surrogated Pore Water





Terrestrial	Location																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
Carbon-14	No Pore water										N								N				N	N	N	N	N	N	N
Cyanide											o							o				o	o	o	o	o	o		
Cobalt-60																													
Chromium											P							P				P	P	P	P	P	P		
Cesium-137											o							o				o	o	o	o	o	o		
Copper											r							r				r	r	r	r	r	r		
Europium-152	No Surface water										e							e				e	e	e	e	e	e	e	
Europium-154											w							w				w	w	w	w	w	w		
Mercury											a							a				a	a	a	a	a	a		
Iodine-129											t							t				t	t	t	t	t	t		
Ammonia											e							e				e	e	e	e	e	e		
Nickel											r							r				r	r	r	r	r	r		
Nitrite	No toxicity data																												
Nitrate											D							D				D	D	D	D	D	D		
Neptunium-237	No Pore water										a							a				a	a	a	a	a	a	a	
Organics											t							t				t	t	t	t	t	t		
Lead											a							a				a	a	a	a	a	a		
Phosphate	No toxicity data																												
Sulfate	No toxicity data																												
Strontium-90																													
Technetium-99																													
Tritium																													
Uranium-234																													
Uranium-238																													
Zinc																													
Aquatic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
Carbon-14	No Pore water data										N								N				N	N	N	N	N	N	N
Cyanide											o							o				o	o	o	o	o	o		
Cobalt-60																													
Chromium											P							P				P	P	P	P	P	P		
Cesium-137											o							o				o	o	o	o	o	o		
Copper											r							r				r	r	r	r	r	r		
Europium-152	No Surface water data										e							e				e	e	e	e	e	e	e	
Europium-154											w							w				w	w	w	w	w	w		
Mercury											a							a				a	a	a	a	a	a		
Iodine-129											t							t				t	t	t	t	t	t		
Ammonia											e							e				e	e	e	e	e	e		
Nickel											r							r				r	r	r	r	r	r		
Nitrite	No toxicity data																												
Nitrate											D							D				D	D	D	D	D	D		
Neptunium-237	No Pore water data										a							a				a	a	a	a	a	a	a	a
Organics											t							t				t	t	t	t	t	t		
Lead											a							a				a	a	a	a	a	a		
Phosphate	No toxicity data																												
Sulfate	No toxicity data																												
Strontium-90																													
Technetium-99																													
Tritium																													
Uranium-234																													
Uranium-238																													
Zinc																													
AREAS	B/C	K	N	D	D	H					F						HT				300								
	Not different from reference																												
	= 5% above reference (chronic)																												
	= 50% above reference (acute)																												

Figure 4.20. Levels of Ecological Risk Above Reference for Contaminants in Study Area Segments for Terrestrial and Aquatic Organisms. (The white, blank cells within otherwise colored rows are due to lack of pore water or sediment data for that segment/contaminant combination.)



Potentially significant radiological doses to terrestrial organisms primarily are due to cobalt-60 and cesium-137. The reference concentration of cesium-137 is relatively high. Cesium-137 is present in sediment in Segment 1 at high enough concentrations that greater than 65 percent of simulations of exposure for terrestrial species at risk were above LOELs (Figure 4.13). No radionuclide produced doses above acute effects levels in any segment. Technetium-99 did not constitute a radiological hazard anywhere, but did pose a chronic toxic risk to plants in Segments 8-10, 14, and 20. The chemical (as opposed to radiological) hazard to animals remains unknown, however, because of the lack of chemical toxicity data for organisms other than plants.

Non-radioactive metals contributing to chronic risk in excess of reference levels for terrestrial organisms were chromium, copper, lead, mercury, and zinc. Chronic risk from chromium was found below the 100-H and 100-K Areas. Chronic risk from lead and mercury was found in most segments.

Non-radiological metals contributing to an acute risk for aquatic organisms were copper, lead, mercury, and zinc. The acute risk from zinc was associated with the 100-K Area, while the acute risk from lead was downstream of the 100-D, 100-F, 100-K Areas and the old Hanford townsite. Other non-radiological metals that contributed to risk to aquatic organisms included chromium (Segments 2, 4, 5, 9, and 10), copper (Segments 4 and 20), lead (Segments 7 and 20), mercury (most segments), and zinc (Segments 7, 8, and 17). Chronic risk to aquatic organisms from non-radiological metals appeared to be associated mainly with former reactor sites, for example, the 100-K, -D, and -H Areas. As discussed previously, the potential risk to aquatic organisms from these metals, particularly zinc, may be less than predicted by the model because actual bioavailability in the field may be lower than the values used in the model. It also was not possible to adjust all acute toxicity values to the pore water levels of hardness and pH because of gaps in the data. Thus, many metals such as zinc may have reduced toxicity under field conditions.

A chronic risk to aquatic organisms was posed by cobalt-60 in Segment 6. Another contaminant from Hanford Site origin that contributed to chronic risk to aquatic organisms was cyanide (Segments 20 and 21). The risk appeared to be associated with the 300 Area.

Several metals occur in relatively high concentrations in abiotic media in areas upstream of Hanford Site. These include cobalt-60, cesium-137, chromium, copper, lead, mercury, nickel, and zinc (see Table 4.25). Offsite sources for these metals include worldwide fallout (cesium-137) effluents from the COMINCO smelter at Trail, British Columbia, and contaminated sediment entering the Columbia River system from the Spokane River. These have been the focus of a number of studies by the Washington State Department of Ecology, EPA, and the U.S. Geological Survey in the Columbia River system above the Hanford Site. As noted earlier, statistical comparisons of sediment concentrations showed no significant rise above reference concentrations for nickel, lead, or zinc, and showed small increases for chromium in Segments 2 and 4 and for copper in Segment 14. Consequently, additional risk due to Hanford Site input for these metals is expected to be small.

Species experiencing the greatest direct hazards from exposures to contaminants can be identified by summing the risk scores (see Table 4.28 for definition of risk scores) across contaminants for each