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Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan

Volume 3 of 4

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Appendices C-L

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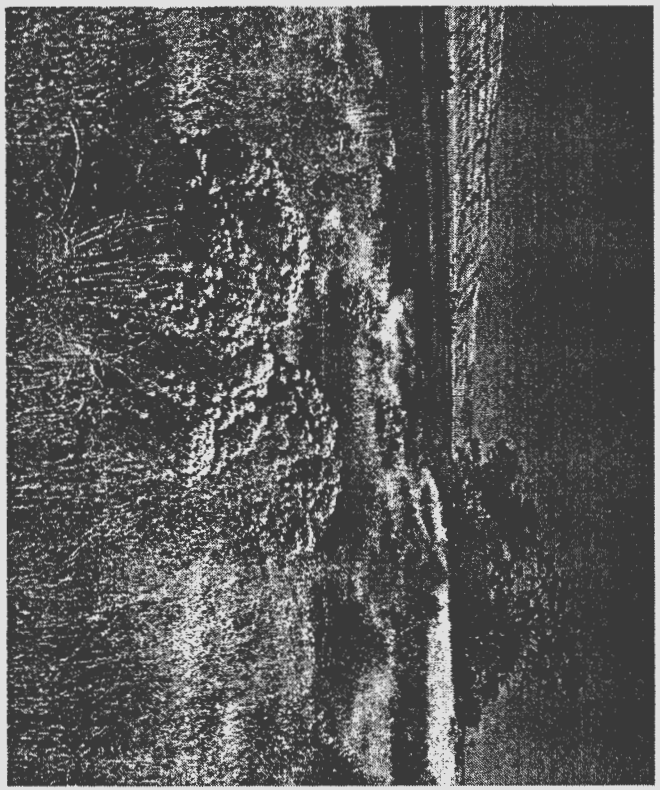

Appendix C

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C.0 Ecological Risk Assessment Methodology and Calculations

This appendix describes the methods that were used to estimate radiation doses and hazard indices (HI) associated with the intake of hazardous chemicals by ecological receptors at the Hanford Site. Detailed results of the risk assessment are presented and are summarized by geographic area in Chapter 5.0 of the *Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan* (HRA-EIS) (DOE 1996).

C.1 Ecological Risk Assessment Methodology

The general method used in the HRA-EIS follows the approach recommended in the *Hanford Site Baseline Risk Assessment Methodology (HSBRAM)*[1] (DOE-RL 1993). The basic steps used in ecological risk assessment are (1) problem formulation, (2) characterization of potential exposures and associated ecological effects, and (3) comprehensive presentation of the results as a risk characterization (EPA 1992). This section describes these steps in terms specific to the HRA-EIS.

C.1.1 Problem Formulation

The Hanford Site supports a variety of arid terrestrial habitats; a major aquatic habitat (the Columbia River); and a number of threatened, endangered, or candidate species. For purposes of the HRA-EIS, these habitats and adjacent offsite habitats constitute the ecosystem potentially at risk. Contaminants of potential concern include a wide variety of radionuclides and hazardous chemicals. Ecological receptors may be exposed to these substances in surface and subsurface soils, ground and surface water, and uptake through the food chain. Effects from exposure can be chronic (i.e., long-term, low-level exposure that may cause latent damage that does not appear until later) or acute (i.e., direct mortality) depending on the magnitude and frequency of exposure.

Preparation of an ecological risk assessment requires selection of assessment and measurement endpoints. Assessment endpoints are the specific ecological characteristics to be protected, and measurement endpoints are characteristics that can be measured and correspond in some way to the assessment endpoints. In the HRA-EIS, the assessment endpoint for effects of radionuclides and hazardous chemicals is prevention of adverse effects from these substances on ecological receptors. The measurement endpoints that correspond to this assessment endpoint are (1) estimated radiation dose, which is compared to the 1-rad/day expected to have no adverse effects on aquatic organisms (NCRP 1991) and the 0.1-rad/day below which radiation exposure is not considered harmful to terrestrial organisms (IAEA 1992), and (2) the ratio of estimated intake of hazardous chemicals compared to the intake expected to have a No Observable Adverse Effect Level (NOAEL). The latter ratio is called the HI; a value greater than 1.0 indicates a potential for adverse effects.

[1]At the time of this writing, the *Hanford Site Baseline Risk Assessment Methodology (HSBRAM)* was used to conduct the ecological risk assessment. Since that time, it has been updated and revised in the *Hanford Site Risk Assessment Methodology (HSRAM)* (DOE-RL 1995).

C.1.2 Conceptual Model

Estimation of potential radiation and hazardous chemical effects requires a conceptual model that illustrates transport of constituents of potential concern to ecological receptors. The conceptual model used in this analysis is a simple food chain consisting of three wildlife species and a generic plant (Figure C-1). The wildlife species used are the Great Basin pocket mouse, the coyote, and the red-tailed hawk. The single exposure pathway considered is plant uptake from soil followed by ingestion of vegetation by the pocket mouse, and ingestion of mice by the coyote and the hawk. This model was designed to assess the effects at several trophic levels (primary producer, herbivore, and mammalian and avian carnivore), while being simple enough to efficiently assess potential effects at the many waste sites within the scope of the HRA-EIS. Hazards to aquatic receptors were assessed by estimating radiation doses from surface water radionuclide concentrations.

C.1.3 Source Terms

Source terms for constituents of concern in soils were the same as those used for the human health risk assessment, which is described in Appendix B of the HRA-EIS. The maximum estimated concentration at time zero (1989) was used throughout the analysis. For a number of chemicals, data were provided for a compound where only one element in the compound was of concern for possible adverse effects. For example, the element of concern in sodium dichromate is chromium. In these cases, the concentration of the specific element was computed based on the atomic weights of the elements making up the compound. Chemical concentrations used to estimate HIs are listed in Table C-1; radionuclide concentrations used to estimate radiation doses are listed in Table C-2. Volume-based concentrations were converted to weight-based concentrations (mg/kg for chemicals, pCi/g for radionuclides), assuming a soil density of 1.76 g/cm^3.

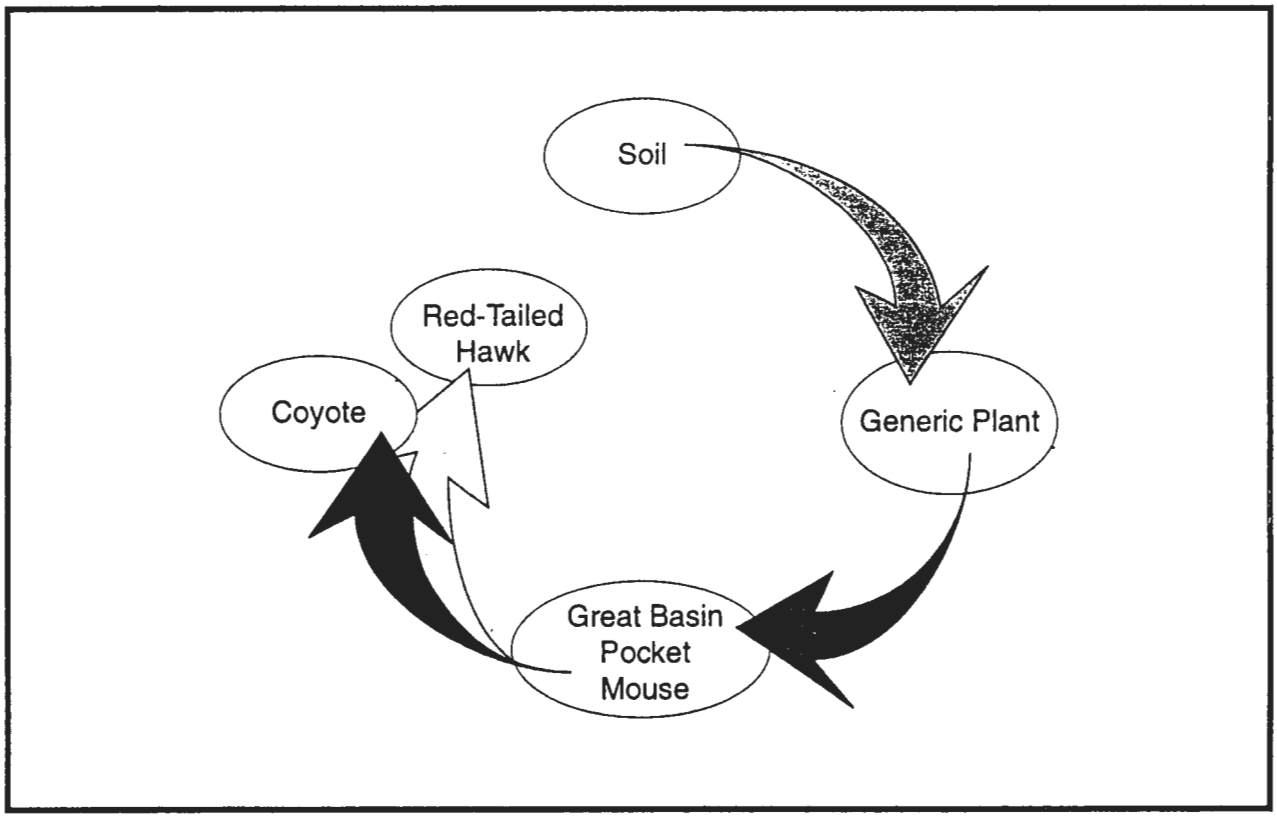
C.1.4 Exposure Assessment

This section describes the general methods that were used to estimate intake of hazardous chemicals, the associated HIs, and the radiation doses resulting from radionuclide intake. This section also describes the equations typically presented in the risk assessment literature, and then describes the modifications used to calculate unit risk factors (URF) in order to simplify computations. Application of the URFs to ecological receptors results in an estimated radiation dose or chemical HI rather than a probability of some adverse effect as in the human health risk assessment. However, the term "URF" is maintained here for purposes of consistency with the similar methodology used for the human health risk assessment presented in Appendix B of the HRA-EIS.

C.1.4.1 Estimation of Hazardous Chemical Intake. Contaminant uptake by a generic plant was estimated by multiplying the contaminant concentration in the soil by the soil-to-plant concentration factors used in *GENII--The Hanford Environmental Radiation Dosimetry Software System* (GENII model) at the Hanford Site (Napier et al. 1988). The equation used was:

$$C_{vi} = (C_{si})(B_{vi})(0.4) \qquad (1)$$

Figure C-1. Conceptual Model for Estimating Hazard Indices and Radiation Doses to Ecological Receptors.



where:

C_{vi} = Contaminant concentration in plant (mg/kg wet weight)
C_{si} = Contaminant concentration in soil (mg/kg dry weight)
B_{vi} = Soil-to-plant concentration factor (unitless). (The factor for grain concentration was used, rather than for vegetative portions; the pocket mouse was assumed to consume seeds)
0.4 = Wet weight/dry weight conversion (DOE-RL 1994).

The intake rate of hazardous chemicals by a herbivore through consumption of plants was calculated using the following equation:

$$I_i = (C_{vi})(IR)(FI)/(BW) \quad (2)$$

where:

I_i = Intake rate of the i_{th} contaminant (mg/kg/day)
C_{vi} = Contaminant concentration in plant (mg/kg)
IR = Ingestion rate of food (kg/day wet weight)
FI = Fraction ingested from contaminated source (unitless)
BW = Body weight (kg wet weight).

Intake rates by carnivores are calculated similarly, substituting the contaminant concentrations in the herbivore for the concentrations in plants. Contaminant concentrations in herbivore muscle are estimated using Equation 3.

$$C_{mi} = (C_{vi})(IR)(FI)(B_{mi}) \quad (3)$$

where:

C_{mi} = Contaminant concentration in muscle (mg/kg wet weight)
C_{vi} = Contaminant concentration in plant (mg/kg wet weight)
IR = Ingestion rate of plants by herbivore (kg/day)
FI = Fraction ingested from a contaminated source (unitless)
B_{mi} = Plant-to-muscle transfer factor (day/kg). (Plant-to-beef transfer factors used in the GENII model at the Hanford Site were used where available [Napier et al. 1988], or from *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture* [Baes et al. 1984] where not). The transfer factors used to calculate URFs for chemicals are identified in Table C-3.

Ingestion rates and body weights used in calculating URFs for the HRA-EIS are listed in Table C-4.

C.1.4.2 Calculation of Hazard Indices. Hazard indices (the ratio of estimated contaminant intake rate to the exposure expected to have no adverse effect) were calculated by dividing the intake rate by the NOAEL (Equation 4).

$$HI = I/NOAEL \tag{4}$$

where I is calculated as described in Equation 2. NOAELs for contaminants of concern were obtained from the scientific literature, and were scaled to the body weight of the receptor as described below. Both factors are expressed as mg/kg body weight per day.

An HI greater than 1.0 for a given chemical indicates that estimated intake exceeds the threshold "safe" level. For sites with multiple chemicals present, the HIs may be summed, making the conservative assumption that the modes of action and target organs of the chemicals are similar. Therefore, a site may be said to present a hazard if the sum of HIs exceeds 1.0, even if the individual chemical HIs are less than 1.0. This approach was modified to allow calculation of HIs directly from soil concentrations, without the necessity of separate calculations of plant uptake from soil, plant consumption by the mouse, and so forth, for each Hanford Site location.

NOAELs were obtained, in order of preference, from the *Toxicological Benchmarks for Wildlife* (Opresko et al. 1993) or the U.S. Department of Energy (DOE-RL 1994). Wildlife NOAELs obtained (Opresko et al. 1993) were scaled to the body weight of the pocket mouse or coyote using the equation:

$$NOAEL_y = (NOAEL_x)[(bw_x)/(bw_y)]^{1/3} \tag{5}$$

where:

$NOAEL_y$ = NOAEL for the organism of interest
$NOAEL_x$ = NOAEL for the experimental animal available from the literature
bw_y = Body weight of the organism of interest
bw_x = Body weight of the experimental animal with the known NOAEL.

Wildlife NOAELs obtained from the *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE-RL 1994) were used directly, as listed, without attempting to scale them to body weight. Red-tailed hawk NOAELs were taken directly from the values for this species in the *Toxicological Benchmarks for Wildlife* (Opresko et al. 1993) or as the avian NOAELs from DOE-RL (1994). In some cases NOAELs were reported for compounds where a specific element in the compound was the one of primary concern for adverse effects (Opresko et al. 1993). In these cases, a NOAEL for the specific element was computed based on the atomic weights of the elements comprising the compound. This procedure was directly analogous to the procedure used to estimate element-specific contaminant concentration, as described in Section C.1.3. Scaling factors used to adjust NOAELs are listed in Table C-5, (Opresko et al. 1993), and NOAELs and data sources are listed in Table C-6. NOAELs for plants were obtained as soil concentrations from the *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants* (Suter et al. 1993), and HIs were calculated as the waste unit soil concentration divided by the NOAEL. It was, therefore, not necessary to calculate URFs for plants.

C.1.4.3 Calculation of Unit Risk Factors for Chemicals. Unit risk factors were calculated to allow computation of the HI for any specified contaminant and/or receptor that was directly derived from the soil concentration.

C.1.4.3.1 Pocket Mouse Unit Risk Factors. Expanding Equation 4 for estimation of the HI for the pocket mouse consuming the chemical of interest:

$$HI_i = I_i/NOAEL_i \tag{6}$$

$$= [(C_{vi})(IR)(FI)/(BW)]/NOAEL; \text{ expanding } C_{vi},$$

$$= [(C_{si})(B_{vi})(0.4)(IR)(FI)/(BW)]/NOAEL$$

The URF was defined as:

$$URF_i = NOAEL_i/[(B_{vi})(0.4)(IR)(FI)/(BW)] \tag{7}$$

such that:

$$HI_i = C_{si}/URF_i. \tag{8}$$

The fraction ingested (FI) was assumed to be 1.0 for all pocket mouse, coyote, and hawk calculations. This simplifies Equation 7, substituting in the ingestion rate and body weight for the pocket mouse (see Table C-4) to:

$$URF_i = NOAEL_i/[(B_{vi})(0.4)(0.0067 \text{ kg/d})(1.0)/(0.0235 \text{ kg})] \tag{9}$$

$$= NOAEL_i/[(B_{vi})(0.4)(0.2851/d)].$$

C.1.4.3.2 Coyote and Red-Tailed Hawk Unit Risk Factors. A similar process was used to calculate URFs for the coyote and red-tailed hawk. Calculation of factors for these receptors required using the chemical concentration in mouse muscle, C_{mi}, as an input variable; the calculations are presented in Equations 10 through 14.

$$HI_i = I_i/NOAEL_i \tag{10}$$

$$= [(C_{mi})(IR)(FI)/(BW)]/NOAEL; \text{ expanding } C_{mi} \text{ (see Equation 3)},$$

$$HI_i = [(C_{vi})(IR_{mouse})(B_{mi})(IR_{coyote})/(BW_{coyote})]/NOAEL; \text{ expanding } C_{vi},$$

$$HI_i = [(C_{si})(B_{vi})(0.4)(IR_{mouse})(B_{mi})(IR_{coyote})/(BW_{coyote})]/NOAEL.$$

As above, the URF was defined as:

$$URF_i = NOAEL_i/[(B_{vi})(0.4)(IR_{mouse})(B_{mi})(IR_{coyote})/(BW_{coyote})] \quad (11)$$

such that

$$HI_i = C_{si}/URF_i. \quad (12)$$

Incorporating the ingestion rate for the pocket mouse and the ingestion rate and body weight for the coyote (see Table C-4):

$$URF_i = NOAEL_i/[(B_{vi})(0.4)(0.0067\ kg/d)(B_{mi})(1.3\ kg/d)/(10\ kg)] \quad (13)$$

$$= NOAEL_i/[(B_{vi})(0.4)(B_{mi})(0.000871/d)].$$

The calculation for the hawk is similar, substituting the ingestion and body weights of 1.1 kg/d and 1.0 kg, respectively, into Equation 13,

$$URF_i = NOAEL_i/[(B_{vi})(0.4)(B_{mi})(0.00737/d)]. \quad (14)$$

The resulting URFs used to calculate HIs for the pocket mouse, coyote, and red-tailed hawk are listed in Table C-7.

C.1.4.4 Estimation of Radiation Doses to Ecological Receptors. Radiation doses to ecological receptors were calculated using URFs similar to those discussed for chemicals. The basic equation used was:

$$Dose\ (rad/day) = (5.11 \times 10^{-5})(MeV)(C) \quad (15)$$

where:

5.11×10^{-5}	=	Constant (rad d^{-1} pCi^{-1} g MeV^{-1} disintegration)
MeV	=	Mean energy of decay (MeV per disintegration)
C	=	Radionuclide concentration in organism (pCi/g dry weight).

The constant was derived as follows:

$$5.11 \times 10^{-5} = (A)(B)(C)(D)(E)(F)(G)$$

where:

A = 1 Ci/10^{12} pCi
B = 3.7 x 10^{10} disintegrations/Ci-sec
C = 3,600 sec/hr
D = 24 hr/d
E = 10^6 eV/MeV
F = 1.6 x 10^{-12} erg/eV
G = 1 rad-g/100 ergs.

C.1.4.4.1 Derivation of Unit Risk Factors for Radiation Doses to Plants. Equation 15 written for a generic plant is:

$$D_{Pr}\ (\text{rad/d}) = (5.11 \times 10^{-5})(MeV_{Pr})(C_{Pr}) \tag{16}$$

where:

MeV_{Pr} = Average effective energy of decay of radionuclide r in the plant
C_{Pr} = Concentration of radionuclide r in plant (pCi/g = $[C_{sr}][B_{vr}]$), where
C_{sr} = Concentration of radionuclide r in soil (pCi/g)
B_{vr} = Soil-to-plant concentration factor (unitless) for radionuclide r.

Expanding Equation 16 to express radiation dose as a function of soil concentration,

$$D_{Pr}\ (\text{rad/d}) = (5.11 \times 10^{-5})(MeV_{Pr})(C_{sr})(B_{vr}). \tag{17}$$

The URF (K_{Pr} to avoid confusion with the chemical URFs) for calculating the radiation dose to a plant caused by uptake from soil is:

$$K_{Pr} = (5.11 \times 10^{-5})(MeV_{Pr})(B_{vr}). \tag{18}$$

The dose Equation 17 is simplified to:

$$D_{Pr}\ (\text{rad/d}) = (C_{sr})(K_{Pr}). \tag{19}$$

C.1.4.4.2 Derivation of Unit Risk Factors for Radiation Doses to the Pocket Mouse. The derivation of the URF for radiation dose to the pocket mouse is similar to the derivation of URFs for the chemical HI for the pocket mouse and the radiation dose to the plant. Following Equation 16, the estimated dose is:

$$D_{Mr}\ (\text{rad/d}) = (5.11 \times 10^{-5})(MeV_{Mr})(C_{Mr}), \tag{20}$$

where the terms are defined in the same manner as for the plant (Section C.1.4.4.1) and C_{Mr} (the radionuclide concentration in the mouse) is calculated using Equation 3, but expressing the soil concentration in pCi/g and multiplying the right side of the equation by 0.001 kg/g to adjust for the difference in units (chemical concentrations are expressed in mg/kg), yielding Equation 21.

$$C_{Mr} = (C_{Pr})(IR)(FI)(B_{Mr})(0.4)(0.001) \tag{21}$$

where:

C_{Mr}	=	Contaminant concentration in mouse (pCi/g wet weight)
C_{Pr}	=	Contaminant concentration in plant (pCi/g dry weight)
IR	=	Ingestion rate of plants by herbivore (g/day)
FI	=	Fraction ingested from a contaminated source (unitless) = 1.0
B_{Mr}	=	Plant-to-muscle transfer factor (day/kg). (Plant-to-beef transfer factors used in the GENII model at the Hanford Site were used where available [Napier et al. 1988], or from *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture* [Baes et al. 1984] where not)
0.4	=	wet weight/dry weight conversion (DOE-RL 1994)
0.001	=	kg/g (conversion factor for plant-to-beef transfer factors, which have units of days/kg).

Expanding Equation 20,

$$D_{Mr} = (C_{Pr})(IR_M)(FI_M)(B_{Mr})(5.11 \times 10^{-5})(MeV_{Mr}), \tag{22}$$

and expanding C_{Pr} using Equation 1,

$$D_{Mr} = (C_{sr})(B_{vr})(0.4)(IR_M)(FI_M)(B_{Mr})(5.11 \times 10^{-5})(MeV_{Mr}). \tag{23}$$

Following the reasoning in Equations 17 through 19, the URF K_{Mr} for calculating the radiation dose to a pocket mouse from consumption of plants growing in contaminated soil is:

$$K_{Mr} = (5.11 \times 10^{-5})(MeV_{Mr})(B_{vr})(0.4)(IR_M)(FI_M)(B_{Mr}). \tag{24}$$

The dose equation is simplified to:

$$D_{Mr}\ (rad/d) = (C_{sr})(K_{Mr}). \tag{25}$$

As with chemicals, FI was assumed to be 1.0 for the pocket mouse, coyote, and hawk.

C.1.4.4.3 Derivation of Unit Risk Factors for Radiation Doses to the Coyote and Hawk. The derivation of risk factors for the coyote and the hawk was similar to derivation of risk factor for radiation dose for the pocket mouse and the chemical HI for the coyote. The concentration of radionuclides in the coyote was calculated as:

$$C_{Cr} = (C_{Mr})(IR)(FI)(B_{mmr}) \tag{26}$$

where:

C_{Cr} = Radionuclide concentration in coyote (pCi/g wet weight)
C_{Mr} = Contaminant concentration in pocket mouse (pCi/g wet weight, calculated in Equation 21)
IR = Ingestion rate of mice by coyote (kg/day)
FI = Fraction ingested from a contaminated source (unitless)
B_{mmr} = Muscle-to-muscle transfer factor (assumed to be 1.0).

The resulting equation for radiation dose, expanding Equation 21 is:

$$D_{Cr} = (C_{sr})(B_{vr})(0.4)(IR_M)(B_{Mr})(5.11 \times 10^{-5})(MeV_{Cr})(IR_C) \tag{27}$$

The URF K_C is:

$$K_C = (B_{vr})(0.4)(IR_M)(B_{Mr})(5.11 \times 10^{-5})(MeV_{Cr})(IR_C). \tag{28}$$

The URF for the hawk was calculated using the same equation, substituting MeV_{Hr} and IR_H for MeV_{Cr} and IR_C, respectively.

Unit risk factors for radiation doses calculated in this manner are listed in Table C-8. The soil-to-plant transfer factors used in the GENII model for the Hanford Site were used in the analysis (Napier et al. 1988). Organism-specific MeVs were obtained from the *Methods for Estimating Doses to Organisms from Radioactive Materials Released Into the Aquatic Environment* (Baker and Soldat 1992), assuming radii of 1.4, 2, 30, and 5 cm (0.6, 0.8, 12, and 2 in.) for the generic plant, pocket mouse, coyote, and red-tailed hawk, respectively.

C.1.4.4.4 Estimation of Radiation Dose to Aquatic Receptors. Mean and maximum radiation doses to aquatic receptors were estimated for a generic aquatic plant, invertebrate, fish, and the muskrat using the constants provided in *A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment* (Killough and McKay 1976) and the same source terms used in the human health risk assessment presented in Appendix B of the HRA-EIS. Concentrations used in the analysis are listed in Tables C-9 and C-10.

C.2 Results

Estimated HIs and radiation doses to ecological receptors are presented in Tables C-11 through C-23. Results are presented for four geographic areas (Columbia River, Central Plateau, Reactors on the River, and All Other Areas) and for each grid cell within the geographic areas. Division of the Hanford Site into grid cells for purposes of risk assessment is discussed in Appendix B of the HRA-EIS. The results are presented for each individual chemical or radionuclide, by cell, within each geographic area. Tables C-12, C-14, C-16, C-18, C-20, and C-22 provide the results summed by cell for all chemicals or radionuclides within the cell (i.e., the total HI or radiation dose resulting from contaminants within that grid cell). Table C-23 presents the estimated radiation doses to aquatic receptors. This appendix does not assess the significance of these calculations.

C.3 Uncertainties

A quantitative uncertainty analysis was not undertaken because of the level of effort required to assess and present the analysis for each grid cell on the Hanford Site. Source data is probably the primary contributor to uncertainty in calculating both the HIs and the radiation doses, as described in Appendix B of the HRA-EIS. Additional source data could either increase or decrease the estimated hazards; the maximum chemical and radionuclide concentrations were used for all analyses so that the estimate would represent an upper-bound value. Secondary contributors to uncertainty are considered to be the conceptual model and the transfer factors used to estimate plant uptake and assimilation in the pocket mouse. The conceptual model does not include potential dose contributions from water ingestion, inhalation, or direct radiation exposure. Inclusion of these pathways would increase the estimated radiation doses and chemical HIs. The model also assumes that organisms obtain all food from contaminated sources. Accounting for home range size relative to grid cell size would decrease the estimated risks for the coyote and hawk, which range over a larger area than the 1-km^2 (0.39-mi^2) grid cell area.

Additional data on transfer factors could either increase or decrease the estimated hazards; again, use of the maximum concentrations, essentially assuming direct uptake from the waste, was intended to ensure that the hazard estimates are an upper bound. Additional secondary contributors to uncertainty are the NOAELs for hazardous chemicals, and the assumption that radionuclides have infinite half-lives in the environment and are perfectly assimilated by the hawk and coyote. Although NOAEL estimates could be too high (making the HI too low), additional data (or calculations accounting for radiological decay) in either of these areas probably would reduce the estimates of hazard. Data regarding body weight and ingestion rates are considered to be minor contributors to uncertainty, because estimates of these parameters are better than estimates of the other variables. The assumption that the fraction ingested from a contaminated source equals 1.0 is a contributor to the conservatism of the hazard estimates rather than a source of uncertainty. Reduction of this value for a given receptor would reduce the HI or radiation dose.

Table C-1. Chemical Concentrations Used as Input to Hazard Index Calculations. (4 sheets)

Area	Cell ID	CAS No.	Chemical (Time 0)	Soil (g/cm^3)	Chemical Name		Concentration (mg/kg)	
					Const. 1	Const. 2	Const. 1	Const. 2
All Other Areas	591122	108101	MIBK	3.72 E-02	MIBK		2.11 E+04	
	591122	7440611	U	2.48 E-02	U		1.41 E+04	
	591122	14797558	NO_3	1.24 E-02	NO_3		7.05 E+03	
	594115	7439921	PbII	5.62 E-05	PbII		3.19 E+01	
	594115	7439976	Hg	9.36 E-07	Hg		5.32 E-01	
	594115	7440020	NiII	2.81 E-04	NiII		1.60 E+02	
	594115	7440224	AgI	2.81 E-05	Ag	I	7.34 E+00	8.62 E+00
	594115	7440417	Be	9.36 E-07	Be		5.32 E-01	
	594115	7440439	CdII	1.87 E-06	CdII		1.06 E+00	
	594115	7440473	CrVI	9.36 E-05	CrVI		5.32 E+01	
	594115	7440508	CuII	1.87 E-03	CuII		1.06 E+03	
	594115	7440611	U	9.36 E-04	U		5.32 E+02	
	594115	7646857	ZnII	9.36 E-05	ZnII		5.32 E+01	
	594115	7782414	F	1.87 E-04	F		1.06 E+02	
Central Plateau	565133	14797558	NO_3	5.00 E-06	NO_3		2.84 E+00	
	566133	14797558	NO_3	1.08 E-05	NO_3		6.12 E+00	
	566134	1302427	NaAl	8.33 E-05	Na	Al	2.09 E+01	2.46 E+01
	566134	1310732	NaOH	5.56 E-05	Na	OH	1.82 E+01	1.34 E+01
	566134	6484522	NH_4NO_3	7.27 E-04	NH_4	NO_3	9.30 E+01	3.20 E+02
	566134	7647145	Na	5.88 E-03	Na		3.34 E+03	
	566134	7697372	HNO_3	5.88 E-02	NO_3		3.28 E+04	
	566134	10588019	$Na_2Cr_2O_7$	5.56 E-05	CrVI		1.10 E+01	
	566134	13473900	$Al(NO_3)_3$	3.53 E-02	Al	NO_3	2.55 E+03	1.75 E+04
	566134	14797558	NO_3	3.53 E-02	NO_3		2.01 E+04	
	566135		$AlF(NO_3)_2$	4.12 E-02	Al	F	5.85 E+03	4.12 E+03
	566135	56235	CCl_4	4.56 E-02	CCl_4		2.59 E+04	
	566135	126738	TBP	3.86 E-03	TBP		2.19 E+03	
	566135	1310732	NaOH	1.72 E-02	Na	OH	5.63 E+03	4.16 E+03
	566135	1809194	DBBP	2.63 E-03	DBBP		1.50 E+03	
	566135	6484522	NH_4NO_3	4.00 E-03	NH_4	NO_3	5.11 E+02	1.76 E+03
	566135	7601549	PO_4	1.33 E-02	PO_4		7.58 E+03	
	566135	7647145	Na	4.76 E-01	Na		2.71 E+05	
	566135	7697372	HNO_3	7.65 E-03	NO_3		4.26 E+03	
	566135	7782414	F	1.07 E-01	F		6.06 E+04	
	566135	10124375	$Ca(NO_3)_2$	2.55 E-02	Ca	NO_3	5.69 E+03	8.79 E+03
	566135	10377603	$Mg(NO_3)_2$	3.53 E-02	Mg	NO_3	3.29 E+03	1.68 E+04
	566135	12808798	SO_4	2.00 E-03	SO_4		1.14 E+03	
	566135	13473900	$AlNO_3$	3.73 E-02	Al	NO_3	2.69 E+03	1.85 E+04
	566135	13520688	$FeNO_3$	7.84 E-03	Fe II/III	NO_3	1.03 E+03	3.43 E+03
	566135	14797558	NO_3	5.88 E-01	NO_3		3.34 E+05	

Table C-1. Chemical Concentrations Used as Input to Hazard Index Calculations. (4 sheets)

Area	Cell ID	CAS No.	Chemical (Time 0)	Soil (g/cm³)	Chemical Name		Concentration (mg/kg)	
					Const. 1	Const. 2	Const. 1	Const. 2
Central Plateau (continued)	566136		NaSi	5.62 E-01	NaSi		3.19 E+05	
	566136	62760	$Na_2C_2O_4$	8.70 E-02	Na		1.69 E+04	
	566136	1302427	NaAl	1.46 E+00	Na	Al	3.67 E+05	4.31 E+05
	566136	1310732	NaOH	1.35 E+00	Na	OH	4.41 E+05	3.26 E+05
	566136	6484522	NH_4NO_3	4.55 E-01	NH_4	NO_3	5.81 E+04	2.00 E+05
	566136	7447407	K	5.56 E-02	K		3.16 E+04	
	566136	7601549	PO_4	3.26 E+00	PO_4		1.85 E+06	
	566136	7647145	Na	1.01 E+01	Na		5.75 E+06	
	566136	7782414	F	4.49 E-01	F		2.55 E+05	
	566136	12808798	SO_4	6.74 E-01	SO_4		3.83 E+05	
	566136	13943583	FeCN	1.30 E-02	Fe II/III	CN	3.10 E+03	4.31 E+03
	566136	14797558	NO_3	1.35 E+01	NO_3		7.66 E+06	
	566136	Nitrite	NO_2	1.57 E+00	NO_2		8.94 E+05	
	567133	7647145	Na	1.76 E-02	Na		1.00 E+04	
	567133	14797558	NO_3	4.12 E-02	NO_3		2.34 E+04	
	567134	108101	MIBK	1.30 E-02	MIBK		7.38 E+03	
	567134	6484522	NH_4NO_3	9.09 E-03	NH_4	NO_3	1.16 E+03	4.00 E+03
	567134	7647145	Na	6.36 E-03	Na		3.62 E+03	
	567134	7697372	HNO_3	2.27 E-01	NO_3		1.27 E+05	
	567134	10588019	$Na_2Cr_2O_7$	1.30 E-02	CrVI		2.58 E+03	
	567134	13473900	$AlNO_3$	3.64 E-02	Al	NO_3	2.62 E+03	1.80 E+04
	567134	14797558	NO_3	1.00 E-01	NO_3		5.68 E+04	
	567135	126738	NPH	7.41 E-01	NPH		4.21 E+05	
	567135	7601549	TBP	2.41 E-01	TBP		1.37 E+05	
	567135		PO_4	3.18 E-01	PO_4		1.81 E+05	
	567135	7647145	Na	2.27 E+00	Na		1.29 E+06	
	567135	12808798	SO_4	4.55 E-01	SO_4		2.58 E+05	
	567135	14797558	NO_3	5.45 E+00	NO_3		3.10 E+06	
	567136	62760	$Na_2C_2O_4$	3.10 E+00	Na		6.05 E+05	
	567136	1310732	NaOH	1.64 E-04	Na	OH	5.36 E+01	3.96 E+01
	567136	6484522	NH_4NO_3	1.38 E+00	NH_4	NO_3	1.76 E+05	6.07 E+05
	567136	7447407	K	2.07 E+01	K		1.18 E+07	
	567136	7601549	PO_4	7.24 E+00	PO_4		4.11 E+06	
	567136	7647145	Na	8.62 E+01	Na		4.90 E+07	
	567136	7664939	H_2SO_4	4.55 E-03	H_2SO_4		2.58 E+03	
	567136	7697372	HNO_3	4.55 E-03	NO_3		2.53 E+03	
	567136	7782414	F	1.38 E+01	F		7.84 E+06	
	567136	10588019	$Na_2Cr_2O_7$	4.55 E-05	CrVI		9.01 E+00	
	567136	12808798	SO_4	8.28 E-01	SO_4		4.70 E+05	
	567136	14797558	NO_3	1.00 E+02	NO_3		5.68 E+07	

Table C-1. Chemical Concentrations Used as Input to Hazard Index Calculations. (4 sheets)

Area	Cell ID	CAS No.	Chemical (Time 0)	Soil (g/cm^3)	Chemical Name		Concentration (mg/kg)	
					Const. 1	Const. 2	Const. 1	Const. 2
Central Plateau (continued)	567137	14797558	NO_3	8.33 E-04	NO_3		4.73 E+02	
	573134	62760	$Na_2C_2O_4$	5.26 E-03	Na		1.03 E+03	
	573134	7601549	PO_4	4.21 E-01	PO_4		2.39 E+05	
	573134	7647145	Na	4.53 E+00	Na		2.57 E+06	
	573134	12808798	SO_4	4.74 E-01	SO_4		2.69 E+05	
	573134	13943583	FeCN	2.63 E-02	Fe II/III	CN	6.25 E+03	8.70 E+03
	573134	14797558	NO_3	1.11 E+01	NO_3		6.28 E+06	
	573136	144627	C_2O_4	7.50 E-02	C_2O_4		4.26 E+04	
	573136	6484522	NH_4NO_3	6.00 E-01	NH_4	NO_3	7.67 E+04	2.64 E+05
	573136	7447407	K	5.00 E-01	K		2.84 E+05	
	573136	7601549	PO_4	1.81 E-01	PO_4		1.03 E+05	
	573136	7647145	Na	2.19 E+00	Na		1.24 E+06	
	573136	7697372	HNO_3	2.22 E-02	NO_3		1.24 E+04	
	573136	7782414	F	3.13 E-01	F		1.78 E+05	
	573136	10588019	$Na_2Cr_2O_7$	2.22 E-03	CrVI		4.41 E+02	
	573136	12808798	SO_4	2.22 E-02	SO_4		1.26 E+04	
	573136	13473900	$Al(NO_3)_3$	3.13 E-02	Al	NO_3	2.25 E+03	1.55 E+04
	573136	14797558	NO_3	2.50 E+00	NO_3		1.42 E+06	
	573137	144627	NaSi	8.33 E-01	NaSi		4.73 E+05	
	573137		C_2O_4	1.40 E-01	C_2O_4		7.93 E+04	
	573137	506876	$(NH_4)_2CO_3$	1.98 E-02	NH_4	CO_3	2.60 E+03	8.19 E+03
	573137	1302427	NaAl	2.08 E+00	Na	Al	5.23 E+05	6.14 E+05
	573137	1310732	NaOH	3.17 E-01	Na	OH	1.03 E+05	7.65 E+04
	573137	6484522	NH_4NO_3	5.12 E-02	NH_4	NO_3	6.54 E+03	2.25 E+04
	573137	7447407	K	9.30 E-01	K		5.29 E+05	
	573137	7601549	PO_4	3.33 E+00	PO_4		1.89 E+06	
	573137	7647145	Na	1.08 E+01	Na		6.16 E+06	
	573137	7664939	H_2SO_4	3.11 E-01	H_2SO_4		1.77 E+05	
	573137	7782414	F	5.58 E-01	F		3.17 E+05	
	573137	12808798	SO_4	7.50 E-01	SO_4		4.26 E+05	
	573137	13943583	FeCN	9.52 E-03	Fe II/III	CN	2.26 E+03	3.15 E+03
	573137	14797558	NO_3	1.42 E+01	NO_3		8.05 E+06	
	573137	Nitrite	NO_2	1.67 E+00	NO_2		9.47 E+05	
	574136	78466	NPH	2.79 E-01	NPH		1.59 E+05	
	574136		TBPPH	1.63 E-01	TBPPH		9.25 E+04	
	574136	7647145	Na	3.49 E-02	Na		1.98 E+04	
	574136	7697372	HNO_3	1.00 E-01	NO_3		5.57 E+04	
	574136	14797558	NO_3	9.30 E-02	NO_3		5.29 E+04	
	575135	126738	NPH	5.71 E-01	NPH		3.25 E+05	
	575135		TBP	3.33 E-01	TBP		1.89 E+05	

Table C-1. Chemical Concentrations Used as Input to Hazard Index Calculations. (4 sheets)

Area	Cell ID	CAS No.	Chemical (Time 0)	Soil (g/cm^3)	Chemical Name		Concentration (mg/kg)	
					Const. 1	Const. 2	Const. 1	Const. 2
Central Plateau (continued)	575135	6484522	NH_4NO_3	2.86 E-01	NH_4	NO_3	3.65 E+04	1.26 E+05
	575135	7647145	Na	1.90 E-02	Na		1.08 E+04	
	575135	10588019	$Na_2Cr_2O_7$	5.24 E-04	CrVI		1.04 E+02	
	575135	12808798	SO_4	2.38 E-02	SO_4		1.35 E+04	
	575135	14797558	NO_3	1.45 E+00	NO_3		8.23 E+05	
	575136		NPH	1.29 E+00	NPH		7.31 E+05	
	575136	50328	BP	1.97 E-02	BP		1.12 E+04	
	575136	126738	TBP	7.14 E-01	TBP		4.06 E+05	
	575136	506876	$(NH_4)_2CO_3$	4.85 E-02	NH_4	CO_3	6.36 E+03	2.01 E+04
	575136	14797558	NO_3	3.03 E-01	NO_3		1.72 E+05	
Reactors on River	565144	62760	$Na_2C_2O_4$	3.86 E-02	Na		7.52 E+03	
	565144	5329146	NaSulfam	2.32 E-01	Na		2.54 E+04	
	565144	10588019	$Na_2Cr_2O_7$	3.86 E-02	CrVI		7.65 E+03	
	565145	10588019	$Na_2Cr_2O_7$	1.02 E-05	CrVI		2.03 E+00	
	569146	1310732	NaOH	3.20 E-01	Na	OH	1.04 E+05	7.72 E+04
	569146	7439976	Hg	1.43 E-02	Hg		8.10 E+03	
	569147	7664939	H_2SO_4	1.49 E-04	H_2SO_4		8.49 E+01	
	569147	7664939	H_2SO_4	1.49 E-04	SO_4		8.49 E+01	
	569147	7758987	Cu_2SO_4	7.47 E-06	CuI		1.69 E+00	
	569147	10588019	$Na_2Cr_2O_7$	4.48 E-03	CrVI		8.89 E+02	
	573151	62760	$Na_2C_2O_4$	2.23 E-03	Na		4.35 E+02	
	573151	5329146	NaSulfam	2.23 E-03	Na		2.45 E+02	
	573151	7632044	KBO_2	9.42 E-02	K	B	2.55 E+04	7.06 E+03
	573151	10588019	$Na_2Cr_2O_7$	7.81 E-04	CrVI		1.55 E+02	
	573152	10588019	$Na_2Cr_2O_7$	1.01 E-05	CrVI		2.01 E+00	
	574152	10588019	$Na_2Cr_2O_7$	1.95 E-05	CrVI		3.86 E+00	
	577152	62760	$Na_2C_2O_4$	1.54 E-02	Na		3.00 E+03	
	577152	5329146	NaSulfam	1.54 E-02	Na		1.69 E+03	
	577152	10588019	$Na_2Cr_2O_7$	4.68 E-02	CrVI		9.28 E+03	
	578152	10588019	$Na_2Cr_2O_7$	2.37 E-05	CrVI		4.70 E+00	
	580147	62760	$Na_2C_2O_4$	8.56 E-02	Na		1.67 E+04	
	580147	5329146	NaSulfam	8.56 E-02	Na		9.39 E+03	
	580147	7664939	H_2SO_4	5.31 E-04	SO_4		3.02 E+02	
	580147	10588019	$Na_2Cr_2O_7$	8.56 E-02	CrVI		1.70 E+04	
	581147	10588019	$Na_2Cr_2O_7$	1.42 E-05	CrVI		2.81 E+00	

Const. = Constituent of concern contained in chemical.
ID = identification.

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
All Other Areas	589127	Co-60	1.16 E-09
	590121	Co-60	5.72 E-10
	590121	Pu-239	3.99 E-10
	590121	U-235	3.00 E-16
	590121	U-238	3.23 E-18
	592116	Co-60	2.47 E-15
	592116	Th-232	1.09 E-07
	592116	U-235	1.74 E-10
	592116	U-238	3.73 E-09
	593116	Co-60	2.39 E-15
	593116	U-235	3.49 E-11
	593116	U-238	7.46 E-10
	594116	Co-60	2.11 E-09
	594116	Cs-137	5.33 E-08
	594116	Pu-239	2.40 E-11
Central Plateau	594116	Pu-240	2.21 E-12
	594116	U-235	1.25 E-13
	594116	U-238	2.70 E-12
	565133	Co-60	3.44 E-09
	565133	Cs-137	6.98 E-10
	565133	Pu-240	5.26 E-10
	565133	Ru-106	1.04 E-16
	565133	Sr-90	1.05 E-09
	565133	U-235	2.44 E-11
	565134	Cs-137	8.92 E-12
	565134	H-3	6.78 E-09
	565134	Ru-106	8.58 E-25
	565134	Sr-90	5.49 E-12
	566133	Am-241	6.91 E-12
	566133	Co-60	1.22 E-08
	566133	Cs-134	8.84 E-09
	566133	Cs-137	2.03 E-09
	566133	Pu-239	9.23 E-09
	566133	Pu-240	2.74 E-09
	566133	Ru-106	1.57 E-10
	566133	Sr-90	1.57 E-08
	566133	U-235	6.98 E-12
	566134	Am-241	2.59 E-09
	566134	Co-60	1.19 E-06
	566134	Cs-134	6.46 E-07

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm³
Central Plateau (continued)	566134	Cs-137	6.08 E-07
	566134	H-3	1.03 E-06
	566134	Pu-239	8.68 E-06
	566134	Pu-240	2.66 E-06
	566134	Ru-106	1.47 E-13
	566134	Sr-90	7.35 E-07
	566134	U-235	2.33 E-07
	566135	Am-241	4.21 E-10
	566135	Co-60	1.36 E-06
	566135	Cs-137	3.49 E-07
	566135	H-3	9.44 E-10
	566135	Pu-238	6.37 E-12
	566135	Pu-239	6.05 E-05
	566135	Pu-240	1.80 E-05
	566135	Pu-241	1.05 E-09
	566135	Ru-106	4.45 E-14
	566135	Sr-90	3.44 E-07
	566135	U-235	3.25 E-12
	566136	Co-60	8.31 E-05
	566136	Cs-134	4.71 E-09
	566136	Cs-137	4.34 E-05
	566136	Pm-147	5.81 E-11
	566136	Pu-239	2.17 E-06
	566136	Pu-240	4.26 E-07
	566136	Ru-106	8.90 E-14
	566136	Sr-90	6.13 E-07
	566136	Th-232	1.03 E-09
	566136	U-235	3.21 E-08
	566137	Cs-137	2.60 E-10
	566137	Sr-90	1.40 E-10
	567133	Co-60	1.04 E-07
	567133	Cs-137	3.77 E-08
	567133	H-3	3.74 E-11
	567133	Pu-239	2.36 E-08
	567133	Pu-240	7.00 E-09
	567133	Ru-106	1.66 E-16
	567133	Sr-90	1.51 E-08
	567133	U-235	1.04 E-11
	567134	Am-241	2.93 E-12
	567134	Co-60	3.80 E-06

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm³
Central Plateau (continued)	567134	Cs-137	6.39 E-07
	567134	H-3	8.54 E-13
	567134	Pu-239	8.28 E-08
	567134	Pu-240	2.45 E-08
	567134	Ru-106	1.59 E-13
	567134	Sr-90	1.26 E-06
	567134	U-235	2.05 E-09
	567134	U-238	3.94 E-11
	567135	Cs-134	2.89 E-07
	567135	Sr-90	9.59 E-09
	567136	Co-60	2.70 E-06
	567136	Cs-137	1.00 E-05
	567136	Pu-239	2.39 E-04
	567136	Pu-240	7.10 E-05
	567136	Sr-90	8.92 E-06
	567136	U-235	1.53 E-09
	567137	Cs-137	1.31 E-07
	567137	Ru-106	9.98 E-15
	567137	Sr-90	1.48 E-07
	569140	Cs-137	2.83 E-08
	569140	Ru-106	7.83 E-20
	569140	Sr-90	5.28 E-09
	570140	Cs-137	1.80 E-08
	570140	Pu-239	2.21 E-11
	570140	Ru-106	6.47 E-20
	570140	Sr-90	3.38 E-09
	570140	U-235	4.87 E-13
	571140	Cs-137	1.80 E-08
	571140	Pu-239	8.62 E-11
	571140	Pu-240	2.56 E-11
	571140	Ru-106	6.47 E-20
	571140	Sr-90	3.38 E-09
	571140	U-235	6.29 E-13
	573134	Co-60	1.31 E-05
	573134	Cs-137	5.81 E-06
	573134	Pu-239	8.62 E-07
	573134	Pu-240	2.56 E-07
	573134	Ru-106	1.25 E-14
	573134	Sr-90	2.97 E-06
	573134	U-235	1.22 E-09

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
Central Plateau (continued)	573134	U-238	7.26 E-10
	573136	Am-241	1.08 E-10
	573136	Co-60	6.25 E-07
	573136	Cs-137	4.26 E-07
	573136	H-3	1.55 E-08
	573136	Po-210	2.17 E-07
	573136	Pu-239	2.83 E-05
	573136	Pu-240	1.64 E-06
	573136	Re-187	1.97 E-14
	573136	Ru-106	5.17 E-12
	573136	Sn-123M	4.38 E-12
	573136	Sr-90	1.59 E-07
	573136	U-234	2.32 E-09
	573136	U-235	2.00 E-09
	573136	U-238	3.57 E-09
	573137	Cs-134	4.40 E-09
	573137	Cs-137	1.12 E-05
	573137	Pu-239	1.00 E-05
	573137	Ru-106	7.34 E-15
	573137	Sr-90	6.32 E-06
	573137	U-238	1.89 E-09
	574135	Am-241	2.34 E-11
	574135	Co-60	1.09 E-08
	574135	Cs-137	2.44 E-09
	574135	H-3	5.61 E-07
	574135	I-129	3.24 E-12
	574135	Pm-147	9.45 E-12
	574135	Pu-238	9.97 E-12
	574135	Pu-239	2.30 E-09
	574135	Pu-240	8.61 E-10
	574135	Pu-241	1.28 E-09
	574135	Ru-106	9.35 E-12
	574135	Sr-90	2.50 E-09
	574135	U-235	2.45 E-12
	574136	Cs-137	3.20 E-09
	574136	Eu-154	4.24 E-16
	574136	Pu-239	5.33 E-08
	574136	Ru-106	4.11 E-15
	574136	Sr-90	5.16 E-04
	574136	U-235	1.19 E-05

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
Central Plateau (continued)	574136	U-238	6.55 E-10
	574139	Am-241	3.52 E-15
	574139	Cs-137	7.62 E-09
	574139	H-3	1.42 E-09
	574139	Pm-147	9.59 E-12
	574139	Pu-239	7.74 E-10
	574139	Ru-106	1.08 E-15
	574139	Sr-90	1.71 E-09
	574139	U-235	2.83 E-11
	575135	Am-241	2.61 E-10
	575135	Co-60	3.30 E-05
	575135	Cs-137	7.70 E-06
	575135	H-3	8.89 E-07
	575135	I-129	1.01 E-11
	575135	Pm-147	2.40 E-09
	575135	Pu-239	1.51 E-07
	575135	Pu-240	4.46 E-08
	575135	Pu-241	6.72 E-10
	575135	Ru-106	3.81 E-09
	575135	Sn-113	1.39 E-12
	575135	Sr-90	8.89 E-06
	575135	U-235	1.33 E-06
	575136	Co-58	1.14 E-07
	575136	Co-60	4.72 E-10
	575136	Cs-137	7.91 E-08
	575136	H-3	5.24 E-11
	575136	Pu-239	2.38 E-08
	575136	Pu-240	6.48 E-11
	575136	Ru-106	7.11 E-15
	575136	Sr-90	7.80 E-09
	575136	U-235	1.43 E-10
	575136	U-238	1.64 E-11
	575137	Cs-137	5.70 E-12
	575137	Sr-90	5.08 E-12

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
Reactors on River	564143	C-14	9.48 E-12
	564143	Co-60	3.62 E-09
	564143	Cs-137	2.07 E-11
	564143	Eu-152	2.05 E-10
	564143	Eu-154	3.36 E-10
	564143	H-3	4.63 E-08
	564143	Ni-63	1.42 E-09
	564143	Sr-90	2.06 E-11
	565143	C-14	7.33 E-11
	565143	Co-60	2.81 E-09
	565143	Cs-137	2.51 E-11
	565143	Eu-152	2.47 E-10
	565143	Eu-154	4.05 E-10
	565143	H-3	1.45 E-10
	565143	Ni-63	1.29 E-09
	565143	Sr-90	2.51 E-11
	565144	Co-60	1.22 E-05
	565144	Cs-134	1.12 E-11
	565144	Cs-137	1.23 E-08
	565144	Eu-152	6.94 E-09
	565144	Eu-154	3.76 E-10
	565144	Eu-155	1.98 E-09
	565144	H-3	2.81 E-05
	565144	Ni-63	3.89 E-07
	565144	Pu-238	1.76 E-10
	565144	Pu-239	1.75 E-10
	565144	Pu-240	1.95 E-11
	565144	Sr-90	1.22 E-08
	565144	U-235	2.85 E-13
	565144	U-238	1.95 E-10
	565145	C-14	1.08 E-10
	565145	Co-60	1.02 E-07
	565145	Cs-134	7.30 E-13
	565145	Cs-137	1.35 E-09
	565145	Eu-152	2.04 E-09
	565145	Eu-154	7.47 E-10
	565145	Eu-155	9.00 E-10
	565145	H-3	2.92 E-11
	565145	Pu-238	5.06 E-14
	565145	Pu-239	2.60 E-12

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
Reactors on River (continued)	565145	Pu-240	2.78 E-12
	565145	Sr-90	2.46 E-11
	565145	U-235	9.85 E-13
	565145	U-238	2.20 E-12
	568146	C-14	2.77 E-07
	568146	Co-60	1.62 E-12
	568146	Cs-134	2.99 E-14
	568146	Cs-137	8.79 E-12
	568146	Eu-152	1.18 E-12
	568146	Eu-154	2.54 E-13
	568146	Eu-155	1.44 E-12
	568146	H-3	1.74 E-07
	568146	Sr-90	1.50 E-11
	568146	U-235	2.89 E-13
	569146	C-14	2.77 E-07
	569146	Co-60	2.17 E-08
	569146	Cs-134	3.05 E-16
	569146	Cs-137	2.35 E-09
	569146	Eu-152	1.96 E-10
	569146	Eu-154	4.02 E-10
	569146	Eu-155	2.80 E-11
	569146	H-3	1.20 E-07
	569146	Ni-63	1.85 E-09
	569146	Pu-239	5.43 E-11
	569146	Pu-240	6.07 E-12
	569146	Sb-125	4.91 E-11
	569146	Sr-90	6.23 E-09
	569146	U-235	6.39 E-14
	569146	U-238	6.65 E-12
	569147	C-14	1.34 E-11
	569147	Co-60	4.93 E-10
	569147	Cs-134	3.19 E-12
	569147	Cs-137	2.04 E-09
	569147	Eu-152	8.91 E-09
	569147	Eu-154	2.33 E-09
	569147	Eu-155	9.21 E-11
	569147	H-3	1.90 E-10
	569147	Ni-63	2.05 E-09
	569147	Pu-238	2.58 E-12
	569147	Pu-239	6.73 E-11

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
Reactors on River (continued)	569147	Pu-240	7.47 E-12
	569147	Sr-90	1.23 E-10
	569147	U-235	4.16 E-14
	569147	U-238	4.74 E-12
	571149	Fe-59	6.69 E-21
	571149	Zr-95	6.43 E-18
	571149	Ce-144	2.87 E-11
	571149	Co-60	5.97 E-08
	571149	Cs-134	3.31 E-10
	571149	Cs-137	5.78 E-08
	571149	H-3	2.38 E-08
	571149	Mn-54	6.40 E-11
	571149	Nb-95	2.39 E-25
	571149	Pu-239	5.00 E-10
	571149	Ru-103	1.13 E-23
	571149	Ru-106	1.75 E-10
	571149	Sr-90	4.51 E-08
	571149	Tc-99	9.82 E-09
	572150	C-14	7.70 E-12
	572150	Co-60	7.02 E-10
	572150	Cs-137	1.68 E-11
	572150	Eu-152	1.64 E-10
	572150	Eu-154	2.52 E-10
	572150	H-3	3.46 E-11
	572150	Ni-63	1.10 E-09
	572150	Sr-90	1.68 E-11
	573150	Co-60	4.22 E-10
	573151	C-14	1.04 E-11
	573151	Co-60	3.24 E-08
	573151	Cs-134	9.82 E-14
	573151	Cs-137	2.88 E-09
	573151	Eu-152	3.01 E-10
	573151	Eu-154	3.40 E-10
	573151	Eu-155	1.79 E-10
	573151	H-3	3.60 E-10
	573151	Ni-63	8.31 E-10
	573151	Pu-239	9.09 E-12
	573151	Pu-240	1.01 E-12
	573151	Sr-90	3.83 E-09
	573151	U-235	2.23 E-14

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
Reactors on River (continued)	573151	U-238	2.77 E-12
	573152	Co-60	1.67 E-10
	573152	Cs-134	1.62 E-13
	573152	Cs-137	3.06 E-09
	573152	Eu-152	1.12 E-09
	573152	Eu-154	1.83 E-10
	573152	Eu-155	1.56 E-11
	573152	H-3	9.16 E-11
	573152	Pu-238	3.73 E-15
	573152	Pu-239	7.97 E-12
	574152	Cs-134	3.18 E-13
	574152	Cs-137	5.90 E-09
	574152	Eu-152	2.17 E-09
	574152	Eu-154	3.52 E-10
	574152	Eu-155	3.00 E-11
	574152	H-3	1.76 E-10
	574152	Pu-239	1.53 E-11
	574152	Pu-240	1.70 E-12
	574152	Sr-90	1.35 E-10
	574152	U-235	1.17 E-13
	574152	U-238	1.32 E-11
	577152	C-14	9.57 E-12
	577152	Co-60	1.82 E-09
	577152	Cs-134	1.18 E-15
	577152	Cs-137	2.49 E-10
	577152	Eu-152	5.79 E-10
	577152	Eu-154	2.81 E-10
	577152	Eu-155	6.52 E-12
	577152	H-3	4.30 E-11
	577152	Pu-238	2.85 E-13
	577152	Pu-239	9.79 E-12
	577152	Pu-240	5.54 E-15
	577152	Sr-90	6.22 E-11
	577152	U-235	9.79 E-12
	577152	U-238	8.23 E-13
	578152	C-14	9.25 E-14
	578152	Co-60	1.46 E-10
	578152	Cs-134	2.99 E-15
	578152	Cs-137	9.18 E-10
	578152	Eu-152	2.00 E-09

Table C-2. Radionuclide Source Term Concentrations Used to Estimate Radiation Dose. (10 sheets)

Area	Cell ID	Radionuclide	Ci/cm^3
Reactors on River (continued)	578152	Eu-154	9.73 E-10
	578152	Eu-155	2.28 E-11
	578152	H-3	6.61 E-12
	578152	Pu-238	2.96 E-15
	578152	Pu-239	1.58 E-11
	578152	Pu-240	1.76 E-12
	578152	Sr-90	1.81 E-10
	578152	U-235	3.69 E-13
	578152	U-238	4.21 E-11
	579147	Co-60	7.56 E-10
	580147	C-14	5.54 E-11
	580147	Co-60	1.00 E-09
	580147	Cs-134	6.00 E-12
	580147	Cs-137	1.94 E-08
	580147	Eu-152	4.17 E-10
	580147	Eu-154	3.54 E-10
	580147	Eu-155	2.69 E-10
	580147	H-3	1.88 E-09
	580147	Ni-63	1.38 E-09
	580147	Pu-238	6.92 E-12
	580147	Pu-239	5.08 E-10
	580147	Pu-240	5.65 E-11
	580147	Sr-90	1.30 E-08
	580147	U-235	1.35 E-13
	580147	U-238	2.14 E-11
	581147	C-14	2.00 E-13
	581147	Co-60	1.15 E-10
	581147	Cs-134	1.94 E-14
	581147	Cs-137	1.65 E-10
	581147	Eu-152	1.18 E-09
	581147	Eu-154	2.60 E-10
	581147	Eu-155	2.81 E-11
	581147	H-3	7.12 E-11
	581147	Pu-238	4.22 E-17
	581147	Pu-239	2.15 E-11
	581147	Pu-240	2.45 E-13
	581147	Sr-90	6.83 E-10
	581147	U-235	5.08 E-14
	581147	U-238	3.73 E-12

ID = identification.

Table C-3. Transfer Factors Used to Calculate Unit Risk Factors for Chemicals. (2 sheets)

Chemical	Const. 1	Const. 2	Transfer Factors			
			Soil-to-Plant		Plant-to-Beef	
			Const. 1	Const. 2	Const. 1	Const. 2
AgI	Ag	I	6.00 E-02	4.00 E-01	2.00 E-03	2.00 E-03
$AlF(NO_3)_2$	Al	F	6.50 E-04	2.00 E-02	1.50 E-03	2.00 E-02
$Al(NO_3)_3$	Al	NO_3	6.50 E-04	NA	1.50 E-03	NA
Be	Be		3.30 E-03	NA	8.00 E-04	NA
BP	BP		NA	NA	NA	NA
$Ca(NO_3)_2$	Ca	NO_3	2.00 E+00	NA	1.60 E-03	NA
CCl_4	CCl_4		NA	NA	NA	NA
CdII	CdII		6.00 E-01	NA	4.00 E-04	NA
CrVI	CrVI		4.00 E-03	NA	9.00 E-03	NA
Cu_2SO_4	CuI		5.00 E-02	NA	9.00 E-03	NA
CuII	CuII		5.00 E-02	NA	9.00 E-03	NA
DBBP	DBBP		NA	NA	NA	NA
F	F		2.00 E-02	NA	2.00 E-02	NA
FeCN	Fe II/III	CN	5.00 E-03	NA	2.00 E-02	NA
$FeNO_3$	Fe II/III	NO_3	5.00 E-03	NA	2.00 E-02	NA
H_2SO_4	H_2SO_4		NA	NA	NA	NA
Hg	Hg		1.00 E-01	NA	1.00 E-01	NA
HNO_3	NO_3		NA	NA	NA	NA
K	K		3.00 E+00	NA	1.80 E-02	NA
KBO_2	K	B	3.00 E+00	4.00 E+00	1.80 E-02	2.00 E+00
$Mg(NO_3)_2$	Mg	NO_3	9.90 E-04	NA	1.80 E-02	NA
MIBK	MIBK		NA	NA	NA	NA
Na	Na		1.00 E+01	NA	8.00 E-02	NA
NaAl	Na	Al	1.00 E+01	6.50 E-04	8.00 E-02	1.50 E-03
$Na_2Cr_2O_7$	CrVI		4.00 E-03	NA	9.00 E-03	NA
NaOH	Na	OH	1.00 E+01	NA	8.00 E-02	NA
$Na_2C_2O_4$	Na		NA	NA	NA	NA
NaSi	NaSi		NA	NA	NA	NA
NaSulfam	Na		NA	NA	NA	NA
$(NH_4)_2CO_3$	NH_4	CO_3	NA	NA	NA	NA
NH_4NO_3	NH_4	NO_3	NA	NA	NA	NA
NiII	NiII		5.00 E-02	NA	2.00 E-03	NA
NO_2	NO_2		NA	NA	NA	NA
NO_3	NO_3		NA	NA	NA	NA
NPH	NPH		NA	NA	NA	NA
C_2O_4	C_2O_4		NA	NA	NA	NA
PbII	PbII		1.00 E-02	NA	4.00 E-04	NA
PO_4	PO_4		NA	NA	NA	NA
SO_4	SO_4		NA	NA	NA	NA
TBP	TBP		NA	NA	NA	NA

Table C-3. Transfer Factors Used to Calculate Unit Risk Factors for Chemicals. (2 sheets)

Chemical	Const. 1	Const. 2	Transfer Factors			
			Soil-to-Plant		Plant-to-Beef	
			Const. 1	Const. 2	Const. 1	Const. 2
TBPPH	TBPPH		NA	NA	NA	NA
TriChlor	TCE		1.84 E+00	NA	4.90 E-06	NA
U	U		2.00 E-04	NA	2.00 E-04	NA
ZnII	ZnII		2.00 E+00	NA	1.00 E-01	NA

Source: GENII database (Napier et al. 1988).
NOTE: Blanks in Const. 2 column indicate only one constituent of concern in chemical.
Const. = Constituent of concern contained in chemical.
NA = Not Available.

Table C-4. Body Weights and Ingestion Rates of Ecological Receptors.

Organism	Ingestion rate (g/d)	Body weight (kg)
Pocket Mouse	6.7	0.0235
Coyote	1,300	10
Red-tailed Hawk	1,100	1

Table C-5. Scaling Factors for Adjusting Wildlife No Observed Adverse Effect Levels for Body Size.

Experimental Animal Species	Weight (kg)	Wildlife Species	Weight (kg)	Scaling Factor
rat	0.35	pocket mouse	0.0235	2.46
rat	0.35	coyote	10	0.33
mouse	0.03	pocket mouse	0.0235	1.08
mouse	0.03	coyote	10	0.14
rabbit	3.8	pocket mouse	0.0235	5.45
rabbit	3.8	coyote	10	0.72
dog	12.7	pocket mouse	0.0235	8.15
dog	12.7	coyote	10	1.08
human	70	pocket mouse	0.0235	14.39
human	70	coyote	10	1.91

NOTE: Scaling factors adapted from the *Toxicological Benchmarks for Wildlife* (Opresko et al. 1993).

Table C-6. No Observed Adverse Effect Levels for Chemical Intake by Ecological Receptors.

Chemical	Const. 1	Const. 2	No Observed Adverse Effect Level (mg/kg/day)							
			Plant		Mouse		Coyote		Hawk	
			Const. 1	Const. 2	Const. 1	Const. 2	Const. 1	Const. 2	Const. 1	Const. 2
AgI	Ag	I	2.00 E+00[1]	4.00 E+00[1]	1.50 E-03[3]		1.50 E-03[3]		5.00 E-01[3]	
$AlF(NO_3)_2$	Al	F	1.00 E+01[1]	2.00 E+02[1]	1.34 E-01[3]		1.34 E-01[3]		7.50 E-01[3]	
$Al(NO_3)_3$	Al	NO_3	1.00 E+01[1]		1.34 E-01[3]	2.30 E+01	1.34 E-01[3]	3.06 E+00[2]	7.50 E-01[3]	
Be	Be		1.00 E+01[1]		1.33 E+00[3]		1.77 E-01[2]		5.40 E-02[3]	
BP	BP									
$Ca(NO_3)_2$	Ca	NO_3				2.30 E+01[2]		3.06 E+00[2]		
CCl_4	CCl_4				1.75 E-01[2]		2.32 E-02[2]			
CdII	CdII		2.00 E+00[1]		5.80 E-01[3]		5.80 E-01[3]		2.00 E-02[3]	
CrVI	CrVI		2.00 E+01[1]		5.90 E+00[2]		8.50 E-01[2]		1.50 E-01[3]	
Cu_2SO_4	CuI		4.00 E+01[1]		4.00 E-03[3]		4.00 E-03[3]		1.25 E-01[3]	
CuII	CuII		4.00 E+01[1]		4.00 E-03[3]		4.00 E-03[3]		1.25 E-01[3]	
DBBP	DBBP									
F	F		2.00 E+02[1]							
FeCN	Fe II/III	CN								
$FeNO_3$	Fe II/III	NO_3				2.30 E+01[2]		3.06 E+00[2]		
H_2SO_4	H_2SO_4									
Hg	Hg		3.00 E-01[1]		3.00 E-02[3]		3.00 E-02[3]		5.60 E-03[2]	
HNO_3	NO_3				2.30 E+01[2]		3.06 E+00[2]			
K	K									
KBO_2	K	B		5.00 E-01[1]						
$Mg(NO_3)_2$	Mg	NO_3				2.30 E+01[2]		3.06 E+00[2]		
MIBK	MIBK				1.23 E+01[2]		1.64 E+00[2]			
Na	Na									7.50 E-01[3]
NaAl	Na	Al	2.00 E+00[1]	1.00 E+01[1]		1.50 E-03[3]		1.50 E-03[3]		
$NaCr_2$	CrVI				5.90 E+00[2]		8.50 E-01[2]		1.50 E-01[3]	
NaOH	Na	OH								
$Na_2C_2O_4$	Na	CO_3								
NaSi	NaSi									
NaSulfam	Na									
$(NH_4)_2CO_3$	NH_4									
NH_4NO_3	NH_4	NO_3				2.30 E+01[2]		3.06 E+00[2]		
NiII	NiII		2.50 E+01[1]		2.25 E+01[2]		3.00 E+00[2]		3.50 E-01[3]	
NO_2	NO_2									
NO_3	NO_3				2.30 E+01[2]		3.06 E+00[2]			
NPH	NPH									
C_2O_4	C_2O_4									
PbII	PbII		5.00 E+01[1]		1.90 E-02[3]		1.90 E-02[3]		1.60 E-01[3]	
PO_4	PO_4									
SO_4	SO_4									
TBP	TBP									
TBPPH	TBPPH									
TCE	TCE				1.85 E+02[2]		2.45 E+01[2]			
U	U				1.53 E+00[2]		2.03 E-01[2]		8.90 E+00[2]	
ZnII	ZnII		2.00 E+01[1]		1.24 E+01[2]		1.66 E+00[2]		8.86 E-01[2]	

[1] *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants* (Suter et al. 1993).
[2] *Toxicological Benchmarks for Wildlife* (Opresko et al. 1993), scaled to body size as described in text.
[3] *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE-RL 1994).
Const. = Constituent of concern contained in chemical.

Table C-7. Unit Risk Factors for Calculating Chemical Hazard Indices.

Chemical	Const. 1	Const. 2	Unit Risk Factor					
			Mouse		Coyote		Hawk	
			Const. 1	Const. 2	Const. 1	Const. 2	Const. 1	Const. 2
AgI	Ag	I	2.19 E-01	NA	3.59 E+04	NA	1.41 E+06	NA
$AlF(NO_3)_2$	Al	F	1.81 E+03	NA	3.94 E+08	NA	2.61 E+08	NA
$Al(NO_3)_3$	Al	NO_3	1.81 E+03	NA	3.94 E+08	NA	2.61 E+08	NA
Be	Be		3.53 E+03	NA	1.92 E+08	NA	6.94 E+06	NA
BP	BP		NA	NA	NA	NA	NA	NA
$Ca(NO_3)_2$	Ca	NO_3	NA	NA	NA	NA	NA	NA
CCl_4	CCl_4		NA	NA	NA	NA	NA	NA
CdII	CdII		8.48 E+00	NA	6.94 E+06	NA	2.83 E+04	NA
CrVI	CrVI		1.29 E+04	NA	6.78 E+07	NA	1.41 E+06	NA
Cu_2SO_4	CuI		7.02 E-01	NA	2.55 E+04	NA	9.42 E+04	NA
CuII	CuII		7.02 E-01	NA	2.55 E+04	NA	9.42 E+04	NA
DBBP	DBBP		NA	NA	NA	NA	NA	NA
F	F		NA	NA	NA	NA	NA	NA
FeCN	Fe II/III	CN	NA	NA	NA	NA	NA	NA
$FeNO_3$	Fe II/III	NO_3	NA	NA	NA	NA	NA	NA
H_2SO_4	H_2SO_4		NA	NA	NA	NA	NA	NA
Hg	Hg		2.63 E+00	NA	8.61 E+03	NA	1.90 E+02	NA
HNO_3	NO_3		NA	NA	NA	NA	NA	NA
K	K		NA	NA	NA	NA	NA	NA
KBO_2	K	B	NA	NA	NA	NA	NA	NA
$Mg(NO_3)_2$	Mg	NO_3	NA	NA	NA	NA	NA	NA
MIBK	MIBK		NA	NA	NA	NA	NA	NA
Na	Na		NA	NA	NA	NA	NA	NA
NaAl	Na	Al	NA	2.02 E+01	NA	4.42 E+06	NA	2.61 E+08
$Na_2Cr_2O_7$	CrVI		1.29 E+04	NA	6.78 E+07	NA	1.41 E+06	NA
NaOH	Na	OH	NA	NA	NA	NA	NA	NA
$Na_2C_2O_4$	Na		NA	NA	NA	NA	NA	NA
NaSi	NaSi		NA	NA	NA	NA	NA	NA
NaSulfam	Na		NA	NA	NA	NA	NA	NA
$(NH_4)_2CO_3$	NH_4	CO_3	NA	NA	NA	NA	NA	NA
NH_4NO_3	NH_4	NO_3	NA	NA	NA	NA	NA	NA
NiII	NiII		3.95 E+03	NA	8.60 E+07	NA	1.19 E+06	NA
NO_2	NO_2		NA	NA	NA	NA	NA	NA
NO_3	NO_3		NA	NA	NA	NA	NA	NA
NPH	NPH		NA	NA	NA	NA	NA	NA
C_2O_4	C_2O_4		NA	NA	NA	NA	NA	NA
PbII	PbII		1.67 E+01	NA	1.36 E+07	NA	1.36 E+07	NA
PO_4	PO_4		NA	NA	NA	NA	NA	NA
SO_4	SO_4		NA	NA	NA	NA	NA	NA
TBP	TBP		NA	NA	NA	NA	NA	NA
TBPPH	TBPPH		NA	NA	NA	NA	NA	NA
TCE	TCE		8.80 E+02	NA	7.82 E+09	NA	NA	NA
U	U		6.69 E+04	NA	1.46 E+10	NA	7.55 E+10	NA
ZnII	ZnII		5.46 E+01	NA	2.38 E+04	NA	1.50 E+03	NA

NOTE: Blanks in Const. 2 column indicate only one constituent of concern in chemical.
Const. = Constituent of concern contained in chemical.
NA = Not Available (no NOAEL, transfer factors, or both).
NOAEL = No Observable Adverse Effect Level.

Table C-8. Unit Risk Factors and Associated Parameters Used to Calculate Radiation Doses.

Radionuclide	Effective Decay Energy (MeV)				Transfer Factor		Unit Risk Factor			
	Plant	Mouse	Coyote	Hawk	Soil/Plant (Bv)	Plant/Muscle (Bm)	Plant (Kp)	Mouse (Km)	Coyote (Kc)	Hawk (Kh)
Am-241	5.51 E+00	5.51 E+00	5.51 E+00	5.51 E+00	2.00 E-04	2.00 E-05	5.63 E-08	3.02 E-15	3.92 E-12	3.32 E-12
C-14	5.00 E-02	5.00 E-02	5.00 E-02	5.00 E-02	1.00 E+00	1.00 E+00	2.56 E-06	6.85 E-09	8.90 E-06	7.53 E-06
Co-58	7.28 E-02	9.05 E-02	6.33 E-01	1.74 E-01	4.00 E-03	2.00 E-02	1.49 E-08	9.92 E-13	9.02 E-09	2.10 E-09
Co-60	1.95 E-01	2.37 E-01	1.56 E+00	4.37 E-01	4.00 E-03	2.00 E-02	3.99 E-08	2.60 E-12	2.22 E-08	5.27 E-09
Cs-134	2.30 E-01	2.59 E-01	1.14 E+00	3.96 E-01	1.00 E-02	3.00 E-02	1.18 E-07	1.06 E-11	6.09 E-08	1.79 E-08
Cs-137	2.57 E-01	2.67 E-01	5.82 E-01	3.16 E-01	1.00 E-02	3.00 E-02	1.31 E-07	1.10 E-11	3.11 E-08	1.43 E-08
Eu-152	1.50 E+00	1.50 E+00	1.50 E+00	1.50 E+00	2.00 E-03	6.00 E-03	1.53 E-07	2.47 E-12	3.20 E-09	2.71 E-09
Eu-154	3.11 E-01	3.11 E-01	9.65 E-01	4.28 E-01	2.00 E-03	6.00 E-03	3.18 E-08	5.11 E-13	2.06 E-09	7.74 E-10
Eu-155	6.85 E-02	6.85 E-02	6.85 E-02	6.85 E-02	2.00 E-03	6.00 E-03	7.00 E-09	1.13 E-13	1.46 E-10	1.24 E-10
H-3	5.80 E-03	5.80 E-03	5.80 E-03	5.80 E-03	1.00 E+00	1.00 E+00	2.96 E-07	7.94 E-10	1.03 E-06	8.74 E-07
I-129	6.02 E-02	6.28 E-02	8.72 E-02	6.94 E-02	4.00 E-01	2.00 E-03	1.23 E-06	6.88 E-12	1.24 E-08	8.36 E-09
Mn-54	3.64 E-02	5.14 E-02	5.12 E-01	1.22 E-01	2.00 E-01	5.00 E-04	3.72 E-07	7.04 E-13	9.12 E-09	1.84 E-09
Nb-95	NA	NA	NA	NA	8.00 E-03	2.60 E-07	NA	NA	NA	NA
Ni-63	1.76 E-02	1.76 E-02	1.76 E-02	1.76 E-02	5.00 E-02	2.00 E-03	4.50 E-08	2.41 E-13	3.13 E-10	2.65 E-10
Pm-147	6.20 E-02	6.20 E-02	6.20 E-02	6.20 E-02	1.00 E-03	5.00 E-03	3.17 E-09	4.25 E-14	5.52 E-11	4.67 E-11
Po-210	NA	NA	NA	NA	1.00 E-03	4.50 E-03	NA	NA	NA	NA
Pu-238	5.51 E+00	5.51 E+00	5.51 E+00	5.51 E+00	4.00 E-05	2.00 E-06	1.13 E-08	6.04 E-17	7.85 E-14	6.64 E-14
Pu-239	5.15 E+00	5.15 E+00	5.15 E+00	5.15 E+00	4.00 E-05	2.00 E-06	1.05 E-08	5.64 E-17	7.33 E-14	6.21 E-14
Pu-240	5.16 E+00	5.16 E+00	5.16 E+00	5.16 E+00	4.00 E-05	2.00 E-06	1.05 E-08	5.65 E-17	7.35 E-14	6.22 E-14
Pu-241	5.35 E-03	5.35 E-03	6.36 E-03	5.35 E-03	4.00 E-05	2.00 E-06	1.09 E-11	5.86 E-20	9.06 E-17	6.45 E-17
Re-187	NA	NA	NA	NA	9.90 E-04	9.90 E-04	NA	NA	NA	NA
Ru-106	1.44 E+00	1.44 E+00	1.56 E+00	1.46 E+00	2.00 E-01	2.00 E-03	1.47 E-05	7.89 E-11	1.11 E-07	8.80 E-08
Sb-125	1.05 E-01	1.13 E-01	3.53 E-01	1.50 E-01	5.00 E-02	1.00 E-03	2.68 E-07	7.74 E-13	3.14 E-09	1.13 E-09
Sn-113	NA	NA	NA	NA	1.00 E-02	1.00 E-02	NA	NA	NA	NA
Sn-123M	NA	NA	NA	NA	1.00 E-02	1.00 E-02	NA	NA	NA	NA
Sr-90	2.08 E+00	2.08 E+00	2.08 E+00	2.08 E+00	2.00 E-01	8.00 E-04	2.12 E-05	4.56 E-11	5.92 E-08	5.01 E-08
Tc-99	8.40 E-02	8.40 E-02	8.40 E-02	8.40 E-02	4.00 E+01	9.90 E-04	1.72 E-04	4.56 E-10	5.92 E-07	5.01 E-07
Th-232	4.00 E+00	4.00 E+00	4.00 E+00	4.00 E+00	4.00 E-04	5.00 E-03	8.18 E-08	1.10 E-12	1.42 E-09	1.21 E-09
U-234	4.90 E+00	4.90 E+00	4.90 E+00	4.90 E+00	2.00 E-04	2.00 E-04	5.01 E-08	2.68 E-14	3.49 E-11	2.95 E-11
U-235	4.60 E+00	4.60 E+00	4.60 E+00	4.60 E+00	2.00 E-04	2.00 E-04	4.70 E-08	2.52 E-14	3.28 E-11	2.77 E-11
U-238	4.30 E+00	4.30 E+00	4.30 E+00	4.30 E+00	2.00 E-04	2.00 E-04	4.39 E-08	2.36 E-14	3.06 E-11	2.59 E-11

NA = Not available in the *Methods for Estimating Doses to Organisms from Radioactive Materials Released Into the Aquatic Environment* (Baker and Soldat 1992).

Table C-9. Water Concentrations Used to Calculate Maximum Radiation Doses to Aquatic Organisms.

Radionuclide	Location				
	100-N Springs (pCi/L)	216-B-3 (pCi/L)	216-N-8 (pCi/L)	400 Area (pCi/L)	Columbia River (pCi/L)
Be-7		1.55 E+01		5.23 E+00	6.82 E+01
Ce-134		8.35 E+00		8.98 E-01	
Co-60	5.20 E+00	4.74 E-01		6.02 E-01	1.25 E+00
Cs-137			9.64 E-01	1.97 E+00	
Cs-134		7.33 E-01		7.29 E-01	
Eu-154		1.29 E+00		3.47 E+00	
Eu-155		2.34 E+00		1.27 E+00	
H-3	7.70 E+02	4.69 E+02	5.12 E+02	7.33 E+03	1.62 E+02
K-40		7.14 E+01		6.85 E+01	5.88 E+01
Pu-238					
Pu-239					
Ru-106		8.34 E+00	7.97 E+01	2.24 E+00	8.43 E+00
Sb-125		1.99 E+00		5.93 E-01	7.29 E-01
Sr-90	1.50 E+02		1.93 E+00		
Tc-99		3.55 E+05	1.07 E+02		5.24 E+01
U-234					3.10 E-01
U-235					
U-238					
Zn-65		1.45 E+00		2.18 E+00	
Zr-95		1.87 E+01		1.33 E+01	

Table C-10. Water Concentrations Used to Calculate Mean Radiation Doses to Aquatic Organisms.

Radionuclide	Location				
	100-N Springs (pCi/L)	216-B-3 (pCi/L)	216-N-8 (pCi/L)	400 Area (pCi/L)	Columbia River (pCi/L)
Be-7	2.75 E+01		2.64 E+00	2.48 E-01	1.45 E+01
Co-60	1.20 E+00			8.01 E-01	
Cs-137					
Cs-134				8.33 E-01	
Eu-154	1.33 E+01			8.19 E-01	
Eu-155		6.48 E-01	3.95 E+02	6.53 E+03	
H-3	3.90 E+02	1.42 E+02		3.27 E+01	1.32 E+01
K-40	1.06 E+02	3.10 E+01			3.25 E+01
Pu-238					
Pu-239			1.86 E+00		
Ru-106		3.20 E+00	1.67 E+00		3.91 E-01
Sr-90	4.90 E+01		5.97 E+01		
Tc-99	2.44 E+00				1.42 E+01
U-234					2.76 E-01
U-235					
U-238				7.44 E-01	
Zn-65				2.92 E+00	
Zr-95		2.08 E+00			

Table C-11. Hazard Index, Chemical by Cell, Reactors on the River.

Cell ID	Chemical	Hazard Index			
		Plant	Mouse	Coyote	Hawk
565144	$Na_2C_2O_4$				
565144	NaSulfam				
565144	$Na_2Cr_2O_7$	3.83 E+03	5.91 E-01	1.13 E-04	5.41 E-03
565145	$Na_2Cr_2O_7$	1.02 E+00	1.57 E-04	3.00 E-08	1.44 E-06
569146	NaOH				
569146	Hg	2.70 E+04	3.08 E+03	9.41 E-01	4.27 E+01
569147	H_2SO_4				
569147	H_2SO_4				
569147	Cu_2SO_4	4.23 E-02	2.41 E+00	6.62 E-05	1.79 E-05
569147	$Na_2Cr_2O_7$	4.45 E+02	6.87 E-02	1.31 E-05	6.29 E-04
573151	$Na_2C_2O_4$				
573151	NaSulfam				
573151	KBO_2	1.41 E+04			
573151	$Na_2Cr_2O_7$	7.74 E+01	1.20 E-02	2.28 E-06	1.10 E-04
573152	$Na_2Cr_2O_7$	1.00 E+00	1.55 E-04	2.96 E-08	1.42 E-06
574152	$Na_2Cr_2O_7$	1.93 E+00	2.98 E-04	5.70 E-08	2.73 E-06
577152	$Na_2C_2O_4$				
577152	NaSulfam				
577152	$Na_2Cr_2O_7$	4.64 E+03	7.17 E-01	1.37 E-04	6.56 E-03
578152	$Na_2Cr_2O_7$	2.35 E+00	3.63 E-04	6.93 E-08	3.33 E-06
580147	$Na_2C_2O_4$				
580147	NaSulfam				
580147	H_2SO_4				
580147	$Na_2Cr_2O_7$	8.49 E+03	1.31 E+00	2.50 E-04	1.20 E-02
581147	$Na_2Cr_2O_7$	1.40 E+00	2.17 E-04	4.14 E-08	1.99 E-06

NOTE: Blanks indicate no data for NOAELs, transfer factors, or both. See tables of these variables for details.

ID = identification.
NOAEL = No Observable Adverse Effect Level.

Table C-12. Hazard Index, Summed by Cell, Reactors on the River.

Cell ID	Hazard Index			
	Plant	Mouse	Coyote	Hawk
565144	3.83 E+03	5.91 E-01	1.13 E-04	5.41 E-03
565145	1.02 E+00	1.57 E-04	3.00 E-08	1.44 E-06
569146	2.70 E+04	3.08 E+03	9.41 E-01	4.27 E+01
569147	4.45 E+02	2.48 E+00	7.94 E-05	6.47 E-04
573151	1.42 E+04	1.20 E-02	2.28 E-06	1.10 E-04
573152	1.00 E+00	1.55 E-04	2.96 E-08	1.42 E-06
574152	1.93 E+00	2.98 E-04	5.70 E-08	2.73 E-06
577152	4.64 E+03	7.17 E-01	1.37 E-04	6.56 E-03
578152	2.35 E+00	3.63 E-04	6.93 E-08	3.33 E-06
580147	8.49 E+03	1.31 E+00	2.50 E-04	1.20 E-02
581147	1.40 E+00	2.17 E-04	4.14 E-08	1.99 E-06

ID = identification.

Table C-13. Estimated Radiation Dose, Radionuclide by Cell, Reactors on the River. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
564143	C-14	1.38 E-05	3.69 E-08	4.80 E-05	4.06 E-05
564143	Co-60	8.20 E-05	5.34 E-09	4.57 E-05	1.08 E-05
564143	Cs-137	1.54 E-06	1.29 E-10	3.65 E-07	1.68 E-07
564143	Eu-152	1.78 E-05	2.87 E-10	3.73 E-07	3.15 E-07
564143	Eu-154	6.06 E-06	9.74 E-11	3.93 E-07	1.48 E-07
564143	H-3	7.79 E-03	2.09 E-05	2.71 E-02	2.30 E-02
564143	Ni-63	3.62 E-05	1.94 E-10	2.52 E-07	2.13 E-07
564143	Sr-90	2.49 E-04	5.34 E-10	6.94 E-07	5.87 E-07
565143	C-14	1.06 E-04	2.85 E-07	3.71 E-04	3.14 E-04
565143	Co-60	6.37 E-05	4.15 E-09	3.55 E-05	8.42 E-06
565143	Cs-137	1.88 E-06	1.57 E-10	4.44 E-07	2.04 E-07
565143	Eu-152	2.15 E-05	3.46 E-10	4.49 E-07	3.80 E-07
565143	Eu-154	7.31 E-06	1.18 E-10	4.74 E-07	1.78 E-07
565143	H-3	2.44 E-05	6.54 E-08	8.51 E-05	7.20 E-05
565143	Ni-63	3.28 E-05	1.76 E-10	2.29 E-07	1.94 E-07
565143	Sr-90	3.02 E-04	6.48 E-10	8.43 E-07	7.13 E-07
565144	Co-60	2.76 E-01	1.80 E-05	1.54 E-01	3.65 E-02
565144	Cs-134	7.51 E-07	6.80 E-11	3.89 E-07	1.14 E-07
565144	Cs-137	9.18 E-04	7.67 E-08	2.17 E-04	9.99 E-05
565144	Eu-152	6.05 E-04	9.72 E-09	1.26 E-05	1.07 E-05
565144	Eu-154	6.80 E-06	1.09 E-10	4.41 E-07	1.65 E-07
565144	Eu-155	7.88 E-06	1.27 E-10	1.65 E-07	1.39 E-07
565144	H-3	4.73 E+00	1.27 E-02	1.65 E+01	1.39 E+01
565144	Ni-63	9.95 E-03	5.33 E-08	6.93 E-05	5.87 E-05
565144	Pu-238	1.13 E-06	6.05 E-15	7.86 E-12	6.65 E-12
565144	Pu-239	1.05 E-06	5.62 E-15	7.30 E-12	6.18 E-12
565144	Pu-240	1.17 E-07	6.25 E-16	8.12 E-13	6.87 E-13
565144	Sr-90	1.48 E-01	3.17 E-07	4.12 E-04	3.49 E-04
565144	U-235	7.61 E-09	4.08 E-15	5.31 E-12	4.49 E-12
565144	U-238	4.86 E-06	2.61 E-12	3.39 E-09	2.87 E-09
565145	C-14	1.56 E-04	4.19 E-07	5.45 E-04	4.61 E-04
565145	Co-60	2.31 E-03	1.50 E-07	1.29 E-03	3.05 E-04
565145	Cs-134	4.88 E-08	4.41 E-12	2.53 E-08	7.42 E-09
565145	Cs-137	1.01 E-04	8.41 E-09	2.38 E-05	1.10 E-05
565145	Eu-152	1.78 E-04	2.86 E-09	3.71 E-06	3.14 E-06
565145	Eu-154	1.35 E-05	2.17 E-10	8.75 E-07	3.28 E-07
565145	Eu-155	3.58 E-06	5.76 E-11	7.48 E-08	6.33 E-08
565145	H-3	4.91 E-06	1.32 E-08	1.71 E-05	1.45 E-05
565145	Pu-238	3.23 E-10	1.73 E-18	2.25 E-15	1.91 E-15
565145	Pu-239	1.56 E-08	8.35 E-17	1.08 E-13	9.18 E-14
565145	Pu-240	1.66 E-08	8.92 E-17	1.16 E-13	9.82 E-14

Table C-13. Estimated Radiation Dose, Radionuclide by Cell, Reactors on the River. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
565145	Sr-90	2.97 E-04	6.36 E-10	8.27 E-07	6.99 E-07
565145	U-235	2.63 E-08	1.41 E-14	1.83 E-11	1.55 E-11
565145	U-238	5.50 E-08	2.95 E-14	3.83 E-11	3.24 E-11
568146	C-14	4.02 E-01	1.08 E-03	1.40 E+00	1.18 E+00
568146	Co-60	3.68 E-08	2.39 E-12	2.05 E-08	4.86 E-09
568146	Cs-134	2.00 E-09	1.81 E-13	1.03 E-09	3.04 E-10
568146	Cs-137	6.56 E-07	5.48 E-11	1.55 E-07	7.13 E-08
568146	Eu-152	1.03 E-07	1.66 E-12	2.15 E-09	1.82 E-09
568146	Eu-154	4.59 E-09	7.38 E-14	2.98 E-10	1.12 E-10
568146	Eu-155	5.73 E-09	9.21 E-14	1.20 E-10	1.01 E-10
568146	H-3	2.94 E-02	7.87 E-05	1.02 E-01	8.66 E-02
568146	Sr-90	1.81 E-04	3.87 E-10	5.04 E-07	4.26 E-07
568146	U-235	7.73 E-09	4.14 E-15	5.39 E-12	4.56 E-12
569146	C-14	4.02 E-01	1.08 E-03	1.40 E+00	1.18 E+00
569146	Co-60	4.91 E-04	3.20 E-08	2.74 E-04	6.48 E-05
569146	Cs-134	2.04 E-11	1.84 E-15	1.05 E-11	3.10 E-12
569146	Cs-137	1.75 E-04	1.47 E-08	4.15 E-05	1.91 E-05
569146	Eu-152	1.71 E-05	2.75 E-10	3.58 E-07	3.03 E-07
569146	Eu-154	7.25 E-06	1.17 E-10	4.70 E-07	1.77 E-07
569146	Eu-155	1.11 E-07	1.79 E-12	2.33 E-09	1.97 E-09
569146	H-3	2.03 E-02	5.43 E-05	7.06 E-02	5.98 E-02
569146	Ni-63	4.72 E-05	2.53 E-10	3.29 E-07	2.78 E-07
569146	Pu-239	3.25 E-07	1.74 E-15	2.26 E-12	1.92 E-12
569146	Pu-240	3.64 E-08	1.95 E-16	2.54 E-13	2.15 E-13
569146	Sb-125	7.49 E-06	2.16 E-11	8.77 E-08	3.15 E-08
569146	Sr-90	7.52 E-02	1.61 E-07	2.10 E-04	1.77 E-04
569146	U-235	1.71 E-09	9.15 E-16	1.19 E-12	1.01 E-12
569146	U-238	1.66 E-07	8.90 E-14	1.16 E-10	9.79 E-11
569147	C-14	1.95 E-05	5.22 E-08	6.78 E-05	5.74 E-05
569147	Co-60	1.12 E-05	7.27 E-10	6.22 E-06	1.48 E-06
569147	Cs-134	2.13 E-07	1.93 E-11	1.10 E-07	3.24 E-08
569147	Cs-137	1.52 E-04	1.27 E-08	3.61 E-05	1.66 E-05
569147	Eu-152	7.76 E-04	1.25 E-08	1.62 E-05	1.37 E-05
569147	Eu-154	4.21 E-05	6.77 E-10	2.73 E-06	1.02 E-06
569147	Eu-155	3.66 E-07	5.89 E-12	7.66 E-09	6.48 E-09
569147	H-3	3.20 E-05	8.57 E-08	1.11 E-04	9.43 E-05
569147	Ni-63	5.25 E-05	2.81 E-10	3.66 E-07	3.09 E-07
569147	Pu-238	1.65 E-08	8.86 E-17	1.15 E-13	9.75 E-14
569147	Pu-239	4.02 E-07	2.16 E-15	2.80 E-12	2.37 E-12
569147	Pu-240	4.48 E-08	2.40 E-16	3.12 E-13	2.64 E-13
569147	Sr-90	1.49 E-03	3.18 E-09	4.14 E-06	3.50 E-06
569147	U-235	1.11 E-09	5.95 E-16	7.73 E-13	6.54 E-13
569147	U-238	1.18 E-07	6.34 E-14	8.24 E-11	6.98 E-11
571149	Fe-59				
571149	Zr-95				

Table C-13. Estimated Radiation Dose, Radionuclide by Cell, Reactors on the River. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
571149	Ce-144				
571149	Co-60	1.35 E-03	8.80 E-08	7.53 E-04	1.78 E-04
571149	Cs-134	2.21 E-05	2.00 E-09	1.14 E-05	3.36 E-06
571149	Cs-137	4.31 E-03	3.60 E-07	1.02 E-03	4.69 E-04
571149	H-3	4.01 E-03	1.07 E-05	1.40 E-02	1.18 E-02
571149	Mn-54	1.35 E-05	2.56 E-11	3.32 E-07	6.68 E-08
571149	Nb-95	2.99 E-06	1.60 E-14	2.08 E-11	1.76 E-11
571149	Pu-239	1.47 E-03	7.85 E-09	1.11 E-05	8.76 E-06
571149	Ru-103				
571149	Ru-106				
571149	Sr-90	5.44 E-01	1.17 E-06	1.52 E-03	1.28 E-03
571149	Tc-99	9.58 E-01	2.54 E-06	3.30 E-03	2.79 E-03
572150	C-14	1.12 E-05	3.00 E-08	3.90 E-05	3.30 E-05
572150	Co-60	1.59 E-05	1.03 E-09	8.86 E-06	2.10 E-06
572150	Cs-137	1.25 E-06	1.05 E-10	2.97 E-07	1.36 E-07
572150	Eu-152	1.43 E-05	2.30 E-10	2.99 E-07	2.53 E-07
572150	Eu-154	4.55 E-06	7.31 E-11	2.95 E-07	1.11 E-07
572150	H-3	5.83 E-06	1.56 E-08	2.03 E-05	1.72 E-05
572150	Ni-63	2.81 E-05	1.51 E-10	1.96 E-07	1.66 E-07
572150	Sr-90	2.02 E-04	4.34 E-10	5.64 E-07	4.77 E-07
573150	Co-60	9.55 E-06	6.22 E-10	5.32 E-06	1.26 E-06
573151	C-14	1.51 E-05	4.04 E-08	5.25 E-05	4.45 E-05
573151	Co-60	7.34 E-04	4.78 E-08	4.09 E-04	9.70 E-05
573151	Cs-134	6.56 E-09	5.94 E-13	3.40 E-09	9.98 E-10
573151	Cs-137	2.15 E-04	1.79 E-08	5.09 E-05	2.34 E-05
573151	Eu-152	2.62 E-05	4.22 E-10	5.48 E-07	4.64 E-07
573151	Eu-154	6.13 E-06	9.86 E-11	3.98 E-07	1.49 E-07
573151	Eu-155	7.10 E-07	1.14 E-11	1.48 E-08	1.26 E-08
573151	H-3	6.07 E-05	1.63 E-07	2.11 E-04	1.79 E-04
573151	Ni-63	2.12 E-05	1.14 E-10	1.48 E-07	1.25 E-07
573151	Pu-239	5.44 E-08	2.92 E-16	3.79 E-13	3.21 E-13
573151	Pu-240	6.05 E-09	3.24 E-17	4.22 E-14	3.57 E-14
573151	Sr-90	4.62 E-02	9.91 E-08	1.29 E-04	1.09 E-04
573151	U-235	5.96 E-10	3.19 E-16	4.15 E-13	3.51 E-13
573151	U-238	6.91 E-08	3.70 E-14	4.81 E-11	4.07 E-11
573152	Co-60	3.78 E-06	2.46 E-10	2.11 E-06	4.99 E-07
573152	Cs-134	1.08 E-08	9.78 E-13	5.59 E-09	1.64 E-09
573152	Cs-137	2.29 E-04	1.91 E-08	5.41 E-05	2.49 E-05
573152	Eu-152	9.80 E-05	1.58 E-09	2.05 E-06	1.73 E-06
573152	Eu-154	3.30 E-06	5.31 E-11	2.14 E-07	8.04 E-08
573152	Eu-155	6.20 E-08	9.97 E-13	1.30 E-09	1.10 E-09
573152	H-3	1.54 E-05	4.13 E-08	5.37 E-05	4.55 E-05
573152	Pu-238	2.39 E-11	1.28 E-19	1.66 E-16	1.41 E-16
573152	Pu-239	4.77 E-08	2.55 E-16	3.32 E-13	2.81 E-13
573152	Pu-240	5.30 E-09	2.84 E-17	3.70 E-14	3.13 E-14

Table C-13. Estimated Radiation Dose, Radionuclide by Cell, Reactors on the River. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
573152	Sr-90	8.46 E-04	1.81 E-09	2.36 E-06	2.00 E-06
573152	U-235	2.61 E-09	1.40 E-15	1.82 E-12	1.54 E-12
573152	U-238	1.76 E-07	9.41 E-14	1.22 E-10	1.04 E-10
574152	Co-60	7.28 E-06	4.74 E-10	4.06 E-06	9.61 E-07
574152	Cs-134	2.12 E-08	1.92 E-12	1.10 E-08	3.24 E-09
574152	Cs-137	4.40 E-04	3.68 E-08	1.04 E-04	4.79 E-05
574152	Eu-152	1.89 E-04	3.03 E-09	3.94 E-06	3.34 E-06
574152	Eu-154	6.36 E-06	1.02 E-10	4.12 E-07	1.55 E-07
574152	Eu-155	1.19 E-07	1.92 E-12	2.50 E-09	2.11 E-09
574152	H-3	2.97 E-05	7.95 E-08	1.03 E-04	8.75 E-05
574152	Pu-239	9.18 E-08	4.92 E-16	6.39 E-13	5.41 E-13
574152	Pu-240	1.02 E-08	5.47 E-17	7.12 E-14	6.02 E-14
574152	Sr-90	1.63 E-03	3.49 E-09	4.54 E-06	3.84 E-06
574152	U-235	3.12 E-09	1.67 E-15	2.18 E-12	1.84 E-12
574152	U-238	3.28 E-07	1.76 E-13	2.29 E-10	1.94 E-10
577152	C-14	1.39 E-05	3.72 E-08	4.84 E-05	4.09 E-05
577152	Co-60	4.13 E-05	2.69 E-09	2.30 E-05	5.45 E-06
577152	Cs-134	7.89 E-11	7.14 E-15	4.09 E-11	1.20 E-11
577152	Cs-137	1.85 E-05	1.55 E-09	4.39 E-06	2.02 E-06
577152	Eu-152	5.04 E-05	8.11 E-10	1.05 E-06	8.92 E-07
577152	Eu-154	5.08 E-06	8.17 E-11	3.30 E-07	1.24 E-07
577152	Eu-155	2.59 E-08	4.17 E-13	5.42 E-10	4.59 E-10
577152	H-3	7.24 E-06	1.94 E-08	2.52 E-05	2.13 E-05
577152	Pu-238	1.83 E-09	9.79 E-18	1.27 E-14	1.08 E-14
577152	Pu-239	5.85 E-08	3.14 E-16	4.08 E-13	3.45 E-13
577152	Pu-240	3.32 E-11	1.78 E-19	2.31 E-16	1.96 E-16
577152	Sr-90	7.51 E-04	1.61 E-09	2.09 E-06	1.77 E-06
577152	U-235	2.62 E-07	1.40 E-13	1.82 E-10	1.54 E-10
577152	U-238	2.06 E-08	1.10 E-14	1.43 E-11	1.21 E-11
578152	C-14	1.34 E-07	3.60 E-10	4.68 E-07	3.96 E-07
578152	Co-60	3.32 E-06	2.16 E-10	1.85 E-06	4.38 E-07
578152	Cs-134	2.00 E-10	1.81 E-14	1.04 E-10	3.04 E-11
578152	Cs-137	6.85 E-05	5.72 E-09	1.62 E-05	7.45 E-06
578152	Eu-152	1.74 E-04	2.80 E-09	3.64 E-06	3.08 E-06
578152	Eu-154	1.76 E-05	2.83 E-10	1.14 E-06	4.28 E-07
578152	Eu-155	9.05 E-08	1.46 E-12	1.89 E-09	1.60 E-09
578152	H-3	1.11 E-06	2.98 E-09	3.88 E-06	3.28 E-06
578152	Pu-238	1.90 E-11	1.02 E-19	1.32 E-16	1.12 E-16
578152	Pu-239	9.45 E-08	5.07 E-16	6.59 E-13	5.57 E-13
578152	Pu-240	1.06 E-08	5.67 E-17	7.37 E-14	6.23 E-14
578152	Sr-90	2.18 E-03	4.68 E-09	6.08 E-06	5.14 E-06
578152	U-235	9.85 E-09	5.28 E-15	6.86 E-12	5.81 E-12
578152	U-238	1.05 E-06	5.64 E-13	7.33 E-10	6.20 E-10
579147	Co-60	1.71 E-05	1.12 E-09	9.54 E-06	2.26 E-06
580147	C-14	8.04 E-05	2.16 E-07	2.80 E-04	2.37 E-04

Table C-13. Estimated Radiation Dose, Radionuclide by Cell, Reactors on the River. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
580147	Co-60	2.27 E-05	1.48 E-09	1.27 E-05	3.00 E-06
580147	Cs-134	4.01 E-07	3.63 E-11	2.08 E-07	6.10 E-08
580147	Cs-137	1.45 E-03	1.21 E-07	3.42 E-04	1.57 E-04
580147	Eu-152	3.63 E-05	5.83 E-10	7.58 E-07	6.42 E-07
580147	Eu-154	6.40 E-06	1.03 E-10	4.15 E-07	1.56 E-07
580147	Eu-155	1.07 E-06	1.72 E-11	2.24 E-08	1.89 E-08
580147	H-3	3.16 E-04	8.47 E-07	1.10 E-03	9.32 E-04
580147	Ni-63	3.53 E-05	1.89 E-10	2.46 E-07	2.08 E-07
580147	Pu-238	4.43 E-08	2.37 E-16	3.09 E-13	2.61 E-13
580147	Pu-239	3.04 E-06	1.63 E-14	2.12 E-11	1.79 E-11
580147	Pu-240	3.38 E-07	1.81 E-15	2.36 E-12	2.00 E-12
580147	Sr-90	1.57 E-01	3.38 E-07	4.39 E-04	3.71 E-04
580147	U-235	3.59 E-09	1.93 E-15	2.50 E-12	2.12 E-12
580147	U-238	5.34 E-07	2.86 E-13	3.72 E-10	3.15 E-10
581147	C-14	2.90 E-07	7.76 E-10	1.01 E-06	8.54 E-07
581147	Co-60	2.61 E-06	1.70 E-10	1.46 E-06	3.45 E-07
581147	Cs-134	1.30 E-09	1.17 E-13	6.72 E-10	1.98 E-10
581147	Cs-137	1.23 E-05	1.03 E-09	2.91 E-06	1.34 E-06
581147	Eu-152	1.03 E-04	1.65 E-09	2.14 E-06	1.81 E-06
581147	Eu-154	4.69 E-06	7.54 E-11	3.04 E-07	1.14 E-07
581147	Eu-155	1.12 E-07	1.80 E-12	2.34 E-09	1.98 E-09
581147	H-3	1.20 E-05	3.22 E-08	4.18 E-05	3.54 E-05
581147	Pu-238	2.70 E-13	1.45 E-21	1.88 E-18	1.59 E-18
581147	Pu-239	1.29 E-07	6.90 E-16	8.97 E-13	7.59 E-13
581147	Pu-240	1.47 E-09	7.88 E-18	1.02 E-14	8.67 E-15
581147	Sr-90	8.24 E-03	1.77 E-08	2.30 E-05	1.94 E-05
581147	U-235	1.36 E-09	7.27 E-16	9.45 E-13	7.99 E-13
581147	U-238	9.31 E-08	4.99 E-14	6.49 E-11	5.49 E-11

ID = identification.

Table C-14. Estimated Radiation Dose, Total by Cell, Reactors on the River.

Cell ID	Estimated Dose (rad/d)			
	Plant	Mouse	Coyote	Hawk
564143	8.20 E-03	2.09 E-05	2.72 E-02	2.30 E-02
565143	5.60 E-04	3.56 E-07	4.94 E-04	3.96 E-04
565144	5.16 E+00	1.27 E-02	1.66 E+01	1.40 E+01
565145	3.06 E-03	5.95 E-07	1.88 E-03	7.96 E-04
568146	4.31 E-01	1.15 E-03	1.50 E+00	1.27 E+00
569146	4.98 E-01	1.13 E-03	1.47 E+00	1.24 E+00
569147	2.57 E-03	1.68 E-07	2.45 E-04	1.88 E-04
571149	1.51 E+00	1.49 E-05	2.06 E-02	1.65 E-02
572150	2.83 E-04	4.76 E-08	6.98 E-05	5.34 E-05
573150	9.55 E-06	6.22 E-10	5.32 E-06	1.26 E-06
573151	4.73 E-02	3.69 E-07	8.54 E-04	4.53 E-04
573152	1.20 E-03	6.41 E-08	1.15 E-04	7.46 E-05
574152	2.30 E-03	1.23 E-07	2.21 E-04	1.44 E-04
577152	8.88 E-04	6.34 E-08	1.04 E-04	7.25 E-05
578152	2.45 E-03	1.70 E-08	3.33 E-05	2.02 E-05
579147	1.71 E-05	1.12 E-09	9.54 E-06	2.26 E-06
580147	1.59 E-01	1.52 E-06	2.18 E-03	1.70 E-03
581147	8.38 E-03	5.35 E-08	7.26 E-05	5.93 E-05

ID = identification.

Table C-15. Hazard Index, Chemical by Cell, Central Plateau. (3 sheets)

Cell ID	Chemical	Hazard Index			
		Plant	Mouse	Coyote	Hawk
565133	NO_3				
566133	NO_3				
566134	NaAl	2.46 E+00	1.21 E+00	5.56 E-06	9.42 E-08
566134	NaOH				
566134	NH_4NO_3				
566134	Na				
566134	HNO_3				
566134	$Na_2Cr_2O_7$	5.51 E+00	8.51 E-04	1.62 E-07	7.79 E-06
566134	$AlF(NO_3)_2$	2.55 E+02	1.41 E+00	6.46 E-06	9.76 E-06
566134	CCl_4				
566135	$AlF(NO_3)_2$	6.05 E+02	3.24 E+00	1.48 E-05	2.24 E-05
566135	CCl_4				
566135	TBP				
566135	NaOH				
566135	DBBP				
566135	NH_4NO_3				
566135	PO_4				
566135	Na		3.24 E+00	1.48 E-05	2.24 E-05
566135	HNO_3				
566135	F	3.03 E+02			
566135	$Ca(NO_3)_2$				
566135	$Mg(NO_3)_2$				
566135	SO_4				
566135	$Al(NO_3)_3$	2.69 E+02	1.49 E+00	6.81 E-06	1.03 E-05
566135	$FeNO_3$ (Fe II/III)				
566135	NO_3				
566136	NaSi				
566136	$Na_2C_2O_4$				
566136	NaAl	4.31 E+04	2.13 E+04	9.75 E-02	1.65 E-03
566136	NaOH				
566136	NH_4NO_3				
566136	K				
566136	PO_4				
566136	Na				
566136	F	1.28 E+03			
566136	SO_4				
566136	FeCN (Fe II/III)				
566136	NO_3				
566136	NO_2				
567133	Na				

Table C-15. Hazard Index, Chemical by Cell, Central Plateau. (3 sheets)

	Cell ID	Chemical	Hazard Index			
			Plant	Mouse	Coyote	Hawk
1	567133	NO_3				
2	567134	MIBK				
3	567134	NH_4NO_3				
4	567134	Na				
5	567134	HNO_3				
6	567134	$Na_2Cr_2O_7$	1.29 E+03	1.99 E-01	3.80 E-05	1.82 E-03
7	567134	$Al(NO_3)_3$	2.62 E+02	1.45 E+00	6.65 E-06	1.01 E-05
8	567134	NO_3				
9	567135	NPH				
10	567135	TBP				
11	567135	PO_4				
12	567135	Na				
13	567135	SO_4				
14	567135	NO_3				
15	567136	$Na_2C_2O_4$				
16	567136	NaOH				
17	567136	NH_4NO_3				
18	567136	K				
19	567136	PO_4				
20	567136	Na				
21	567136	H_2SO_4				
22	567136	HNO_3				
23	567136	F	3.92 E+04			
24	567136	$Na_2Cr_2O_7$	4.51 E+00	6.96 E-04	1.33 E-07	6.38 E-06
25	567136	SO_4				
26	567136	NO_3				
27	567137	NO_3				
28	573134	$Na_2C_2O_4$				
29	573134	PO_4				
30	573134	Na				
31	573134	SO_4				
32	573134	FeCN (Fe II/III)				
33	573134	NO_3				
34	573136	C_2O_4				
35	573136	NH_4NO_3				
36	573136	K				
37	573136	PO_4				
38	573136	Na				
39	573136	HNO_3				
40	573136	F	8.88 E+02			

Table C-15. Hazard Index, Chemical by Cell, Central Plateau. (3 sheets)

Cell ID	Chemical	Hazard Index			
		Plant	Mouse	Coyote	Hawk
573136	$Na_2Cr_2O_7$	2.20 E+02	3.40 E-02	6.50 E-06	3.12 E-04
573136	SO_4				
573136	$Al(NO_3)_3$	2.25 E+02	1.25 E+00	5.72 E-06	8.64 E-06
573136	NO_3				
573137	NaSi				
573137	C_2O_4				
573137	$(NH_4)_2CO_3$				
573137	NaAl	6.14 E+04	3.04 E+04	1.39 E-01	2.35 E-03
573137	NaOH				
573137	NH_4NO_3				
573137	K				
573137	PO_4				
573137	Na				
573137	H_2SO_4				
573137	F	1.59 E+03			
573137	SO_4				
573137	FeCN (Fe II/III)				
573137	NO_3				
573137	NO_2				
574136	NPH				
574136	TBPPH				
574136	Na				
574136	HNO_3				
574136	NO_3				
575135	NPH				
575135	TBP				
575135	NH_4NO_3				
575135	Na				
575135	$Na_2Cr_2O_7$	5.19 E+01	8.02 E-03	1.53 E-06	7.35 E-05
575135	SO_4				
575135	NO_3				
575136	NPH				
575136	BP				
575136	TBP				
575136	$(NH_4)_2CO_3$				
575136	NO_3				

NOTE: Blanks indicate no data for NOAELs, transfer factors, or both. See tables on these variables for details.

ID = identification.
NOAEL = No Observable Adverse Effect Level.

Table C-16. Hazard Index, Summed by Cell, Central Plateau.

Cell ID	Estimated Dose (rad/d)			
	Plant	Mouse	Coyote	Hawk
565133				
566133				
566134	2.63 E+02	2.62 E+00	1.22 E-05	1.76 E-05
566135	1.18 E+03	7.96 E+00	3.65 E-05	5.51 E-05
566136	4.44 E+04	2.13 E+04	9.75 E-02	1.65 E-03
567133				
567134	1.55 E+03	1.65 E+00	4.46 E-05	1.83 E-03
567135				
567136	3.92 E+04	6.96 E-04	1.33 E-07	6.38 E-06
567137				
573134				
573136	1.33 E+03	1.28 E+00	1.22 E-05	3.20 E-04
573137	6.30 E+04	3.04 E+04	1.39 E-01	2.35 E-03
574136				
575135	5.19 E+01	8.02 E-03	1.53 E-06	7.35 E-05
575136				

NOTE: Blanks indicate no data for NOAELs, transfer factors, or both for constituents of concern in the cell. See chemical-specific table for details.

ID = identification.
NOAEL = No Observable Adverse Effect Level.

Table C-17. Estimated Radiation Dose, Radionuclide by Cell, Central Plateau. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
565133	Co-60	7.79 E-05	5.08 E-09	4.34 E-05	1.03 E-05
565133	Cs-137	5.21 E-05	4.35 E-09	1.23 E-05	5.66 E-06
565133	Pu-240	3.15 E-06	1.69 E-14	2.19 E-11	1.86 E-11
565133	Ru-106	8.68 E-10	4.65 E-15	6.55 E-12	5.19 E-12
565133	Sr-90	1.26 E-02	2.71 E-08	3.52 E-05	2.98 E-05
565133	U-235	6.52 E-07	3.50 E-13	4.54 E-10	3.85 E-10
565134	Cs-137	6.65 E-07	5.56 E-11	1.57 E-07	7.23 E-08
565134	H-3	1.14 E-03	3.06 E-06	3.98 E-03	3.37 E-03
565134	Ru-106	7.17 E-18	3.85 E-23	5.42 E-20	4.29 E-20
565134	Sr-90	6.63 E-05	1.42 E-10	1.85 E-07	1.56 E-07
566133	Am-241	2.21 E-07	1.18 E-14	1.54 E-11	1.30 E-11
566133	Co-60	2.77 E-04	1.80 E-08	1.54 E-04	3.66 E-05
566133	Cs-134	5.90 E-04	5.34 E-08	3.06 E-04	8.99 E-05
566133	Cs-137	1.52 E-04	1.27 E-08	3.59 E-05	1.65 E-05
566133	Pu-239	5.52 E-05	2.96 E-13	3.85 E-10	3.26 E-10
566133	Pu-240	1.64 E-05	8.80 E-14	1.14 E-10	9.68 E-11
566133	Ru-106	1.31 E-03	7.04 E-09	9.91 E-06	7.85 E-06
566133	Sr-90	1.89 E-01	4.06 E-07	5.28 E-04	4.47 E-04
566133	U-235	1.86 E-07	9.99 E-14	1.30 E-10	1.10 E-10
566134	Am-241	8.29 E-05	4.44 E-12	5.77 E-09	4.88 E-09
566134	Co-60	2.70 E-02	1.76 E-06	1.51 E-02	3.57 E-03
566134	Cs-134	4.32 E-02	3.91 E-06	2.24 E-02	6.57 E-03
566134	Cs-137	4.54 E-02	3.79 E-06	1.07 E-02	4.94 E-03
566134	H-3	1.74 E-01	4.65 E-04	6.05 E-01	5.12 E-01
566134	Pu-239	5.19 E-02	2.78 E-10	3.62 E-07	3.06 E-07
566134	Pu-240	1.59 E-02	8.54 E-11	1.11 E-07	9.39 E-08
566134	Ru-106	1.23 E-06	6.59 E-12	9.28 E-09	7.35 E-09
566134	Sr-90	8.88 E+00	1.90 E-05	2.47 E-02	2.09 E-02
566134	U-235	6.21 E-03	3.33 E-09	4.33 E-06	3.66 E-06
566135	Am-241	1.35 E-05	7.22 E-13	9.38 E-10	7.94 E-10
566135	Co-60	3.08 E-02	2.00 E-06	1.72 E-02	4.07 E-03
566135	Cs-137	2.61 E-02	2.18 E-06	6.17 E-03	2.83 E-03
566135	H-3	1.59 E-04	4.26 E-07	5.54 E-04	4.69 E-04
566135	Pu-238	4.08 E-08	2.19 E-16	2.84 E-13	2.41 E-13
566135	Pu-239	3.62 E-01	1.94 E-09	2.52 E-06	2.13 E-06
566135	Pu-240	1.08 E-01	5.77 E-10	7.51 E-07	6.35 E-07
566135	Pu-241	6.50 E-09	3.48 E-17	5.38 E-14	3.83 E-14
566135	Ru-106	3.72 E-07	1.99 E-12	2.81 E-09	2.22 E-09
566135	Sr-90	4.15 E+00	8.90 E-06	1.16 E-02	9.80 E-03
566135	U-235	8.69 E-08	4.66 E-14	6.05 E-11	5.12 E-11

Table C-17. Estimated Radiation Dose, Radionuclide by Cell, Central Plateau. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
566136	Co-60	1.88 E+00	1.23 E-04	1.05 E+00	2.49 E-01
566136	Cs-134	3.14 E-04	2.85 E-08	1.63 E-04	4.79 E-05
566136	Cs-137	3.24 E+00	2.70 E-04	7.66 E-01	3.52 E-01
566136	Pm-147	1.05 E-07	1.40 E-12	1.82 E-09	1.54 E-09
566136	Pu-239	1.30 E-02	6.96 E-11	9.05 E-08	7.66 E-08
566136	Pu-240	2.55 E-03	1.37 E-11	1.78 E-08	1.51 E-08
566136	Ru-106	7.44 E-07	3.99 E-12	5.62 E-09	4.45 E-09
566136	Sr-90	7.40 E+00	1.59 E-05	2.06 E-02	1.75 E-02
566136	Th-232	4.78 E-05	6.40 E-10	8.33 E-07	7.04 E-07
566136	U-235	8.58 E-04	4.60 E-10	5.98 E-07	5.06 E-07
566137	Cs-137	1.94 E-05	1.62 E-09	4.58 E-06	2.11 E-06
566137	Sr-90	1.70 E-03	3.63 E-09	4.72 E-06	4.00 E-06
567133	Co-60	2.35 E-03	1.53 E-07	1.31 E-03	3.11 E-04
567133	Cs-137	2.81 E-03	2.35 E-07	6.65 E-04	3.06 E-04
567133	H-3	6.30 E-06	1.69 E-08	2.19 E-05	1.86 E-05
567133	Pu-239	1.41 E-04	7.57 E-13	9.84 E-10	8.32 E-10
567133	Pu-240	4.19 E-05	2.25 E-13	2.92 E-10	2.47 E-10
567133	Ru-106	1.39 E-09	7.43 E-15	1.05 E-11	8.28 E-12
567133	Sr-90	1.83 E-01	3.92 E-07	5.09 E-04	4.31 E-04
567133	U-235	2.77 E-07	1.48 E-13	1.93 E-10	1.63 E-10
567134	Am-241	9.38 E-08	5.03 E-15	6.54 E-12	5.53 E-12
567134	Co-60	8.60 E-02	5.60 E-06	4.80 E-02	1.14 E-02
567134	Cs-137	4.77 E-02	3.98 E-06	1.13 E-02	5.19 E-03
567134	H-3	1.44 E-07	3.86 E-10	5.01 E-07	4.24 E-07
567134	Pu-239	4.95 E-04	2.66 E-12	3.45 E-09	2.92 E-09
567134	Pu-240	1.47 E-04	7.88 E-13	1.02 E-09	8.67 E-10
567134	Ru-106	1.33 E-06	7.13 E-12	1.00 E-08	7.95 E-09
567134	Sr-90	1.53 E+01	3.27 E-05	4.25 E-02	3.60 E-02
567134	U-235	5.49 E-05	2.94 E-11	3.82 E-08	3.23 E-08
567134	U-238	9.83 E-07	5.27 E-13	6.85 E-10	5.79 E-10
567135	Cs-134	1.93 E-02	1.75 E-06	1.00 E-02	2.94 E-03
567135	Sr-90	1.16 E-01	2.48 E-07	3.23 E-04	2.73 E-04
567136	Co-60	6.12 E-02	3.99 E-06	3.41 E-02	8.09 E-03
567136	Cs-137	7.49 E-01	6.26 E-05	1.77 E-01	8.14 E-02
567136	Pu-239	1.43 E+00	7.66 E-09	9.96 E-06	8.43 E-06
567136	Pu-240	4.26 E-01	2.28 E-09	2.97 E-06	2.51 E-06
567136	Sr-90	1.08 E+02	2.31 E-04	3.00 E-01	2.54 E-01
567136	U-235	4.07 E-05	2.18 E-11	2.84 E-08	2.40 E-08
567137	Cs-137	9.76 E-03	8.15 E-07	2.31 E-03	1.06 E-03
567137	Ru-106	8.35 E-08	4.47 E-13	6.30 E-10	4.99 E-10

Table C-17. Estimated Radiation Dose, Radionuclide by Cell, Central Plateau. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
567137	Sr-90	1.79 E+00	3.84 E-06	4.99 E-03	4.22 E-03
569140	Cs-137	2.11 E-03	1.76 E-07	5.00 E-04	2.30 E-04
569140	Ru-106	6.55 E-13	3.51 E-18	4.94 E-15	3.91 E-15
569140	Sr-90	6.38 E-02	1.37 E-07	1.78 E-04	1.50 E-04
570140	Cs-137	1.34 E-03	1.12 E-07	3.18 E-04	1.46 E-04
570140	Pu-239	1.32 E-07	7.07 E-16	9.20 E-13	7.78 E-13
570140	Ru-106	5.41 E-13	2.90 E-18	4.08 E-15	3.23 E-15
570140	Sr-90	4.08 E-02	8.74 E-08	1.14 E-04	9.62 E-05
570140	U-235	1.30 E-08	6.97 E-15	9.07 E-12	7.67 E-12
571140	Cs-137	1.34 E-03	1.12 E-07	3.18 E-04	1.46 E-04
571140	Pu-239	5.16 E-07	2.77 E-15	3.59 E-12	3.04 E-12
571140	Pu-240	1.53 E-07	8.22 E-16	1.07 E-12	9.04 E-13
571140	Ru-106	5.41 E-13	2.90 E-18	4.08 E-15	3.23 E-15
571140	Sr-90	4.08 E-02	8.74 E-08	1.14 E-04	9.62 E-05
571140	U-235	1.68 E-08	9.01 E-15	1.17 E-11	9.91 E-12
573134	Co-60	2.97 E-01	1.93 E-05	1.65 E-01	3.92 E-02
573134	Cs-137	4.34 E-01	3.62 E-05	1.03 E-01	4.72 E-02
573134	Pu-239	5.16 E-03	2.77 E-11	3.59 E-08	3.04 E-08
573134	Pu-240	1.53 E-03	8.22 E-12	1.07 E-08	9.04 E-09
573134	Ru-106	1.04 E-07	5.59 E-13	7.88 E-10	6.24 E-10
573134	Sr-90	3.58 E+01	7.68 E-05	9.99 E-02	8.45 E-02
573134	U-235	3.27 E-05	1.75 E-11	2.28 E-08	1.93 E-08
573134	U-238	1.81 E-05	9.71 E-12	1.26 E-08	1.07 E-08
573136	Am-241	3.47 E-06	1.86 E-13	2.42 E-10	2.05 E-10
573136	Co-60	1.41 E-02	9.22 E-07	7.89 E-03	1.87 E-03
573136	Cs-137	3.18 E-02	2.66 E-06	7.53 E-03	3.46 E-03
573136	H-3	2.61 E-03	6.98 E-06	9.08 E-03	7.68 E-03
573136	Po-210	1.69 E-01	9.08 E-10	1.18 E-06	9.98 E-07
573136	Pu-239	9.81 E-03	5.26 E-11	6.84 E-08	5.79 E-08
573136	Pu-240				
573136	Re-187				
573136	Ru-106	4.32 E-05	2.32 E-10	3.26 E-07	2.58 E-07
573136	Sn-123M	1.92 E+00	4.12 E-06	5.36 E-03	4.54 E-03
573136	Sr-90	6.60 E-05	3.54 E-11	4.60 E-08	3.89 E-08
573136	U-234				
573136	U-235	5.36 E-05	2.87 E-11	3.73 E-08	3.16 E-08
573136	U-238	8.91 E-05	4.77 E-11	6.21 E-08	5.25 E-08
573137	Cs-134	2.94 E-04	2.66 E-08	1.52 E-04	4.47 E-05
573137	Cs-137	8.39 E-01	7.01 E-05	1.99 E-01	9.13 E-02
573137	Pu-239	5.98 E-02	3.21 E-10	4.17 E-07	3.53 E-07

Table C-17. Estimated Radiation Dose, Radionuclide by Cell, Central Plateau. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
573137	Ru-106	6.14 E-08	3.29 E-13	4.63 E-10	3.67 E-10
573137	Sr-90	7.64 E+01	1.64 E-04	2.13 E-01	1.80 E-01
573137	U-238	4.72 E-05	2.53 E-11	3.29 E-08	2.78 E-08
574135	Am-241	7.49 E-07	4.02 E-14	5.22 E-11	4.42 E-11
574135	Co-60	2.47 E-04	1.61 E-08	1.38 E-04	3.26 E-05
574135	Cs-137	1.82 E-04	1.52 E-08	4.31 E-05	1.98 E-05
574135	H-3	9.44 E-02	2.53 E-04	3.29 E-01	2.78 E-01
574135	I-129	2.27 E-06	1.27 E-11	2.29 E-08	1.54 E-08
574135	Pm-147	1.70 E-08	2.28 E-13	2.96 E-10	2.51 E-10
574135	Pu-238	6.38 E-08	3.42 E-16	4.45 E-13	3.76 E-13
574135	Pu-239	1.38 E-05	7.37 E-14	9.59 E-11	8.11 E-11
574135	Pu-240	5.16 E-06	2.77 E-14	3.59 E-11	3.04 E-11
574135	Pu-241	7.96 E-09	4.27 E-17	6.60 E-14	4.70 E-14
574135	Ru-106	7.81 E-05	4.19 E-10	5.90 E-07	4.67 E-07
574135	Sr-90	3.02 E-02	6.47 E-08	8.41 E-05	7.12 E-05
574135	U-235	6.56 E-08	3.51 E-14	4.57 E-11	3.87 E-11
574136	Cs-137	2.39 E-04	1.99 E-08	5.65 E-05	2.59 E-05
574136	Eu-154	7.65 E-12	1.23 E-16	4.96 E-13	1.86 E-13
574136	Pu-239	3.19 E-04	1.71 E-12	2.22 E-09	1.88 E-09
574136	Ru-106	3.43 E-08	1.84 E-13	2.59 E-10	2.05 E-10
574136	Sr-90	6.23 E+03	1.34 E-02	1.74 E+01	1.47 E+01
574136	U-235	3.18 E-01	1.71 E-07	2.22 E-04	1.88 E-04
574136	U-238	1.64 E-05	8.77 E-12	1.14 E-08	9.65 E-09
574139	Am-241	1.13 E-10	6.04 E-18	7.85 E-15	6.64 E-15
574139	Cs-137	5.69 E-04	4.75 E-08	1.35 E-04	6.18 E-05
574139	H-3	2.39 E-04	6.41 E-07	8.33 E-04	7.05 E-04
574139	Pm-147	1.73 E-08	2.31 E-13	3.01 E-10	2.55 E-10
574139	Pu-239	4.63 E-06	2.48 E-14	3.23 E-11	2.73 E-11
574139	Ru-106	9.01 E-09	4.83 E-14	6.80 E-11	5.39 E-11
574139	Sr-90	2.07 E-02	4.43 E-08	5.76 E-05	4.88 E-05
574139	U-235	7.55 E-07	4.05 E-13	5.26 E-10	4.45 E-10
575135	Am-241	8.37 E-06	4.48 E-13	5.83 E-10	4.93 E-10
575135	Co-60	7.47 E-01	4.87 E-05	4.16 E-01	9.87 E-02
575135	Cs-137	5.75 E-01	4.80 E-05	1.36 E-01	6.25 E-02
575135	H-3	1.50 E-01	4.01 E-04	5.21 E-01	4.41 E-01
575135	I-129	7.09 E-06	3.97 E-11	7.16 E-08	4.82 E-08
575135	Pm-147	4.31 E-06	5.78 E-11	7.51 E-08	6.36 E-08
575135	Pu-239	9.03 E-04	4.84 E-12	6.29 E-09	5.32 E-09
575135	Pu-240	2.67 E-04	1.43 E-12	1.86 E-09	1.58 E-09
575135	Pu-241	4.18 E-09	2.24 E-17	3.46 E-14	2.46 E-14

Table C-17. Estimated Radiation Dose, Radionuclide by Cell, Central Plateau. (5 sheets)

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
575135	Ru-106	3.19 E-02	1.71 E-07	2.41 E-04	1.91 E-04
575135	Sn-113	1.07 E+02	2.30 E-04	2.99 E-01	2.53 E-01
575135	Sr-90	3.55 E-02	1.90 E-08	2.47 E-05	2.09 E-05
575135	U-235	9.63 E-04	6.41 E-08	5.83 E-04	1.36 E-04
575136	Co-58				
575136	Co-60	1.07 E-05	6.96 E-10	5.96 E-06	1.41 E-06
575136	Cs-137	5.90 E-03	4.93 E-07	1.40 E-03	6.42 E-04
575136	H-3	8.83 E-06	2.37 E-08	3.08 E-05	2.60 E-05
575136	Pu-239	1.42 E-04	7.63 E-13	9.92 E-10	8.40 E-10
575136	Pu-240	3.88 E-07	2.08 E-15	2.71 E-12	2.29 E-12
575136	Ru-106	5.94 E-08	3.19 E-13	4.49 E-10	3.55 E-10
575136	Sr-90	9.42 E-02	2.02 E-07	2.63 E-04	2.22 E-04
575136	U-235	3.81 E-06	2.04 E-12	2.66 E-09	2.25 E-09
575136	U-238	4.10 E-07	2.20 E-13	2.86 E-10	2.42 E-10
575137	Cs-137	4.25 E-07	3.55 E-11	1.01 E-07	4.62 E-08
575137	Sr-90	6.13 E-05	1.32 E-10	1.71 E-07	1.45 E-07

NOTE: Blanks indicate data on effective energy of decay not located.
ID = identification.

Table C-18. Estimated Radiation Dose, Total by Cell, Central Plateau.

Cell ID	Estimated Total Dose (rad/d)			
	Plant	Mouse	Coyote	Hawk
565133	1.28 E-02	3.65 E-08	9.10 E-05	4.58 E-05
565134	1.21 E-03	3.06 E-06	3.98 E-03	3.37 E-03
566133	1.92 E-01	4.97 E-07	1.03 E-03	5.98 E-04
566134	9.24 E+00	4.94 E-04	6.78 E-01	5.48 E-01
566135	4.68 E+00	1.35 E-05	3.55 E-02	1.72 E-02
566136	1.25 E+01	4.09 E-04	1.84 E+00	6.18 E-01
566137	1.71 E-03	5.25 E-09	9.31 E-06	6.10 E-06
567133	1.88 E-01	7.97 E-07	2.51 E-03	1.07 E-03
567134	1.54 E+01	4.23 E-05	1.02 E-01	5.25 E-02
567135	1.35 E-01	2.00 E-06	1.03 E-02	3.22 E-03
567136	1.10 E+02	2.97 E-04	5.12 E-01	3.43 E-01
567137	1.80 E+00	4.65 E-06	7.30 E-03	5.28 E-03
569140	6.59 E-02	3.13 E-07	6.78 E-04	3.80 E-04
570140	4.21 E-02	2.00 E-07	4.32 E-04	2.42 E-04
571140	4.21 E-02	2.00 E-07	4.32 E-04	2.42 E-04
573134	3.66 E+01	1.32 E-04	3.68 E-01	1.71 E-01
573136	2.15 E+00	1.47 E-05	2.99 E-02	1.75 E-02
573137	7.73 E+01	2.34 E-04	4.12 E-01	2.71 E-01
574135	1.25 E-01	2.53 E-04	3.29 E-01	2.78 E-01
574136	6.23 E+03	1.34 E-02	1.74 E+01	1.47 E+01
574139	2.15 E-02	7.33 E-07	1.03 E-03	8.15 E-04
575135	1.09 E+02	7.28 E-04	1.37 E+00	8.56 E-01
575136	1.01 E-01	7.83 E-07	2.28 E-03	1.03 E-03
575137	6.18 E-05	1.67 E-10	2.72 E-07	1.91 E-07

ID = identification.

Table C-19. Hazard Index, Chemical by Cell, All Other Areas.

Cell ID	Chemical	Hazard Index			
		Plant	Mouse	Coyote	Hawk
591122	MIBK				
591122	U		2.11 E-01	9.68 E-07	9.68 E-07
591122	NO_3				
594115	PbII	6.38 E-01	1.92 E+00	2.34 E-06	2.34 E-06
594115	Hg	1.77 E+00	2.02 E-01	6.18 E-05	6.18 E-05
594115	NiII	6.38 E+00	4.04 E-02	1.86 E-06	1.86 E-06
594115	AgI	5.82 E+00	3.35 E+01	2.05 E-04	2.05 E-04
594115	Be	5.32 E-02	1.51 E-04	2.77 E-09	2.77 E-09
594115	CdII	5.32 E-01	1.25 E-01	1.53 E-07	1.53 E-07
594115	CrVI	2.66 E+01	4.11 E-03	7.84 E-07	7.84 E-07
594115	CuII	2.66 E+01	1.52 E+03	4.17 E-02	4.17 E-02
594115	U		7.95 E-03	3.65 E-08	3.65 E-08
594115	ZnII	2.66 E+00	9.74 E-01	2.24 E-03	2.24 E-03
594115	F	5.32 E-01			

NOTE: Blanks indicate no data for NOAELs, transfer factors, or both. See tables on these variables for details.
ID = identification.
NOAEL = No Observable Adverse Effect Level.

Table C-20. Hazard Index, Summed by Cell, All Other Areas.

Cell ID	Hazard Index			
	Plant	Mouse	Coyote	Hawk
591122		2.11 E-01	9.68 E-07	1.87 E-07
594115	7.16 E+01	1.55 E+03	4.42 E-02	4.42 E-02

NOTE: Blanks indicate no data for NOAELs, transfer factors, or both for constituents of concern in the cell. See chemical-specific table for details.

ID = identification.
NOAEL = No Observable Adverse Effect Level.

Table C-21. Estimated Radiation Dose, Radionuclide by Cell, All Other Areas.

Cell ID	Radionuclide	Estimated Dose (rad/d)			
		Plant	Mouse	Coyote	Hawk
589127	Co-60	2.62 E-05	1.70 E-09	1.46 E-05	3.46 E-06
590121	Co-60	1.30 E-05	8.44 E-10	7.22 E-06	1.71 E-06
590121	Pu-239	2.39 E-06	1.28 E-14	1.66 E-11	1.41 E-11
590121	U-235	8.01 E-12	4.29 E-18	5.58 E-15	4.72 E-15
590121	U-238	8.06 E-14	4.32 E-20	5.62 E-17	4.75 E-17
592116	Co-60	5.59 E-11	3.64 E-15	3.12 E-11	7.39 E-12
592116	Th-232	5.08 E-03	6.81 E-08	8.85 E-05	7.49 E-05
592116	U-235	4.64 E-06	2.49 E-12	3.23 E-09	2.74 E-09
592116	U-238	9.31 E-05	4.99 E-11	6.49 E-08	5.49 E-08
593116	Co-60	5.41 E-11	3.53 E-15	3.02 E-11	7.15 E-12
593116	U-235	9.31 E-07	4.99 E-13	6.49 E-10	5.49 E-10
593116	U-238	1.86 E-05	9.98 E-12	1.30 E-08	1.10 E-08
594116	Co-60	4.77 E-05	3.11 E-09	2.66 E-05	6.30 E-06
594116	Cs-137	3.98 E-03	3.32 E-07	9.41 E-04	4.32 E-04
594116	Pu-239	1.43 E-07	7.68 E-16	9.98 E-13	8.45 E-13
594116	Pu-240	1.32 E-08	7.09 E-17	9.22 E-14	7.80 E-14
594116	U-235	3.34 E-09	1.79 E-15	2.33 E-12	1.97 E-12
594116	U-238	6.73 E-08	3.61 E-14	4.69 E-11	3.97 E-11

ID = identification.

Table C-22. Estimated Radiation Dose, Total by Cell, All Other Areas.

Cell ID	Estimated Total Dose (rad/d)			
	Plant	Mouse	Coyote	Hawk
589127	2.62 E-05	1.70 E-09	1.46 E-05	3.46 E-06
590121	1.53 E-05	8.44 E-10	7.22 E-06	1.71 E-06
592116	5.18 E-03	6.82 E-08	8.86 E-05	7.50 E-05
593116	1.95 E-05	1.05 E-11	1.37 E-08	1.15 E-08
594116	4.02 E-03	3.35 E-07	9.68 E-04	4.39 E-04

ID = identification.

Table C-23. Estimated Radiation Doses to Aquatic Organisms.

Site	Estimated Dose (rad/d)							
	Plant		Invertebrate		Fish		Muskrat	
	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
100-N Springs	5.73 E-03	4.19 E-03	1.18 E-03	9.43 E-04	3.79 E-05	4.95 E-05	5.92 E-03	1.81 E-02
216-B-3	1.92 E-04	7.20 E-02	7.55 E-05	9.51 E-03	2.87 E-06	2.54 E-02	1.55 E-06	5.01 E-03
216-N-8	1.24 E-04	1.21 E-03	9.20 E-05	1.74 E-03	1.03 E-05	7.68 E-05	2.11 E-04	2.86 E-04
400 Area	4.97 E-04	2.29 E-03	1.95 E-04	7.18 E-04	2.78 E-05	9.20 E-05	2.63 E-05	8.40 E-05
Columbia River	7.04 E-04	9.51 E-04	7.84 E-05	2.81 E-04	8.32 E-06	1.96 E-05	1.42 E-06	1.26 E-05

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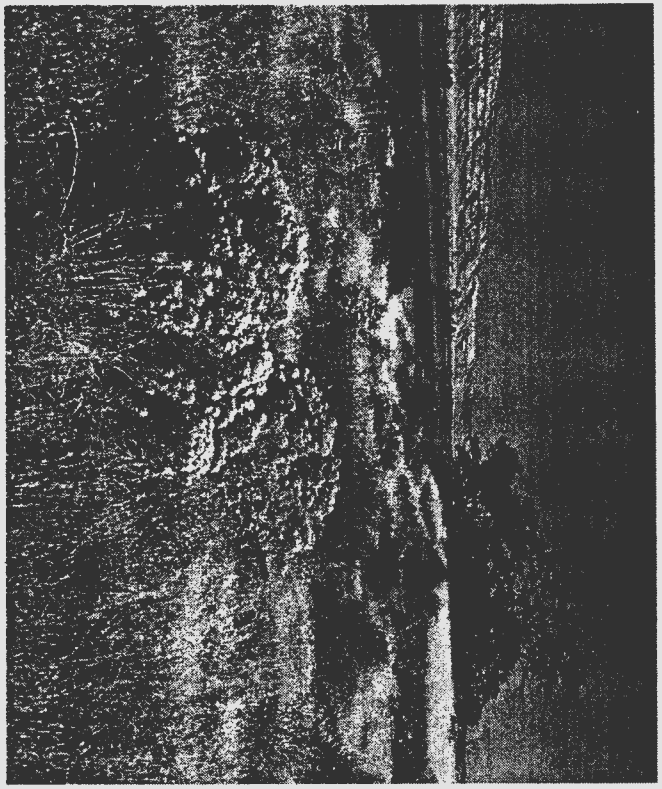

Appendix D

D.0 Groundwater Remediation Strategy and Preliminary Conceptual Design

This Appendix presents a groundwater strategy and preliminary conceptual design for the groundwater remediation systems. The groundwater strategy and preliminary conceptual design are based on future land use objectives for each geographic area. The geographic areas considered in this analysis are Reactors on the River, Central Plateau, and All Other Areas. Table D-1 is a summary of the groundwater remediation strategy used in the *Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan* (HRA-EIS) (DOE 1996).

It should be noted that this strategy was developed to assist in determining the potential environmental impacts resulting from groundwater remediation at the Hanford Site. The assumptions and results presented in this groundwater remediation strategy do not predetermine any potential decisions or assumptions that will be made through the *Resource Conservation and Recovery Act of 1976* (RCRA) or the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) processes.

D.1 Scope

As shown in Table D-1, four strategies were used to develop a preliminary conceptual design for groundwater remediation at the Hanford Site. The four strategies were assessed in a preliminary conceptual manner using available data and information on contaminant plumes, hydrogeologic properties, and previous similar assessments at the Hanford Site (PNL 1995a).

For the Reactors on the River geographic area, the general objective is to protect the river from further impacts as a result of contaminated groundwater plumes. The remediation goal for the Unrestricted Future Land-Use Alternative (see Table D-1) is to allow for eventual unrestricted use of the groundwater. Achieving this goal would require pumping and treating contaminated groundwater plumes to levels that would not preclude any human use. The remediation goal for the Restricted Future Land-Use Alternatives in the Reactors on the River geographic area (R1 and R2) is to allow for certain restricted uses of groundwater. At a minimum, this alternative requires that contaminated groundwater plumes be remediated to levels protective of the Columbia River.

For the Central Plateau geographic area, which includes the 200 West and 200 East Areas and a surrounding buffer area, an Exclusive Future Land-Use Alternative is assessed (see Table D-1). The Exclusive Future Land-Use Alternative assumes that groundwater is not used for an indefinite period but that downgradient areas are protected using pump-and-treat technologies. This strategy would be refined through the CERCLA process and will be based on land use decisions made in the Reactors on the River and All Other Areas geographic areas. For example, if unrestricted land use is designated for the Reactors on the River geographic area, contaminated groundwater originating in the Central Plateau geographic area would need to be remediated to levels such that when the contaminant plume reaches the boundaries of the Reactors on the River geographic area, no human use would be precluded. However, if restricted land use is designated for the Reactors on the River geographic area, contaminated groundwater originating in the Central Plateau geographic area would, at a minimum, need to be remediated to levels protective of the Columbia River.

Table D-1. Summary of Groundwater Remediation Strategy and Conceptual Design.

Land-Use Alternative (Applicable Geographic Area)	Groundwater Remediation Objectives	Exposure Scenario	Means to Accomplish Groundwater Objectives
Unrestricted Columbia River and Reactors on the River	Following remediation, contamination does not preclude any human uses. However, access or certain uses may be prohibited for other reasons (e.g., physical hazards, cultural resource protection, habitat protection).	Agricultural	• Extensive excavation of past-practice waste units and TSD facilities to reduce sources of contamination • Pumping and treating groundwater plumes to levels acceptable under the agricultural exposure scenario • Monitoring natural attenuation of contaminated groundwater plumes • Maintaining institutional controls prohibiting groundwater use until such a time that groundwater sampling results indicate contaminant levels would not preclude any human use
Restricted (R1) Reactors on the River and All Other Areas	Residual contamination precludes some human uses. Restrictions could apply to the surface soils, subsurface soils, surface water, or groundwater.	Recreational, Residential, and Industrial	• Excavation of past-practice waste units and TSD facilities to reduce sources of contamination • Pumping and treating groundwater plumes to levels acceptable under the recreational, residential, or industrial exposure scenario as well as to levels protective of the Columbia River and its ecosystems • Monitoring natural attenuation of contaminated groundwater plumes • Maintaining institutional controls prohibiting groundwater use until such a time that groundwater sampling results indicate that controls are no longer necessary.
Restricted (R2) Reactors on the River and All Other Areas	Residual contamination precludes some human uses. Restrictions could apply to the surface soils, subsurface soils, surface water, or groundwater.	Recreational, Residential, and Industrial	• Pumping and treating groundwater plumes to levels acceptable under the recreational, residential, or industrial exposure scenario as well as to levels protective of the Columbia River and its ecosystems • Monitoring natural attenuation of contaminated groundwater plumes • Maintaining institutional controls prohibiting groundwater use until such a time that groundwater sampling results indicate that controls are no longer necessary.
Exclusive Central Plateau	Potential health risks limit uses and require strict controls on access. Use of the area would be limited specifically to the management of radioactive and hazardous materials, and similar compatible uses. Control of the area would be maintained by DOE. Exclusive use areas could include buffer zones around active facilities.	Industrial	• Pumping and treating localized groundwater plumes to levels acceptable under the industrial exposure scenario • Pumping and treating high concentration core areas of existing plumes which have migrated outside the Central Plateau • Monitoring natural attenuation of contaminated groundwater plumes • Maintaining institutional controls prohibiting groundwater use for an indefinite period.

DOE = U.S. Department of Energy.
TSD = treatment, storage, and/or disposal.

For All Other Areas geographic area (300, 400, 600, 1100, and 3000 Areas), Restricted Future Land-Use Alternatives (R1 and R2) are assessed. The Restricted Future Land-Use Alternatives (R1 and R2) assume that groundwater would not be used in the near-term, but pump-and-treat technologies would be employed to protect the Columbia River (similar to Reactors on the River Restricted Use Alternatives, R1 and R2). This strategy would be refined through the CERCLA process and would be based on land use decisions made in the Reactors on the River geographic area as described above.

For purposes of this groundwater remediation preliminary conceptual design, the specific type of plume control or remediation technology would depend on the cleanup levels required to achieve a specific unrestricted, restricted, or exclusive land use, and would be refined through the CERCLA process. For the purposes of this analysis, cleanup levels for groundwater assumed that, for unrestricted use (either near-term or long-term), U.S. Environmental Protection Agency (EPA) drinking water standards or Washington State water quality standards, whichever were lower, would be used. For protection of the Columbia River, discharge concentrations also would meet drinking water standards or water quality standards, whichever were lower. These standards and associated concentrations, along with the maximum known concentrations for contaminants of concern in the various geographic areas, are summarized in Table D-2.

It is assumed that the pump-and-treat operations discussed in this appendix will continue for a period of at least 10 years. It is recognized, however, that a 10-year time frame might not be appropriate for all alternatives presented in the HRA-EIS. For example, the unrestricted land-use alternative requires that groundwater be remediated to levels that would not preclude any human use. Accomplishing this objective would take longer than 10 years; the HRA-EIS assumes that a period of 30 years would be required. The groundwater remediation strategy for the restricted and exclusive land-use alternatives focuses primarily on remediation of high-concentration core areas of existing contaminant plumes, protection of the Columbia River, and continued restrictions on access to groundwater. The groundwater remediation strategy used for the restricted and exclusive land-use alternatives is consistent with a 10-year time frame.

D.2 Methodology

As stated previously, the purpose of the HRA-EIS is to assess the potential environmental impacts associated with Hanford Site remediation activities that would likely occur in order to achieve a desired future land use objective. Clearly, the remediation of groundwater contamination is a pertinent aspect of this assessment.

While interim and final groundwater remediation technology selection and design will be performed during the CERCLA process, effective and reasonable remediation alternatives must be evaluated as part of the HRA-EIS. The technology selected for evaluation in the HRA-EIS is pump-and-treat. Pump-and-treat has been selected because:

1. It is a well established, often-used technology.

2. It is a proven, effective technology for certain contaminants (i.e., those that are readily extractable) and hydrologic settings.

3. It is the technology currently in use for several CERCLA Interim Remedial Actions at the Hanford Site.

Table D-2. Maximum Detected Plume Concentrations: 1994 Groundwater Sampling (adapted from PNL 1995c). (2 sheets)

Area Name	Plume Constituent	Units	Maximum Plume Concentration	EPA DWS	Washington Water Quality Standard
100-B/C	Chromium	ug/L	>50.0	100	50
	Strontium-90	pCi/L	56.7	8	8
	Tritium	pCi/L	28,000	20,000	20,000
100-D/DR	Chromium	ug/L	1,360	100	50
	Nitrate	mg/L	205	45	45
	Strontium-90	pCi/L	44.0	8	8
	Tritium	pCi/L	69,000	20,000	20,000
100-F	Chromium	ug/L	82.4	100	50
	Nitrate	mg/L	110.0	45	45
	Uranium	ug/L	133.0	20	20
	Strontium-90	pCi/L	20.5	8	8
	Tritium	pCi/L	98,300	20,000	20,000
	Trichloroethylene	ug/L	27.0	5	N/A
100-H	Chromium	ug/L	300.0	100	50
	Nitrate	mg/L	730.0	45	45
	Strontium-90	pCi/L	28.0	8	8
100-KE/KW	Chromium	ug/L	210.0	100	50
	Nitrate	mg/L	110.0	45	45
	Strontium-90	pCi/L	803.0	8	8
	Tritium	pCi/L	1,040,000	20,000	20,000
	Trichloroethylene	ug/L	20.0	5	N/A
100-N	Chromium	ug/L	200.0	100	50
	Cobalt-60	pCi/L	732.0	100	N/A
	Nitrate	mg/L	65	45	45
	Strontium-90	pCi/L	4,030	8	8
	Tritium	pCi/L	74,200	20,000	20,000
200 East	Chromium	ug/L	73.0	100	50
	Nitrate	mg/L	120.0	45	45
	Cyanide	ug/L	39.5	200	200
	Strontium-90	pCi/L	9,740	8	8
	Cesium-137	pCi/L	2,310	10	10
	Tritium	pCi/L	3,370,000	20,000	20,000
	Cobalt-60	pCi/L	40.1	100	N/A
	Iodine-129	pCi/L	11.8	1	1
	Plutonium-239/240	pCi/L	2,670	1	N/A
	Technetium-99	pCi/L	3,700	900	900
	Uranium	ug/L	64.3	20	20

Table D-2. Maximum Detected Plume Concentrations: 1994 Groundwater Sampling (adapted from PNL 1995c). (2 sheets)

Area Name	Plume Constituent	Units	Maximum Plume Concentration	EPA DWS	Washington Water Quality Standard
200 West	Cesium-137	pCi/L	21.8	10	10
	Cobalt-60	pCi/L	13.2	100	N/A
	Cyanide	ug/L	20.0	200	200
	Chromium	ug/L	500.0	100	50
	Nitrate	mg/L	1,700	45	45
	Fluoride	mg/L	5.1	4	4
	Tritium	pCi/L	2,400,000	20,000	20,000
	Iodine-129	pCi/L	86.1	1	1
	Technetium-99	pCi/l	23,700	900	900
	Uranium	ug/L	2,720	20	20
	Carbon tetrachloride	ug/L	5,200	5	0.3
	Chloroform	ug/L	107.0	100	7
	Strontium-90	pCi/L	14.5	8	8
	Trichloroethylene	ug/L	44	5	N/A
300 Area	Chromium	ug/L	<100.0	100	50
	Uranium	ug/L	150	20	20
	Trichloroethylene	ug/L	6.1	5	N/A
600 Area	Cyanide	ug/L	110.0	200	200
	Chromium	ug/L	>100.0	100	50
	Nitrate	mg/L	100	45	45
	Strontium-90	pCi/L	994.0	8	8
	Technetium-99	pCi/L	4,310	900	900
	Tritium	pCi/L	257,000	20,000	20,000
	Trichloroethylene	ug/L	25	5	N/A

DWS = drinking water standard.
EPA = U.S. Environmental Protection Agency.
N/A = not available

D.2.1 Pump-and-Treat Technology

Pump-and-treat technology refers to the selective removal of contaminated groundwater from an aquifer, followed by treatment to remove contaminants consistent with established remedial action objectives. Commonly applied treatment technologies are ion exchange, reverse osmosis and granular

activated carbon. A discussion of treatment technologies is provided in Section D.4. Treated groundwater is either injected back into the aquifer, often to enhance co ntaminant plume hydraulic control, or released directly into a body of surface water. Therefore, this preliminary conceptual design provides two options associated with the discharge of treated groundwater:

1. Discharging treated groundwater directly into the Columbia River at a permitted discharge site.

2. Injecting treated groundwater back into the aquifer.

As indicated in Table D-3, it has been estimated that the discharge of treated groundwater directly to the Columbia River (Option 1) would result in contaminant concentration's well below EPA drinking water standards for the Columbia River[1]. However, it should be noted that with Option 1 there is a potential for accumulation of contaminants in river bank and island sediments which may result in potential impacts to the Columbia River and associated ecosystems over the long-term. This potential would be evaluated through the CERCLA process and the National Pollutant Discharge Elimination System (NPDES) permitting process. Although tritium is not assessed in this groundwater remediation preliminary conceptual design, due to lack of adequate treatment technologies for the removal of tritium from groundwater, it is presented as a contaminant of potential concern for Option 1. The reason for including tritium under Option 1 is that it is assumed tritium will be recovered during pumping operations and discharged in essence, untreated, to the Columbia River. It is anticipated that injecting treated groundwater directly to the aquifer (Option 2) would have insignificant, or no adverse impact on the environment (DOE-RL 1995, EPA 1995; BHI 1995; DOE-RL 1994). However, physical changes such as groundwater mounding (resulting in potential change in groundwater flow patterns) could occur. The process of injecting treated groundwater back into the aquifer assumes the following:

1. Treated groundwater effluent is below applicable water quality standards (e.g., EPA drinking water standards) for all radionuclides (except tritium; see Section D.2.5) and hazardous chemicals.

2. Injection rates are identical to groundwater extraction rates (Table D-4 shows projected groundwater extraction rates).

3. Injection well field is strategically placed to maximize groundwater travel time, allowing for maximum decay of short-lived radioactive contaminants (i.e., tritium), and further dilution of other contaminants (natural attenuation).

4. The number of injection wells, and/or the well size is not specified, but would be established through the CERCLA or RCRA process.

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[1]Equation for estimating contaminant concentrations in the Columbia River following discharge of treated effluent:

CDD = EDR * TEC, where:

- CDD = Contaminant Discharge per Day (pCi/day, ug/day, or mg/day)
- EDR = Effluent Discharge Rate to the Columbia River (L/day)
- TEC = Treated Effluent Concentration (pCi/L, ug/L, or mg/L)
- EC = Estimated Contaminant Concentration in the Columbia River Following Discharge of Treated Effluent (pCi/L, ug/L, or mg/L)
- RF = Columbia River Flow Rate (L/day)

Table D-3. Estimated Contaminant Concentrations in the Columbia River Following Discharge of Treated Effluent.

Discharge Area	Total Discharge Rate	Contaminant of Concern	Treated Effluent Concentration (EPA MCLs unless otherwise stated)	Estimated Concentration in the Columbia River
100 Area (Includes treated effluent from the Central Plateau, Reactors on the River and All Other Areas geographic areas)	20,294 m^3/day	Cs-137	<10.0 pCi/L	~ 0.00228 pCi/L
		^3H	200,000 pCi/L[3]	~ 46.05573 pCi/L
		I-129	<1.0 pCi/L	~ 0.00021 pCi/L
		Pu	<1.0 pCi/L	~ 0.00021 pCi/L
		Sr-90	<8.0 pCi/L	~ 0.00182 pCi/L
		Tc-99	<900.0 pCi/L	~ 0.20723 pCi/L
		CCl_4	<5.0 ug/L	~ 0.00113 ug/L
		Cr	<11.0 ug/L[1]	~ 0.00251 ug/L
		NO_3	<45.0 mg/L	~ 0.01034 mg/L
		TCE	<5.0 ug/L	~ 0.00113 ug/L
		U	<20.0 ug/L[2]	~ 0.00458 ug/L
300 Area (Includes treated effluent from portions of the All Other Areas geographic area)	8,172 m^3/day	^3H	200,000 pCi/L[3]	~18.54575 pCi/L
		NO_3	<45.0 mg/L	~ 0.00416 mg/L
		U	<20.0 ug/L[2]	~ 0.00185 ug/L

[1]Based on the EPA's Chronic Freshwater Quality Criteria (EPA 1986) and the Washington State Standards for Surface Waters (WAC 173-201A).
[2]Proposed Standard.
[3]H is assumed to be discharged to the Columbia River without treatment: EPA DWS is 20,000 pCi/L.
EPA = U.S. Environmental Protection Agency.
MCL = maximum contaminant level.

Assumptions:

Assume a Columbia River flow of 1,020 m^3/sec (minimum flow established at Priest Rapids Dam (DOE-RL 1993)

Assumes that treated effluent meets applicable or proposed water quality standards (e.g., EPA drinking water standards)

Assumes, for the purpose of this analysis, that contaminant concentrations in treated effluent are constant (i.e., at levels specified in previous assumption)

River Flow:

1,020 m^3/sec * 1,000 L/ m^3 = 1,020,000 L/sec
1,020,000 L/sec * 60 sec/min * 1,440 min/day = 88,128,000,000 L/day

100 Area Discharge Rate

20,294 m^3/day * 1,000 L/ m^3 = 20,294,000 L/day

300 Area Discharge Rate

$$8{,}172\ m^3/day * 1{,}000\ L/m^3 = 8{,}172{,}000\ L/day$$

Residual materials from these treatment processes are handled and disposed as radioactive, hazardous, or mixed waste in accordance with applicable standards and regulations.

In general, pump-and-treat technology involves selective placement of groundwater extraction wells and construction of piping manifolds and surface-located treatment facilities. Access roads, operational facilities, and temporary structures might also be needed.

D.2.2 Implementation of Pump-and-Treat Technology

There are numerous strategies for the design and implementation of pump-and-treat systems. Selection of a technology is largely dependent upon site-specific factors such as remediation goals, aquifer and contaminant characteristics, contaminant treatability, and costs. In general, the implementation of pump-and-treat technology is dependent upon three basic factors.

1. The extractability of the contaminants from the aquifer (i.e., how readily the contaminants migrate with the groundwater to the extraction well and how effectively the contaminants are pumped out of the aquifer).

2. The treatability of the contaminants (i.e., how easily are the contaminants removed from the extracted groundwater).

3. The effective placement and pumping of extraction wells such that the contaminant plume is contained and extracted.

For the purposes of the HRA-EIS, it is assumed that the contaminants are readily extracted. Discussions of treatment technologies are presented elsewhere in the HRA-EIS (see Section D.4). The methodology presented here, therefore, concerns the effective placement of extraction well systems.

D.2.3 Extraction Well Placement

The simplest strategy would be extraction well placement in the center of a stagnant contaminant plume. In this case the well is pumped such that contaminants are contained and drawn to the well with the groundwater, and removed from the aquifer. More often, however, the aquifer is not stagnant. Groundwater is continuously flowing under the influence of a hydraulic gradient, and contaminants are dispersed in plumes that migrate with and in the general direction of groundwater flow. This latter condition is the situation governing the movement of most contaminant plumes located in the unconfined aquifer at the Hanford Site.

Given the hydrologic conditions at the Hanford Site, extraction well placement strategy involves the placement of a well or wells in the path of the contaminated groundwater plume in order to completely or, at least, sufficiently capture it. Effective well placement (plume capture) is a function of both well location and the groundwater extraction (pumping) rate. Efficient design of an extraction

well system requires detailed site-specific information and is beyond the scope of the HRA-EIS. A simplified approach, however, can be used that is sufficient for making useful estimates relevant to the purposes of the HRA-EIS. This approach is presented below.

D.2.4 A Simple Well Placement/Plume Capture Methodology

D.2.4.1 Basic Approach. A simple general method for determining the number of wells and pump rates for effectively capturing contaminant plumes at the Hanford Site can be based on the work of Javandel and Tsang (1986). These researchers found that the flow path that serves as the boundary between aquifer flow within the well capture zone and the remainder of aquifer flow is:

$$y = +/- \ (Q/2BU) - (Q/2\Pi BU)\tan\text{-}1\ (y/x) \qquad (1)$$

where:

Q	=	Well pump rate (m^3/sec)
B	=	Aquifer thickness (m)
U	=	Regional aquifer flow velocity (before pumping) (m/sec)
x and y	=	Coordinates with the x-axis parallel to the regional direction of flow and along the shortest flow path, the y-axis perpendicular to the x-axis, and with the origin at the well location.

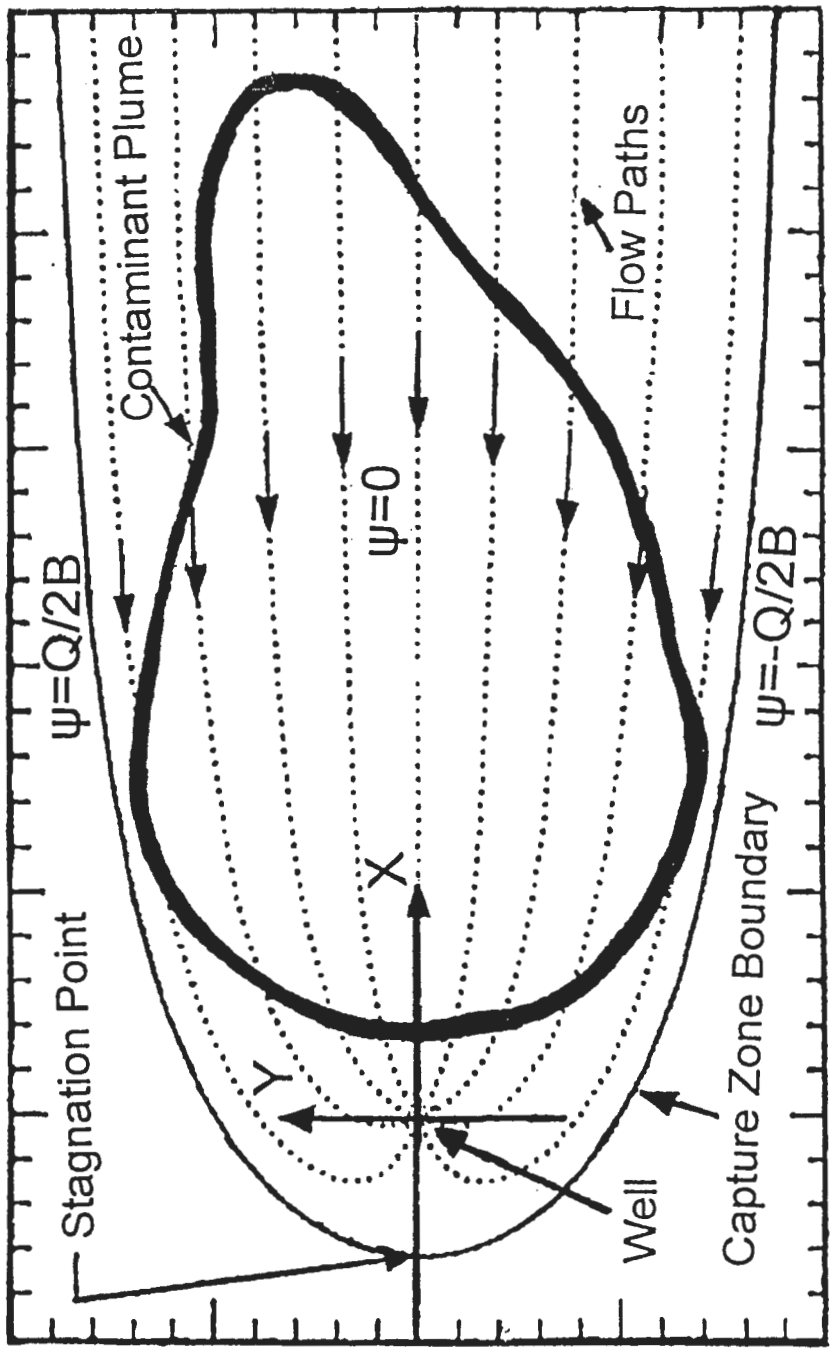
In developing this equation the researchers assumed that the extraction well fully penetrates the aquifer, that the aquifer is confined and has a uniform thickness, that the aquifer is homogeneous and isotropic, and that regional flow in the aquifer is uniform. Similar equations were developed for two, three and 'n' wells equally spaced along the y-axis. Other researchers (BLM 1977) have determined that this equation is also valid for defining well capture zones in unconfined aquifers if the well drawdown in any well does not exceed 25% of the initial aquifer thickness. Therefore, use of this equation to determine capture zones in the unconfined aquifer system at the Hanford Site is valid (assuming less than a 25% aquifer drawdown).

The Javandel and Tsang equation for a single extraction well is depicted graphically in Figure D-1. Flow paths within and outside of the capture zone are also depicted and demonstrate the 'capture' phenomenon. In effect, any contaminant plume that fits within the capture zone boundary will be hydraulically contained and can potentially be remediated using pump-and-treat technology.

D.2.5 Specific Methodology

Using the Javandel and Tsang equation (Equation 1) for a single extraction well, it is apparent that when x = 0, y = +/- Q/2BU, therefore, the 'y-axis capture distance', i.e., the distance along the y-axis between the two points of intersection with the flow path boundary is Q/BU. Again, based

Figure D-1. Graphical Representation of the Javandel and Tsang Equation for a Single Extraction Well (Javandel and Tsang 1986).



upon the work of Javandel and Tsang, it can be shown that this term also represents the 'y-axis capture distance' per well for multiple well systems. This suggests a simple method that can be used to make conservative estimates of the number of wells necessary to capture a given plume. Dividing the maximum contaminant plume width perpendicular to the direction of regional aquifer flow by an appropriately determined 'y-axis capture distance' for a single well will yield the maximum number of wells necessary to capture the plume under consideration.

As noted above, this method can be applied to the contaminant plumes in the unconfined aquifers of the Hanford Site if the maximum total drawdown of any extraction well does not exceed 25% of the total aquifer thickness prior to pumping.

The drawdown determinations are based upon the non-equilibrium method of Theis (Freeze and Cherry 1979; Domenico and Schwartz 1990);

$$s = Q/4\Pi T \;\; W(u);$$

where:

s	=	Drawdown at the well (m)
Q	=	Pumping rate (m^3/d)
T	=	Transmissivity (m^2/d)
W(u)	=	The well function as defined: W(u) = Integral e^{-4}/u du, where:
u	=	$r^2S/4Tt$, and where:
r	=	Well screen radius (m)
S	=	Aquifer specific yield (dimensionless)
T	=	Transmissivity (m^2/d)
t	=	time (days).

For ease of computation, either the modified Theis equations of Cooper and Jacob (1946) or the polynomial approximations of Huntoon (1980) can be used. The method of Huntoon has been incorporated into the DREAM Model (Bonn and Rounds 1990) and was used for the determinations made in this analysis. It is acknowledged that pumping of adjacent wells will affect the drawdown in each well. Because of the linearity of the basic well flow equations, these drawdown effects are additive. It is estimated that compensation for the drawdowns of adjacent wells and well losses would not exceed 20% of the total drawdown at any given well. Therefore, a threshold level for the determination of drawdown from a single well of 20% of aquifer thickness is used instead of 25%.

The specific methodology and results are provided below:

1. List the pertinent contaminant plumes associated with each Hanford Site operating area for the Reactors on the River, Central Plateau, and All Other Areas geographic areas. Graphical depictions of each operating area contaminant plumes have been generated and were used to determine spatial distribution of the contaminant plumes.

   Tritium is not assessed in the HRA-EIS since there is no known feasible remediation technology for the removal of tritium from groundwater.

2. Obtain specific hydrogeologic- and contaminant-specific input variables for each of the Hanford Site operating areas. Parameters and data sources are listed in Table D-3.

3. Determine the maximum plume width perpendicular to the regional direction of aquifer flow. These data have been determined from graphs of each plume and are presented in Table D-3.

4. Determine the pump rate of a fully penetrating well that will have an acceptable drawdown. It was determined that drawdowns for the maximum appropriate pumping rate of 272.6 m^3/d (50 gal/min) were less than 10% of aquifer thickness for all Hanford Site operating areas. Therefore, any pump rate within the range of 55 m^3/d (10 gal/min) to 272.6 m^3/d (50 gal/min) is acceptable. A pump rate of 136.3 m^3/d (25 gal/min) was selected.

5. Calculate the 'y-axis capture distance' for the determined pump rate and aquifer characteristics, i.e., $y = Q/BU$. Y-axis capture distances for each plume are listed in Table D-3.

6. Divide the maximum contaminant plume width perpendicular to the regional aquifer flow by the y-axis capture distance. This gives the number of wells needed to capture the plume. The number of wells for each plume are listed in Table D-4.

7. Locate the wells downgradient from the plume.

D.3 Extraction Well Systems

D.3.1 Reactors on the River – Unrestricted Future Land-Use and Restricted Future Land-Use Alternative (R1)

Groundwater contaminants in the 100 Area reactor sites located along the Columbia River include chromium, nitrate, strontium-90, uranium, and trichloroethylene (TCE). Data are not available on the location and concentrations for all plumes; however, available data are summarized in Table D-2. Hydrologic properties for all the 100 Areas are presented in Table D-3.

D.3.1.1 100-B/C Area. At the 100-B/C Area, the contaminants of interest are strontium-90 and nitrate, which have reported maximum concentrations higher than drinking water standards or water quality standards (PNL 1995a). Maximum reported strontium-90 and nitrate concentrations at the 100-B/C Area are presented in Table D-2. The depth to groundwater in this vicinity averages approximately 30 m (98.4 ft) below ground surface. Three wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 60 m (196.8 ft) below ground surface, would be designed in a pattern to capture the plumes of interest at this site (Figure D-2). A maximum aquifer drawdown of 0.16 m (0.52 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 100-D and 100-H Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be released directly to the Columbia River at a permitted release site or injected back into the aquifer.

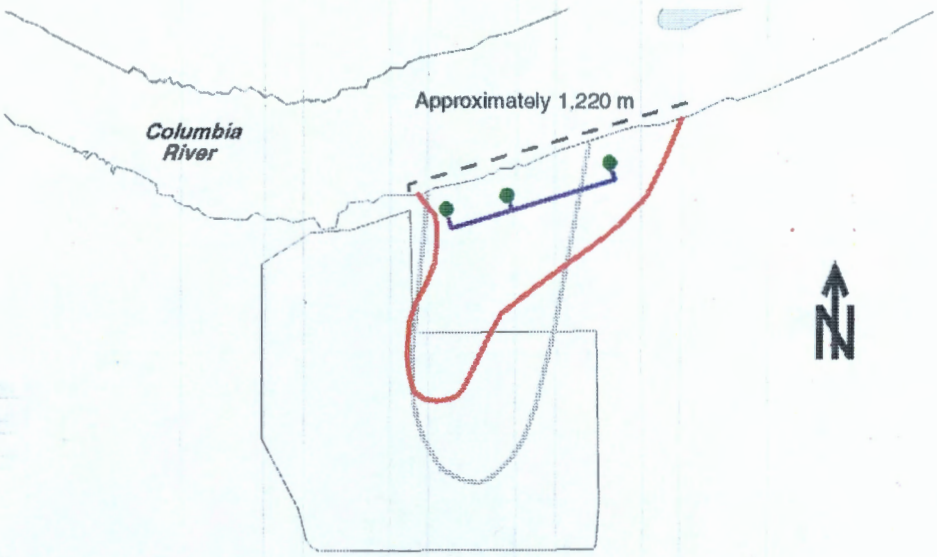
Table D-4. Hydrologic Properties for the Individual Geographic Areas.

Geographic Area	Transmissivity (m^2/d)	Porosity	Specific Yield	Storage Coefficient	Gradient	Aquifer Thickness (m)	Y-axis Capture Distance (m)	Hydraulic Conductivity (m/d)	Contaminants Plumes used in the Analysis
Reactors on the River									
100-B/C	1,500	0.12	0.1	0.2	0.00018	30	504.4	50	Nitrate and Sr-90
100-K	750	0.12	0.1	0.2	0.00025	15	716.8	50	Chromium, Nitrate and Sr-90
100-N	750	0.12	0.1	0.2	0.00038	15	469.7	50	Nitrate and Sr-90
100-D	500	0.12	0.1	0.2	0.00041	10	664.4	50	Chromium, Nitrate and Sr-90
100-H	1,250	0.12	0.1	0.0006	0.001	10	109.0	125	Chromium, Nitrate, Sr-90 and U
100-F	500	0.12	0.1	0.2	0.001	10	272.4	50	Chromium, Nitrate, Sr-90 and U
Central Plateau									
200 East	10,000	0.12	0.1	0.0002	0.00021	15	64.86	667	U, Nitrate, Cs-137, Pu, Sr-90 and Tc-99
200 West	1,000	0.12	0.1	0.0002	0.00068	50	200.3	20	U, Nitrate, Tc-99, I-129 and TCE
All Other Areas									
300 Area	5,000	0.26	0.1	0.009	0.0009	10	30.2	500	U and Nitrate
600 Area	10,000	0.12	0.1	0.0002	0.00021	15	64.86	667	I-129, Sr-90 and Nitrate

Sources: PNL 1995a, PNL 1995b, PNL 1995c, Freeze and Cherry 1979.

9613459.2621

Figure D-2. Extraction Well Placement for the 100-B/C Area.



Legend

- 8 pCi/L Sr-90 Plume Contour
- 20 mg/L NO_3 Plume Contour
- Interwell Piping
- Extraction Well

Calculations

Pump Rate (Q) = 136.2 m3/d
Hydraulic Conductivity (K) = 50 m/d
Aquifer Thickness (B) = 30 m
Transmissivity (T) = 1,500 m2/d
Gradient = 0.00018

Width at Wellhead = Q/T * Gradient
Width at Wellhead = 136.2/(1,500 * 0.00018)
Width at Wellhead = 504.4 m

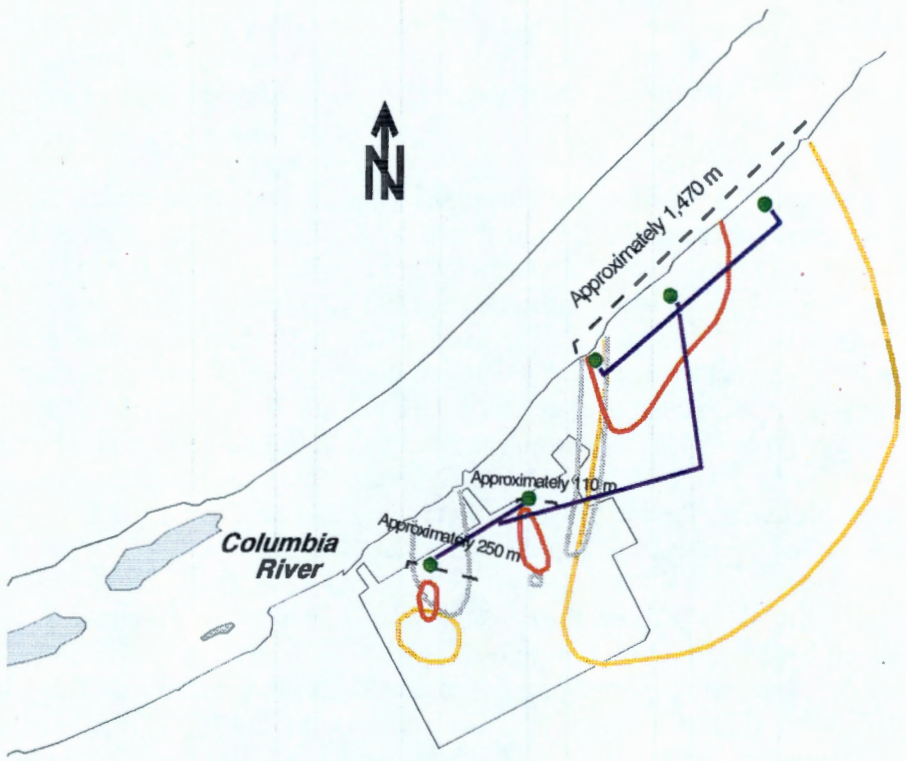
D.3.1.2 100-K Area. At the 100-K Area, the contaminants of interest are chromium, nitrate, and strontium-90, all of which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are presented in Table D-2. The depth to groundwater in this vicinity averages approximately 30 m (98.4 ft) below ground surface. Three distinct plumes were identified; a combined nitrate/chromium/strontium-90 plume and a single strontium-90 plume within the 100-K Area, and a nitrate/chromium/strontium-90 plume between the 100-K and 100-N Areas. Five wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 45 m (147.6 ft) below ground surface, would be designed in a pattern to capture the nitrate/chromium/strontium-90 plumes (Figure D-3). A maximum aquifer drawdown of 0.32 m (1.05 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 100-D and 100-H Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be released directly to the Columbia River at a permitted release site or injected back into the aquifer.

D.3.1.3 100-N Area. At the 100-N Area, the contaminants of interest are strontium-90 and nitrate, both of which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are reported in Table D-2. The depth to groundwater in this vicinity averages approximately 30 m (98.4 ft) below ground surface. Four wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 45 m (147.6 ft) below ground surface, would be designed in a pattern to capture the strontium-90/nitrate plumes of interest in this Area (Figure D-4). A maximum drawdown of 0.32 m (1.05 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 100-D and 100-H Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be released directly to the Columbia River at a permitted release site or injected back into the aquifer.

D.3.1.4 100-D Area. At the 100-D Area, the contaminants of interest are strontium-90, chromium, and nitrate, all of which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are presented in Table D-2. The depth to groundwater in this vicinity averages approximately 30 m (98.4 ft) below ground surface. Six wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 40 m (131.2 ft) below ground surface, would be designed in a pattern to capture the strontium-90/chromium/nitrate plumes of interest at this site (Figure D-5). A maximum drawdown of 0.46 m (1.51 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 100-D and 100-H Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be released directly to the Columbia River at a permitted release site or injected back into the aquifer.

D.3.1.5 100-H Area. At the 100-H Area, the contaminants of interest are chromium, nitrate, strontium-90 and uranium, all of which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are presented in Table D-2. The depth to groundwater in this vicinity averages approximately 30 m (98.4 ft) below ground surface. Fifteen wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 40 m (131.2 ft) below ground surface, would be designed in a pattern to capture the plumes of interest at this site (Figure D-6). A maximum drawdown of 0.22 m (0.72 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 100-D and 100-H Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be released directly to the Columbia River at a permitted release site or injected back into the aquifer.

Figure D-3. Extraction Well Placement for the 100-KE/KW Area.



Legend

- 8 pCi/L Sr-90 Plume Contour
- 45 mg/L NO_3 Plume Contour
- 50 ug/L Cr Plume Contour
- Interwell Piping
- Extraction Well

Calculations

Pump Rate (Q) = 136.2 m3/d
Hydraulic Conductivity (K) = 50 m/d
Aquifer Thickness (B) = 15 m
Transmissivity (T) = 750 m2/d
Gradient = 0.00025

Width at Wellhead = Q/T * Gradient
Width at Wellhead = 136.2/(750 * 0.00025)
Width at Wellhead = 716.8 m

Figure D-4. Extraction Well Placement for the 100-N Area.

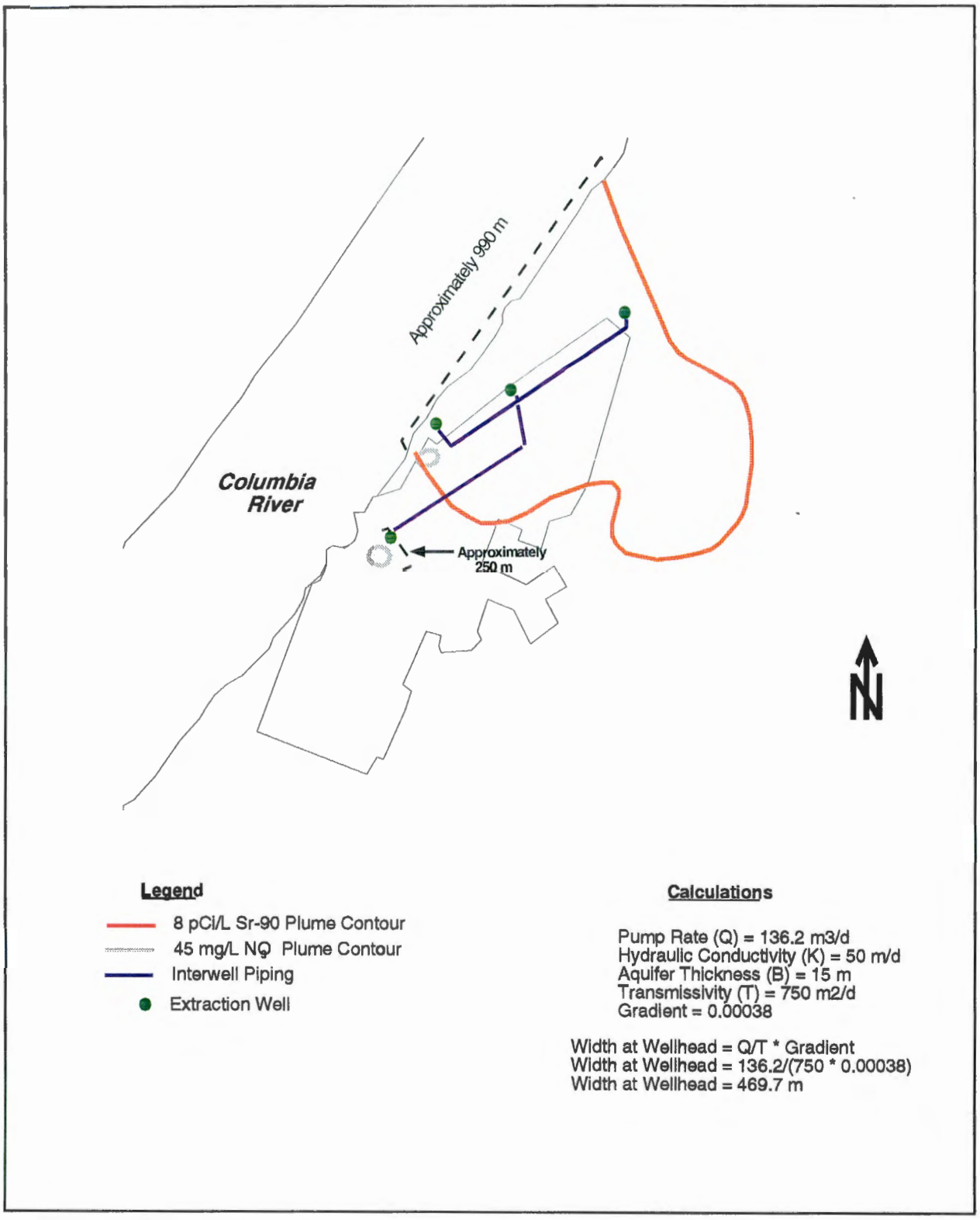
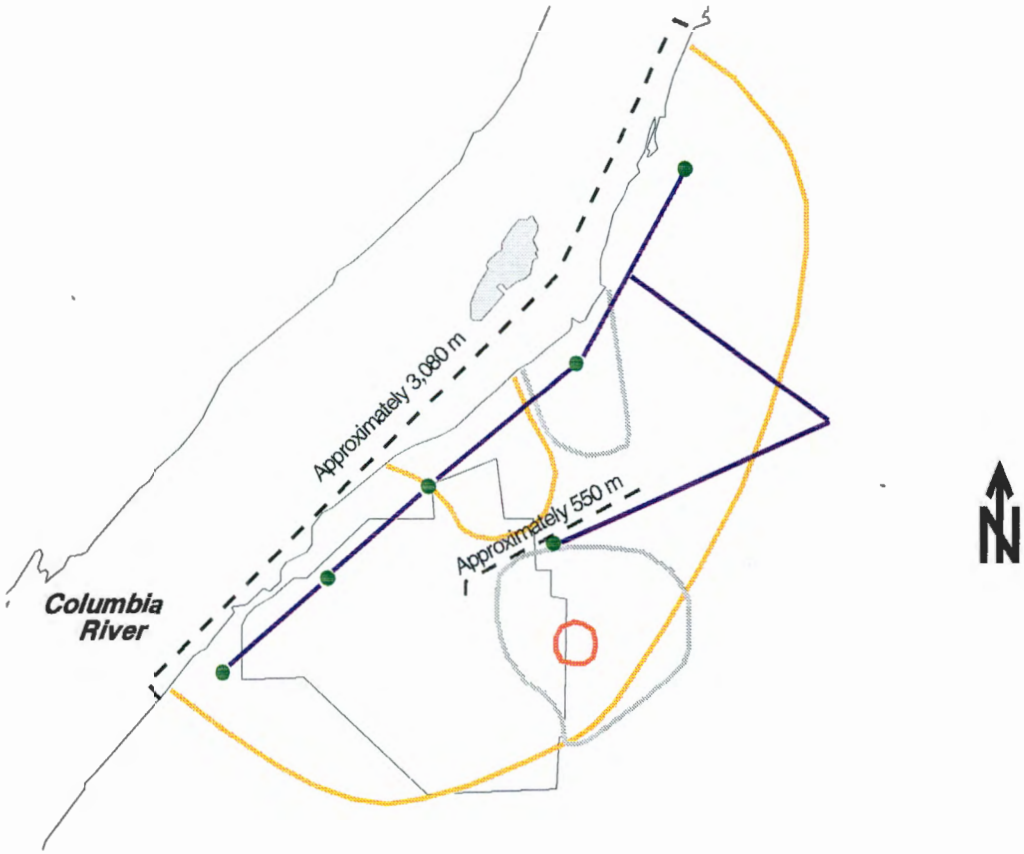


Figure D-5. Extraction Well Placement for the 100-D/DR Area.



Legend

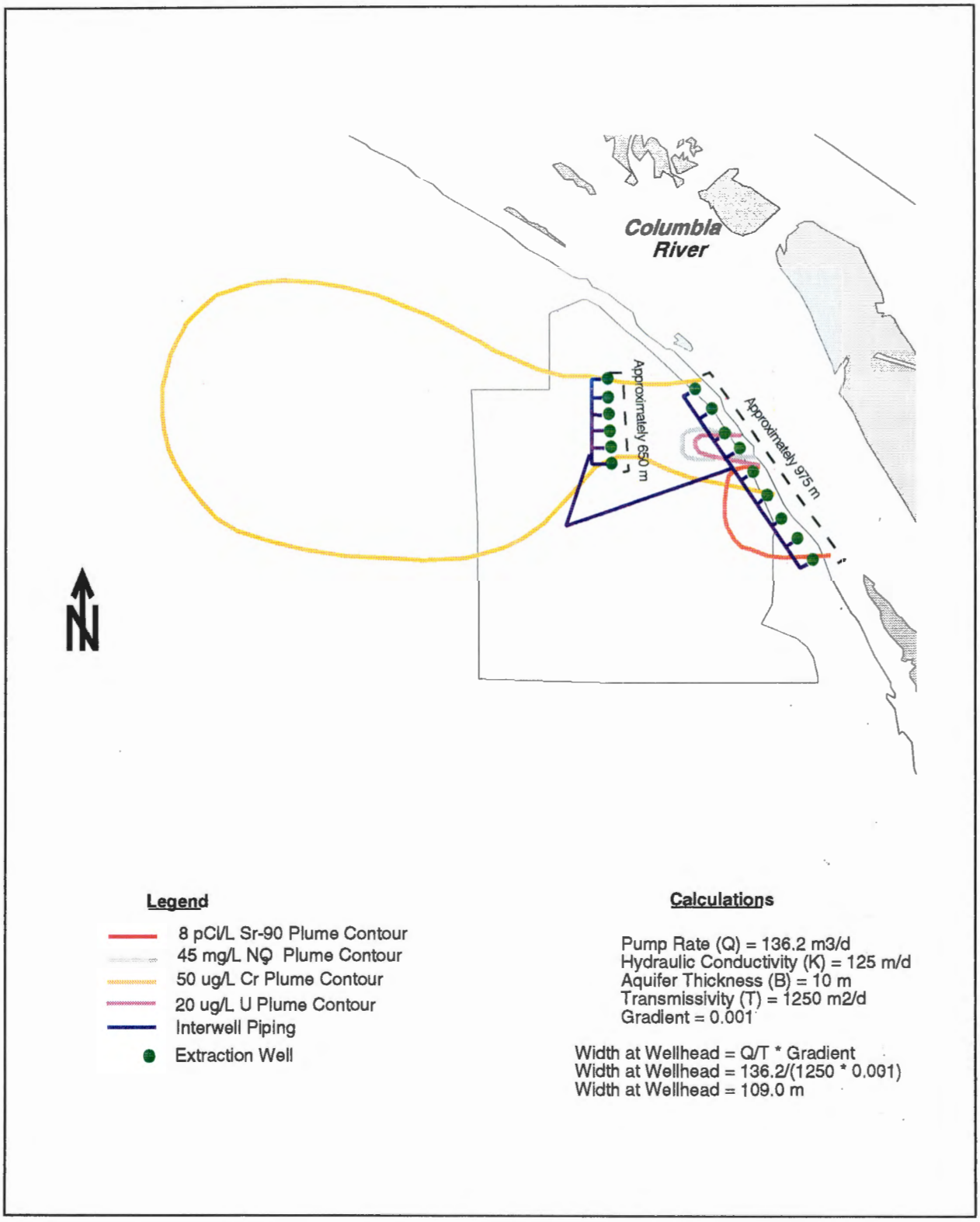
- 8 pCi/L Sr-90 Plume Contour
- 45 mg/L NO_3 Plume Contour
- 50 ug/L Cr Plume Contour
- Interwell Piping
- Extraction Well

Calculations

Pump Rate (Q) = 136.2 m3/d
Hydraulic Conductivity (K) = 50 m/d
Aquifer Thickness (B) = 10 m
Transmissivity (T) = 500 m2/d
Gradient = 0.00041

Width at Wellhead = Q/T * Gradient
Width at Wellhead = 136.2/(500 * 0.00041)
Width at Wellhead = 664.4 m

Figure D-6. Extraction Well Placement for the 100-H Area.



D.3.1.6 100-F Area. At the 100-F Area, the contaminants of interest are nitrate, uranium, chromium and strontium-90, which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are presented in Table D-2. The depth to groundwater in this vicinity averages approximately 30 m (98.4 ft) below ground surface. Nineteen wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 40 m (131.2 ft) below ground surface, would be designed in a pattern to capture the chromium, nitrate, uranium, and strontium-90 plumes of interest at this site (Figure D-7). A maximum drawdown of 0.46 m (1.51 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 100-D and 100-H Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be released directly to the Columbia River or injected back into the aquifer.

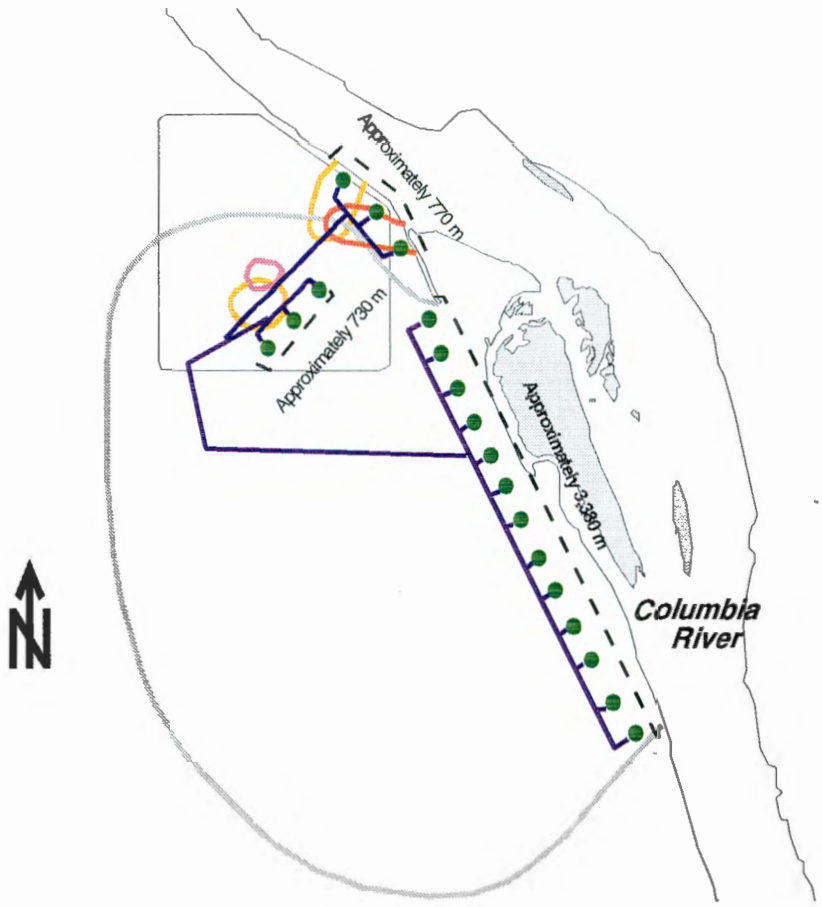
D.3.2 Central Plateau - Exclusive Future Land-Use Alternative

The Central Plateau includes the 200 East and 200 West Areas. Groundwater contaminants in the 200 East and 200 West Areas include: chromium, nitrate, cyanide, fluoride, strontium-90, cesium-137, tritium, cobalt-60, iodine-129, plutonium, technetium-99, uranium, carbon tetrachloride, chloroform, and TCE. Data are not available on the location and concentrations for all plumes. Hydrologic properties for the 200 Areas vary considerably and are presented in Table D-3.

D.3.2.1 200 East Area. The contaminants of interest in the 200 East Area are nitrate, strontium-90, cesium-137, plutonium, technetium-99, iodine-129, and uranium, all of which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are presented in Table D-2. The depth to groundwater in this vicinity averages approximately 100 m (328 ft) below ground surface. Thirteen wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 115 m (377.2 ft) below ground surface, would be designed in a pattern to capture the plumes of interest at this site (Figure D-8). A maximum drawdown of 0.034 m (0.11 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 200 East and 200 West Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be sent (through pipeline) to the proposed 100 Area permitted release site or injected back into the aquifer.

D.3.2.2 200 West Area. The contaminants of interest in the 200 West Area are nitrate, iodine-129, technetium-99, uranium, carbon tetrachloride, and TCE, all of which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are presented in Table D-2. The depth to groundwater in this vicinity averages approximately 70 m (229.6 ft) below ground surface. Twenty-four wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 120 m (393.6 ft) below ground surface, would be designed in a pattern to capture the plumes of interest at this site (Figure D-9). A maximum drawdown of 0.31 m (1.02 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 200 East and 200 West Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be sent (through pipeline) to the proposed 100 Area permitted release site or injected back into the aquifer.

Figure D-7. Extraction Well Placement for the 100-F Area.



Legend

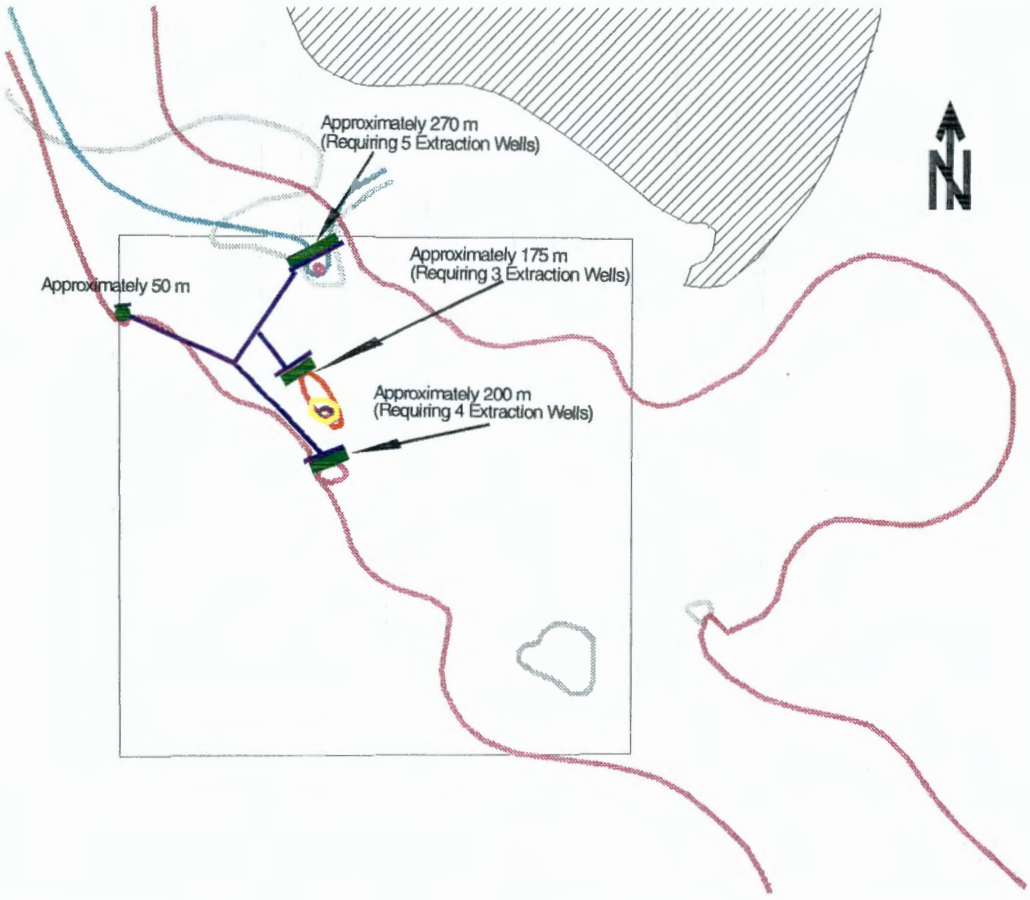
- 8 pCi/L Sr-90 Plume Contour
- 45 mg/L NO_3 Plume Contour
- 50 ug/L Cr Plume Contour
- 20 ug/L U Plume Contour
- Interwell Piping
- Extraction Well

Calculations

Pump Rate (Q) = 136.2 m3/d
Hydraulic Conductivity (K) = 50 m/d
Aquifer Thickness (B) = 10 m
Transmissivity (T) = 500 m2/d
Gradient = 0.001

Width at Wellhead = Q/T * Gradient
Width at Wellhead = 136.2/(500 * 0.001)
Width at Wellhead = 272.4 m

Figure D-8. Extraction Well Placement for the 200 East Area.



Legend

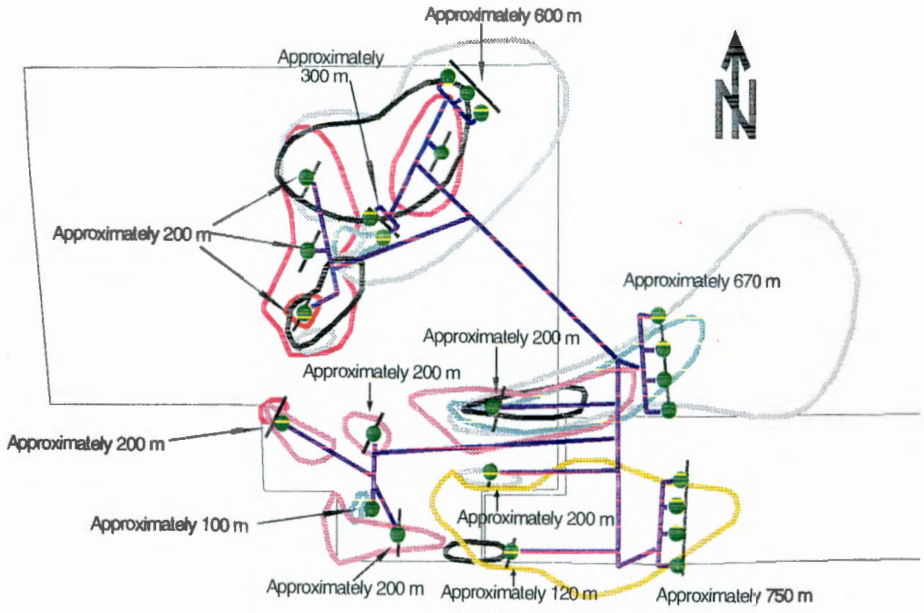
- 8 pCi/L Sr-90 Plume Contour
- 45 mg/L NO_3 Plume Contour
- 1 pCi/L I-129 Plume Contour
- 120 pCi/L Cs-137 Plume Contour
- 20 ug/L U Plume Contour
- 900 pCi/L Tc-99 Plume Contour
- 1 pCi/L Pu Plume Contour
- Interwell Piping
- Extraction Well

Calculations

Pump Rate (Q) = 136.2 m3/d
Hydraulic Conductivity (K) = 667 m/d
Aquifer Thickness (B) = 15 m
Transmissivity (T) = 10,000 m2/d
Gradient = 0.00021

Width at Wellhead = Q/T * Gradient
Width at Wellhead = 136.2/(10,000 * 0.00021)
Width at Wellhead = 64.9 m

Figure D-9. Extraction Well Placement for the 200 West Area.



Legend

- 100 mg/L NO_3 Plume Contour
- 10 pCi/L I-129 Plume Contour
- 20 ug/L U Plume Contour
- 900 pCi/L Tc-99 Plume Contour
- 1000 ug/L CCl_4 Plume Contour
- 5000 ug/L CCl_4 Plume Contour
- 5 ug/L TCE Plume Contour
- Interwell Piping
- Extraction Well

Calculations

Pump Rate (Q) = 136.2 m3/d
Hydraulic Conductivity (K) = 20 m/d
Aquifer Thickness (B) = 50 m
Transmissivity (T) = 1,000 m2/d
Gradient = 0.00068

Width at Wellhead = Q/T * Gradient
Width at Wellhead = 136.2/(1,000 * 0.00068)
Width at Wellhead = 200.3 m

D.3.3 All Other Areas - Restricted Future Land-Use Alternative (R1)

D.3.3.1 300 Area. Hydrologic properties at the 300 Area are summarized in Table D-3. At the 300 Area, the contaminant of interest is uranium, which has reported concentrations higher than drinking water or water quality standards (PNL 1995a). Maximum reported plume concentrations are presented in Table D-2. The depth to groundwater in this area averages approximately 30 m (98.4 ft) below ground surface. Nineteen wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) and a depth of 40 m (131.2 ft) below ground surface, would be designed in a pattern to capture the plumes of interest at this site. A maximum drawdown of 0.06 m (0.20 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located adjacent to the 300 Area. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be released directly to the Columbia River at a permitted release site or injected back into the aquifer.

D.3.3.2 600 Area. Hydrologic properties at the 600 Area are highly variable and depend upon location. Table D-3 shows the transmissivity and storativity values assumed for the 600 Area capture-zone analysis. At the 600 Area, the contaminants of interest are nitrate, strontium-90, and iodine-129, all of which have reported concentrations higher than drinking water or water quality standards (PNL 1995a). Table D-2 shows the maximum reported plume concentrations in the 600 Area. The depth to groundwater in this vicinity is highly variable but averages approximately 85 m (278.8 ft) below ground surface. One hundred five wells, each with a pumping rate of 136.3 m^3/d (25 gal/min) would be designed in a pattern to capture the plumes of interest at this site. All wells were assumed to be 100 m (328 ft) deep. A maximum drawdown of 0.34 m (1.12 ft) was calculated at the end of 10 years of pumping (see Table D-4). The extracted groundwater would be sent to a proposed treatment facility located between the 200 East and 200 West Areas. Once all contaminants of concern had been reduced to acceptable levels, the treated water would be sent (through pipeline) to the proposed 100 Area or 300 Area permitted release sites or injected back into the aquifer (Figures D-10 and D-11).

D.4 Treatment Systems

For this capture-zone analysis, the 100 Areas would have one centralized treatment facility located between the 100-D and 100-H Areas (Figure D-12). Before treatment, the extracted groundwater would contain elevated levels of chromium, nitrate, strontium-90, and uranium. Additionally, it is expected that other plumes present at levels below drinking water standards might be captured by the extraction wells and these contaminants would be introduced into the extracted groundwater headed for the treatment facility. Because of the varied types and numbers of contaminants that might be resident or introduced into the extracted groundwater, it has been assumed that a combination of treatment technologies for a given area would be needed. A combination of reverse osmosis, ion exchange, and granular activated carbon would be used to treat the extracted groundwater. Reverse osmosis treatment would be used for all contaminants except radionuclides, which would require the use of ion exchange. When organics are detected in the extracted groundwater, granular activated carbon would be used as a treatment methodology. All groundwater treatment residuals would be transported to the 200 Areas for storage or disposal. Treated groundwater that meets the EPA drinking water standards, with the exception of tritium which could be at levels greater than EPA drinking water standards, would be either discharged directly to the

Figure D-10. Extraction Well Placement for the 300 Area.

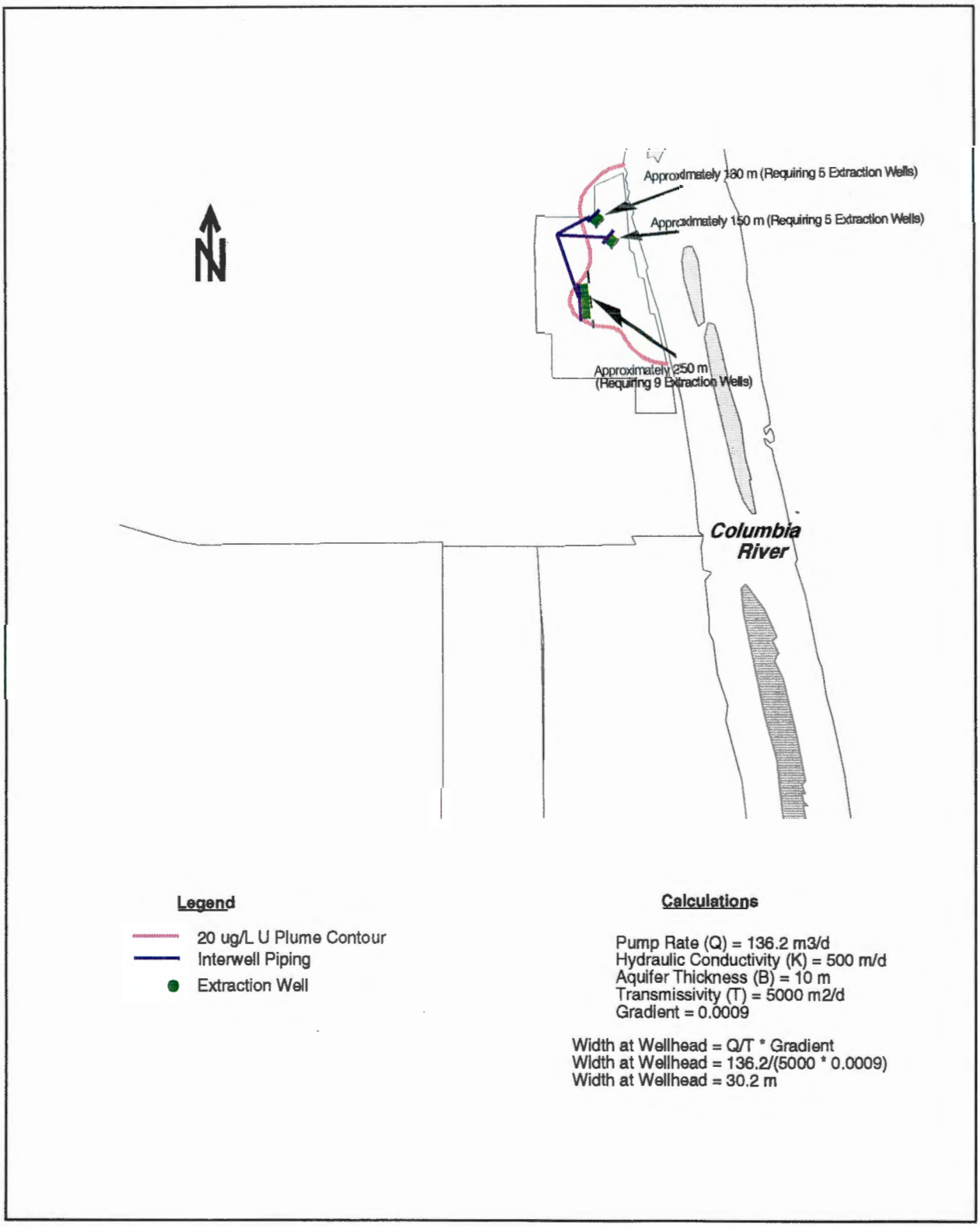
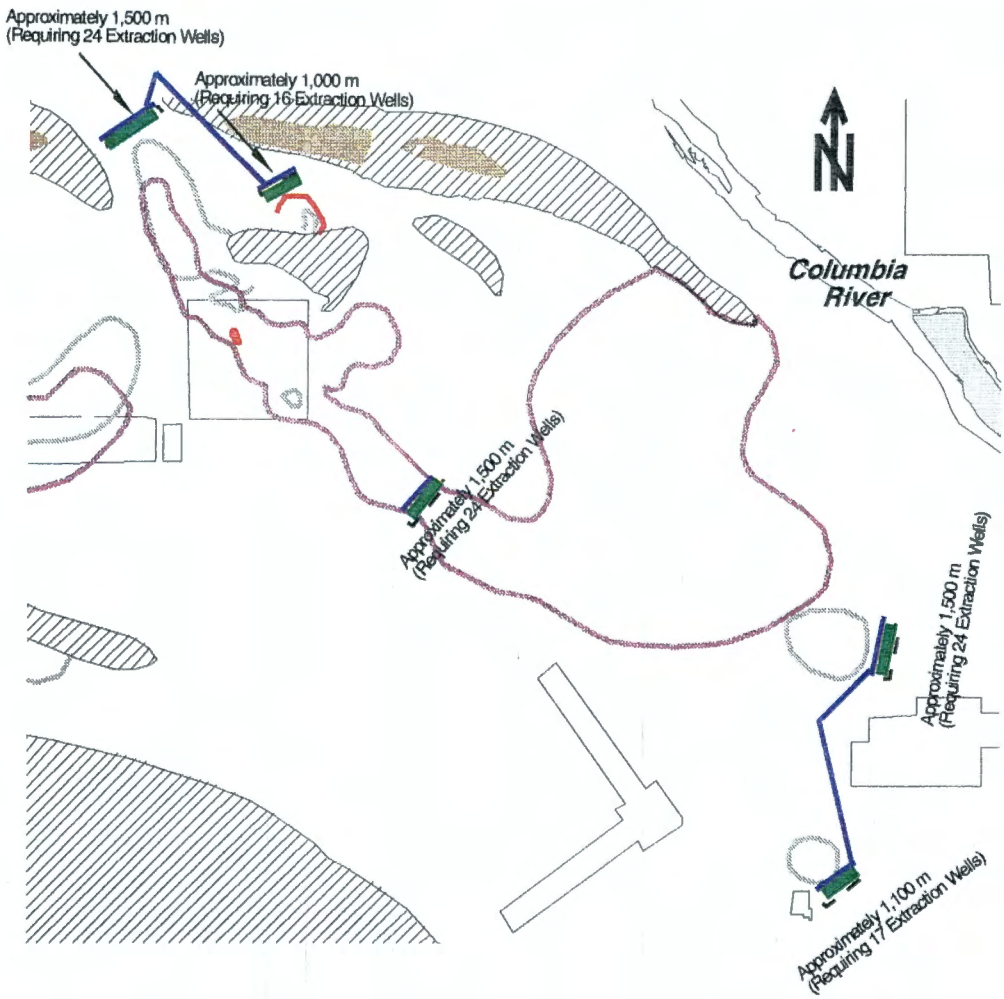


Figure D-11. Extraction Well Placement for the 600 Area.



Legend

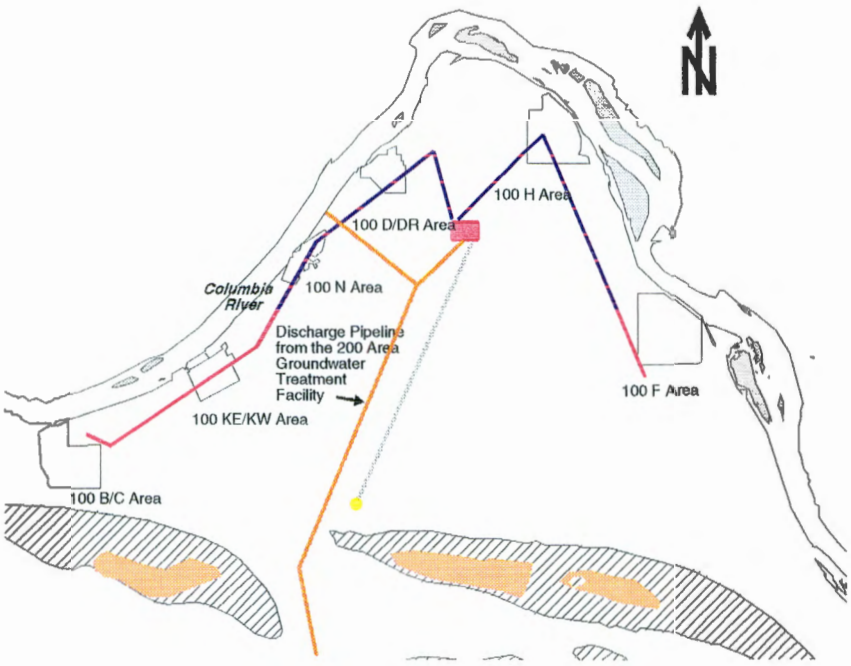
- 8 pCi/L Sr-90 Plume Contour
- 45 mg/L NO_3 Plume Contour
- 1 pCi/L I-129 Plume Contour
- Interwell Piping
- Extraction Well

Calculations

Pump Rate (Q) = 136.2 m3/d
Hydraulic Conductivity (K) = 667 m/d
Aquifer Thickness (B) = 15 m
Transmissivity (T) = 10,000 m2/d
Gradient = 0.00021

Width at Wellhead = Q/T * Gradient
Width at Wellhead = 136.2/(10,000 * 0.00021)
Width at Wellhead = 64.9 m

Figure D-12. 100 Areas Groundwater Treatment Facility.



Legend

- Treatment Facility
- Interwell Piping
- River Discharge Pipeline (Option 1)
- Injection Well Pipeline (Option2)
- Injection Well Field

NOTE: This preliminary conceptual design presents two options for discharge of treated groundwater: (1) Discharge to the Columbia River and (2) Injection back into the aquifer. It is anticipated that only one of these options will be chosen as the preferred means to discharge treated groundwater.

Columbia River (Option 1), or injected back into the aquifer sufficiently upgradient of the Columbia River allowing for maximum decay of relatively short-lived radioactive contaminants (i.e., tritium), and further dilution of other contaminants (Option 2). These treatment technologies are very expensive and are not necessarily proven effective in the removal of all inorganics, organics, and radionuclides to concentrations commensurate with drinking water standards. For example, reducing strontium-90 in water has been achieved commercially only to concentrations of approximately 300 pCi/L using ion exchange units (Robinson et al. 1988; Robinson et al. 1990). Therefore, treatment might not reduce the concentrations to acceptable discharge limits. Also, because the concentrations of many constituents in a given waste stream might be below drinking water standards due to dilution from pumping, treatment might not be needed continuously during the 10-year pumping duration. Final decisions on treatment facility components, well placement, and design will be made through the CERCLA process.

For the 200 Areas, a single treatment facility is proposed to be located between the 200 East and 200 West Areas (Figure D-13). This treatment facility would consist of reverse osmosis and ion exchange units for treatment of inorganics, trace metals, and radionuclides. Granular activated carbon would be used for treating organics, where needed. Treatment residuals would be stored or disposed in the 200 Areas. Treated groundwater that meets the EPA drinking water standards, with the exception of tritium which could be at levels greater than EPA drinking water standards, would be either discharged directly to the Columbia River (Option 1), or injected back into the aquifer sufficiently upgradient of the Columbia River allowing for maximum decay of relatively short-lived radioactive contaminants (i.e., tritium), and further dilution of other contaminants (Option 2).

In the 300 Area, a single treatment plant is proposed (Figure D-14). Because the only radionuclide present in significant quantities is uranium, reverse osmosis treatment would be used. Granular activated carbon would be used for organic constituents of concern. Concentrates and other groundwater treatment waste products would be transported to the 200 Areas for storage or disposal. Treated groundwater that meets the EPA drinking water standards, with the exception of tritium which could be at levels greater than EPA drinking water standards, would be either discharged directly to the Columbia River (Option 1), or injected back into the aquifer sufficiently upgradient of the Columbia River allowing for maximum decay of relatively short-lived radioactive contaminants (i.e., tritium), and further dilution of other contaminants (Option 2).

Table D-5 summarizes the groundwater remediation conceptual design parameters for the Hanford Site.

Table D-5. Summary of Materials and Other Information for the Groundwater Remediation Systems.

Geographic Area	No. of Pumping Wells	Pumping Rate/Well (m^3/d)	Well Depth (m)	Maximum Aquifer Drawdown (m)	Length of Interwell Piping (m)	Length of Piping to Treatment Facility (m)	Pumping Time (years)[3]	Treatment Method	Distance from Treatment System to Discharge Area (m)
Reactors on the River									
100-B/C	3	136.2	60	0.16	800		10	RO/IX/GAC	
100-K	5	136.2	45	0.32	3,250		10	RO/IX/GAC	
100-N	4	136.2	45	0.32	1,200		10	RO/IX/GAC	
100-D	6	136.2	40	0.46	3,500		10	RO/IX/GAC	
100-H	15	136.2	40	0.22	2,800		10	RO/IX/GAC	
100-F	19	136.2	40	0.46	7,200		10	RO/IX/GAC	
						10,300			3,500[1] 7,500[2]
Central Plateau									
200 East	13	136.2	115	0.034	3,500		10	RO/IX/GAC	
200 West	24	136.2	120	0.31	15,000		10	RO/IX/GAC	
						5,500			11,500[1] 10,000[2]
All Other Areas									
300 Area	19	136.2	40	0.06	1,300		10	RO/GAC	
600 Area	105	136.2	100	0.34	16,000		10	RO/IX/GAC	
						23,000			700[1] 9,600[2]
Total for All Areas	213	28,466			52,050	38,800	10		15,700[1] 17,110[2]

Source: PNL 1995a and PNL 1995b.

NOTE: Area disturbed per well = 930 m^2. Assume a 10 m wide strip for the well piping.

[1]River Discharge Option (Option 1).

[2]Aquifer Injection Option (Option 2).

[3]Reactors on the River Unrestricted Future Land Use Alternative assumes 30 years pumping time. This modification is reflected in impact discussions presented in Chapter 5.0.

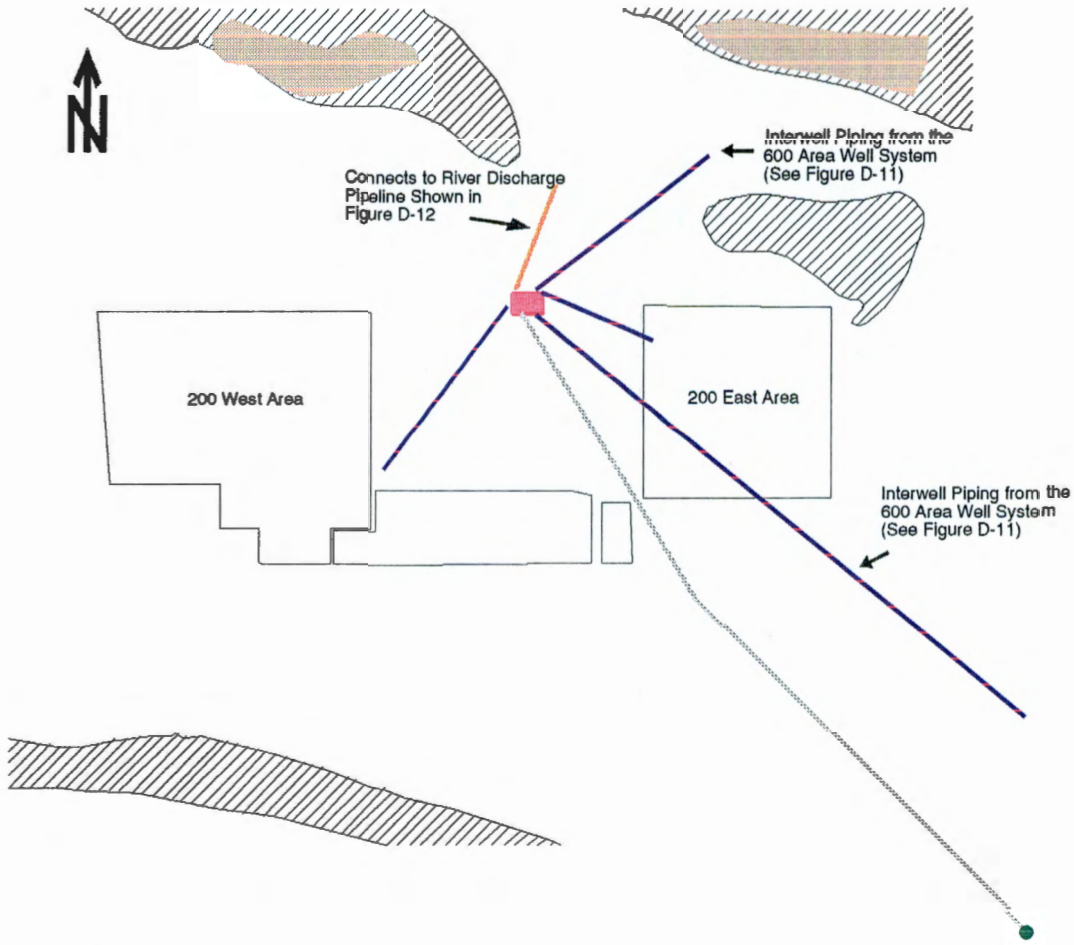
GAC = Granular Activated Carbon.

IX = Ion Exchange.

RO = Reverse Osmosis.

9613459.2629

Figure D-13. 200 Areas Groundwater Treatment Facility.

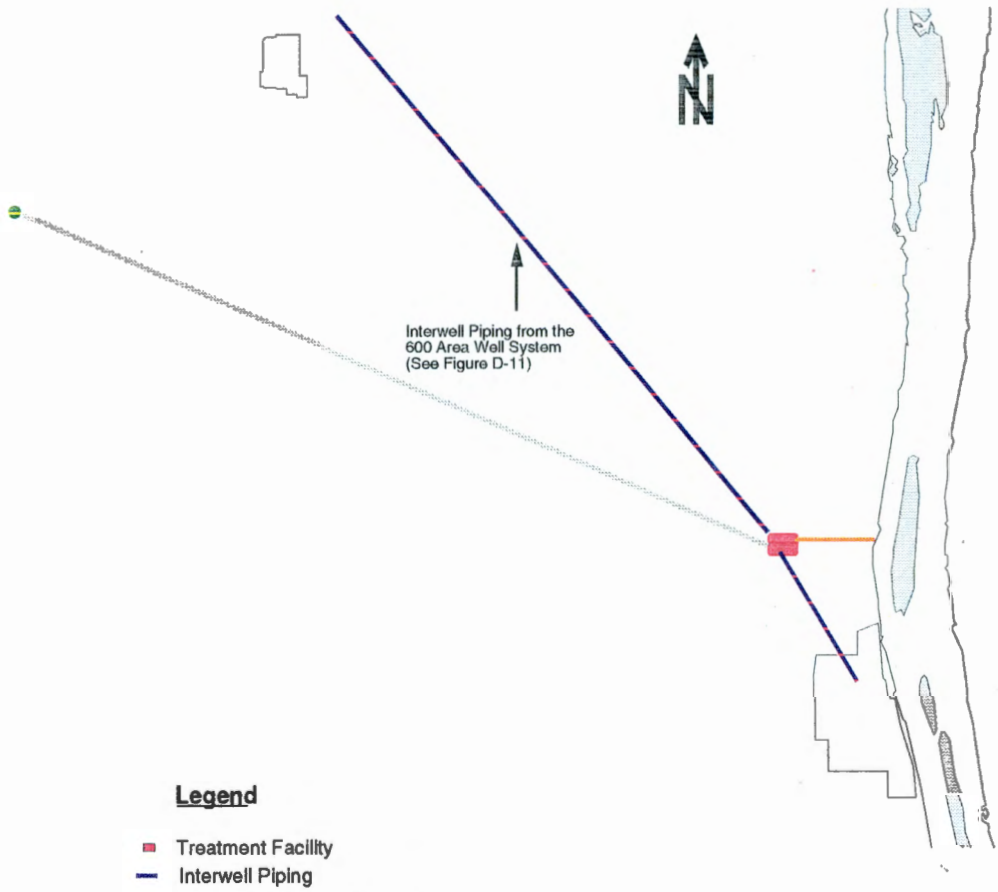


Legend

- Treatment Facility
- Interwell Piping
- River Discharge Pipeline (Option 1)
- Injection Well Pipeline (Option2)
- Injection Well Field

NOTE: This preliminary conceptual design presents two options for discharge of treated groundwater: (1) Discharge to the Columbia River and (2) Injection back into the aquifer. It is anticipated that only one of these options will be chosen as the preferred means to discharge treated groundwater.

Figure D-14. 300 Area Groundwater Treatment Facility.



Legend

- Treatment Facility
- Interwell Piping
- River Discharge Pipeline (Option 1)
- Injection Well Pipeline (Option 2)
- Injection Well Field

NOTE: This preliminary conceptual design presents two options for discharge of treated groundwater: (1) Discharge to the Columbia River and (2) injection back into the aquifer. It is anticipated that only one of these options will be chosen as the preferred means to discharge treated groundwater.

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