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Revision 6

STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units

Document Type: ENV Program/Project: EP&SP

A. Mayenna
INTERA

N. Hasan
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Date Published
May 2014

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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ENVIRONMENTAL CALCULATION COVER PAGE

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Project: 100-D/H RI/FS **Date:** 8 Jan 2014

Calculation Title & Description: STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units

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0-A	Revised initial issue	04-May-2011	All ☒
1	Updated calculation to change source distributions used for PRG calculation	23-Aug-2011	22, 27-28, 30-31, 35-39 ☒
2	Updated calculation to change source distributions used for screening level and PRG values	24-Feb-2012	All ☒
3	Added Section 5.7 for Sr-90 SSL and PRG Calculation for 116-K-2 Trench	01-Jun-2012	27-28 ☒
4	Updates calculation to add analyte CAS #3 93-65-2 (2-(2-methyl-4-chlorophenoxy propionic acid) to list for calculation of SSLs and PRGs; changes to text (not results) to incorporate lessons learned from senior review comments in 300 Area SSL+PRG ECF	02-Aug-2012	All ☒
5	Revised SSL and PRG basis for Sr-90 to use 100:0 initial distributions and added Section 3.6.	08-Nov-2012	All ☒

ENVIRONMENTAL CALCULATION COVER PAGE (CONTINUED)

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Calculation No.: ECF-Hanford-11-0063 **Revision No.:** 6

Revision History:

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Environmental Calculation File

STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units

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Abbreviations

ARARs	applicable regulations and requirements
AWLN	automated water level network
AWQL	applicable water quality standards
CHPRC	CH2M HILL Plateau Remediation Company
COPC	contaminant of potential concern
CPK	peak groundwater concentration
ECF	environmental calculation file
EQL	estimated quantitation limit
FEPs	features, events, and processes
HEIS	Hanford Environmental Information System (environmental database)
HISI	Hanford Information System Inventory (software database)
HSU	hydrostratigraphic unit
MCL	maximum contaminant level
POCal	point of calculation
PRG	preliminary remediation goal
OHWL	ordinary high water level
OU	Operable Unit
RAG	remedial action goal
RESRAD	RESidual RADiation (modeling software)
RUM	Ringold upper mud
SSL	soil screening level
STOMP	Subsurface Transport Over Multiple Phases (modeling software)
TINs	triangulated irregular networks
WAC	Washington Administrative Code
WQS	water quality standard

1 Purpose

The purpose of this environmental calculation file (ECF) is to calculate soil screening levels (SSLs) and preliminary remediation goals (PRGs) for protection of surface water and of groundwater in the 100-D and 100-H source Operable Units (OUs) (specifically, 100-DR-1 and 100-DR-2 in the 100-D Area, and 100HR-1 and 100HR-2 in the 100-H Area). This calculation is performed with models implemented in the STOMP (Subsurface Transport Over Multiple Phases) fate and transport simulation software (PNNL-11216, *STOMP Subsurface Transport Over Multiple Phases: Application Guide*; PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases: Theory Guide*; PNNL-15782, *STOMP Subsurface Transport Over Multiple Phases: Version 4.0: User's Guide*). This calculation follows the approach set forth in DOE/RL-2011-50, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection.* Detailed information on the development and basis of the models implemented in STOMP for this calculation is provided in SGW-50776, *Model Package Report: Vadose Zone Model for the River Corridor.*

SSLs are used in a screening step to identify areas needing further investigation. PRGs represent soil concentration or radionuclide activity that can remain in the vadose zone at a site without causing an exceedance of groundwater, or surface water, quality standards. Based on numerical flow and solute transport simulations developed using a number of bounding assumptions, SSLs and PRGs specific to the 100-D and 100-H source OUs were calculated for 187 non-radionuclides and 25 radionuclides in groundwater and 187 non-radionuclides in surface water (specifically, the Columbia River). The approach used here is to calculate SSLs in the same manner as PRGs, with the difference being that SSLs are calculated using high recharge rates for an irrigated farming scenario (recognizing this is not the planned land use for these OUs), while PRGs are calculated using low recharge rates for planned land use of conservation with native vegetation scenario. This approach honors the primary importance of recharge as parameter influencing breakthrough rates for vadose zone contamination into groundwater, and uses irrigation-based recharge rates to provide an upper bound on this parameter for screening purposes. The SSL and PRG values produced in this calculation are only applicable to the specified OU for those waste sites where the assumptions and conditions described in this ECF are representative.

Conceptual and numerical models of flow and solute transport under variably saturated conditions were developed for conditions representative of the lithology and hydrology observed at waste sites within the 100-D and 100-H source OUs. Conditions specific to the 100 Area, or to the 100-D and 100-H source OUs, include time-varying recharge rates specific to the 100 Area, OU-specific vadose zone thickness and lithology, area-specific hydraulic properties, and OU-specific aquifer fluxes. The numerical modeling implementing the conceptual model is developed assuming aqueous-phase water flow and solute transport under variably saturated conditions follow the Richards equation (termed the water mass conservation equation in STOMP) and the advection-dispersion equation (termed the solute mass conservation equation in STOMP) with radioactive decay and linear sorption and no volatilization or hydrodynamic dispersion.

Contaminant migration from waste sites in the 100-D and 100-H areas through the vadose zone to the underlying aquifer is controlled by the driving forces, interactions between water and sediments, and interactions between the contaminants and the sediments. The hydraulic driving forces include gravity; matric potential gradients; recharge, which is the end result of competition between precipitation, evaporation, transpiration, infiltration, run-off, and run-on; and man-made discharges, such as those from septic tank leach fields, ponds, lagoons, pipe and tank leaks, and irrigation. The types, thicknesses, and properties of the sediments can all affect the rate and direction of solute and water movement to the aquifer. The concentration of a contaminant in the groundwater (and in the downgradient Columbia River) are dependent on the solute flux from the vadose zone; aquifer thickness, hydraulic properties of

vadose zone and aquifer sediments, flux rates; travel distance; groundwater and river water mixing; and the location sampled. Each contaminant's propensity to sorb to vadose zone or aquifer materials can also be important controlling factors on the groundwater concentration determination.

The STOMP-W (water) operational mode of the STOMP software code was used to implement the model for this calculation. The STOMP-W (water) operational model solves the Richards equation (termed the water mass conservation equation in STOMP, which for water phase only reduces to the Richards equation) and the advection-dispersion equation (termed the solute mass conservation equation in STOMP) for dilute solute transport in the aqueous phase under variably saturated conditions in porous media. Volatilization and gas phase transport is conservatively neglected in this calculation to maximize the peak groundwater concentration predicted by the model. The governing equations and constitutive relationships solved by the STOMP code are presented in PNNL-12030. The STOMP numerical simulations provided predictions of groundwater concentration and the time of the peak groundwater concentration for a list of contaminants based on a range of recharge rates, sediment types, vadose-zone thicknesses, and properties appropriate to the 100-D and 100-H source areas. The peak concentration within 1000 years was used in SSL and PRG value calculation. The 1000-year timeframe was based on regulatory agreement.

2 Methodology

One-dimensional numerical fate and transport simulations were used to calculate SSL and PRG values for the 100 Area's 100-D and 100-H source OUs. The STOMP code was selected to perform the simulations on the basis of its ability to adequately simulate the vadose zone features, events, and processes (FEPs) relevant to calculating PRGs in the 100-Area, and to satisfy the other code criteria and attributes identified in DOE/RL-2011-50. DOE/RL-2011-50 describes the approach and provides the regulatory basis for using STOMP for this type of evaluation. Detailed information on the development and basis of the models used in this calculation are provided in SGW-50776.

The methodology described here constitutes the use of an alternative fate and transport model as defined in the Washington Administrative Code (WAC), WAC 173-340-747 (Deriving soil concentrations for groundwater protection). A crosswalk is provided in Attachment A of this ECF that demonstrates how this methodology meets the pertinent requirements of WAC 173-340-747.

Many of the methodologies, model inputs, and assumptions for computing PRGs were developed to determine remedial action goals (RAGs) as part of DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*. Although the calculation methods are similar, the RAGs were calculated with the RESRAD (RESidual RADiation) model (ANL/EAD-4, *User's Manual for RESRAD Version 6*) and the PRGs in this calculation were calculated with STOMP.

2.1 Definition of Soil Screening Levels and Preliminary Remediation Goals

SSLs are risk-based concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data (EPA/540/F095/041, *Soil Screening Guidance: Fact Sheet*). EPA provides a methodology for calculation of risk-based, site-specific SSLs for contaminants in soil that may be used to identify areas needing further investigation at National Priorities List sites. The approach used here is to calculate SSLs in the same manner as PRGs (see below), with the only difference in the calculation being the recharge rates used to represent future conditions: PRGs are calculated based on native vegetation recharge rates, whereas SSLs are calculated based on higher recharge rates for an irrigated farming scenario. This approach recognizes the primary importance of recharge as parameter

influencing breakthrough rates for vadose zone contamination into groundwater, and uses the irrigation based recharge rates as an upper bound on this parameter for screening purposes.

PRGs represent the maximum quantity, whether soil concentration or radionuclide activity, of a contaminant of potential concern (COPC) that can remain in the vadose zone without causing an exceedance of applicable regulatory standards. PRGs (and SSLs) can be defined for protection of groundwater or protection of surface water simply by the choice of the applicable standard used in the calculation. The PRG calculation is based on the predicted peak release of a given COPC under the native vegetation recharge scenario (Section 3.2.1.1) while the SSL calculation is based on a higher recharge (bounding condition) irrigation recharge scenario (Section 3.2.1.2).The value of a PRG or SSL for any particular COPC depends on a number of key factors, including:

- Waste site characteristics, specifically, source mass distribution and distance to the water table
- Land cover condition and the associated net recharge rate
- Interactions between the vadose zone geology and water movement
- Interactions between the vadose zone geology and contaminant chemistry

Model simulations were carried out for the non-radionuclide COPCs identified in ECF-Hanford-12-0023, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*. SSL and PRG values protective of groundwater were calculated for all of these COPCs (non-radionuclide and radionuclide), and SSL and PRG values protective of surface water were calculated for all non-radionuclide COPCs.

2.2 Identification of Representative Stratigraphic Columns

Borehole data were used to identify representative stratigraphic columns for each source area. Two lithologic units are present in the vadose zone in the 100-D and 100-H source areas. These are the gravel-dominated Hanford formation and the Ringold Formation's E unit. The Ringold Formation's E unit contains a slightly smaller percentage of coarse-grained sediments and a higher percentage of finer-grained sediments than the Hanford formation (SGW-40781, *100-HR-3 Remedial Process Optimization Modeling Data Package,* SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*).

The water table elevations of June 2008 were selected to provide representative (not extreme) high water table conditions; the month of June is typically when the highest river stages occur in this reach of the Columbia River. Use of water table elevations from the high water stage period (represented by June 2008 data) result in a conservative (smaller) thickness of the vadose zone for each well and borehole to develop the representative stratigraphic profiles. Imposing conservative bias towards a smaller thickness was made to reduce the travel distance for contaminants in the vadose zone, and thereby bias the resulting peak groundwater concentration calculated to arrive sooner and greater magnitude – resulting in more restrictive SSL and PRG values than otherwise. These well and borehole data were used to estimate the thicknesses of each lithologic unit in each source within vadose zone and aquifer sediments. The wells and boreholes were grouped based on the proportion of each lithologic unit present and total vadose zone thickness. A representative stratigraphic column was selected for each well and borehole group within each source area. This process resulted in the selection of six stratigraphic columns for 100-D, and two stratigraphic columns for 100-H to support model construction (see Section 3.1).

The representative stratigraphic columns include the upper 5 m of the unconfined aquifer, such that the water flux through this downgradient aquifer boundary of the model domain represents a 5-m monitoring

well screen. This is consistent with the requirements for aquifer mixing zone thickness in the WAC, specifically WAC 173-340-747[5][f][i], which specifies that the aquifer mixing zone thickness shall not exceed 5 m in depth. Aquifer dilution is thus directly simulated in the STOMP solution, based on the OU-specific hydraulic gradient imposed as a boundary condition across those 7nodes representing the aquifer portion of the representative stratigraphic column.

2.3 Calculation of Peak Groundwater Concentration within 1000 Years

STOMP is used to solve for water flow and contaminant transport in each of representative stratigraphic columns, under each recharge scenario (one for SSLs, one for PRGs; Section 3.1), for the appropriate initial uniform concentration of contaminant (Section 3.2.4), for each distribution coefficient (K_d) (Section 3.4), for a pair of sequential simulations. The first simulation in this sequential pair is of water flow only for historic recharge conditions, needed to obtain the soil moisture conditions throughout the model domain at the start time for the second simulation. The second simulation in the sequential pair is of water flow and contaminant transport for future recharge scenarios, starting from the imposed initial contaminant distribution and the initial soil moisture conditions provided by the first simulation. The second simulation provided groundwater concentrations in the aquifer flux exiting the model domain at the downgradient boundary for each representative stratigraphic column under each recharge scenario and for each distribution coefficient.

The peak groundwater concentrations within 1000 years was identified from the time series of solute concentrations in the water flux across the downgradient aquifer boundary (representing the 5 m monitoring well) reported by the STOMP code for each flow and transport simulation. The 1000-year timeframe for this calculation was based on regulatory agreement. The average concentration for the topmost 5 m was assumed representative of the groundwater concentration that would be measured within a 5-m long monitoring well screen that straddles the water table. Using the upper 5 m of the aquifer is consistent with the requirements for aquifer mixing zone thickness in WAC 173-340-747[5][f][i].

2.4 Point of Calculation, Point of Compliance, and Protectiveness Criteria

In accordance with risk assessment guidelines, the determination of soil contamination impacts to groundwater and surface water also requires the definition and rationale for (1) the point of calculation (POCal) i.e., the place/point in the groundwater domain where modeled groundwater concentrations are to be assessed for potential impacts and protectiveness (resulting from soil contamination at the point of compliance), and (2) the protectiveness metric, i.e., the groundwater and surface water metric(s) to be used in the assessment of protectiveness at the POCal (DOE/RL-2011-50).

The POCal for the protection of groundwater and surface water is related to the "exposure point" in the context of conventional human health risk assessments (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume 1, Human Health Evaluation Manual [Part A]*) in federal and state regulations and guidelines (DOE/RL-2011-50).

The "point of compliance" under the WAC is the soil throughout the vadose zone (WAC-173-340-740(6)(b)). The POCal is the point where the peak groundwater concentration resulting from the uniform initial soil concentration is calculated in the forward calculation. This peak groundwater concentration is then used to back-calculate the maximum allowable soil concentration at the point of compliance (all soil in the vadose zone) to determine the maximum soil contamination level that will not result in exceedance of groundwater or surface water protection levels.

For this calculation, the POCal is the outflow (downgradient) edge of the 1-D column for the grid blocks that are located in the topmost 5 m of the aquifer, representing the screened portion of a monitoring well.

The peak value of concentration within the topmost 5 m of the aquifer was scaled by the appropriate regulatory compliance criteria in a back-calculation step to determine SSL and PRG values for the point of compliance (vadose zone soil). The protectiveness criteria is the applicable water quality standards for groundwater and surface water (e.g., applicable regulations and requirements [ARARs], maximum contaminant levels [MCLs], or applicable water quality standards [AWQLs]) values for each contaminant. The applicable water quality standard for each contaminant for protectiveness of groundwater and surface water in the 100-D and 100-H Areas are listed in the tables of SSL values in Attachment B, and in the tables of PRG values in Attachment C, of this ECF.

2.5 Calculation of Soil Screening Level and Preliminary Remediation Goal Values

The calculation of peak values of groundwater concentration with STOMP provides the first, forward calculation step to deriving SSL and PRG values. Because STOMP was used in the forward calculation to compute peak groundwater concentrations that result from a unit initial source concentration (1.0 mg/kg soil concentration, uniformly applied over the assumed contaminated thickness of the vadose zone), the result can then be used in a second, back-calculation step to determine SSL and PRG values. The second, or back-calculation, step involves scaling the peak groundwater concentration against the appropriate regulatory compliance criteria to back-calculate the maximum initial soil concentration that would not result in an exceedance. The maximum value obtained from this back-calculation step is assigned as the SSL or PRG value (depending on the recharge scenario used). As a measure of maximum allowable contaminant concentration in the soil, SSLs and PRGs are expressed as contaminant mass per mass of soil for non-radionuclides (e.g., mg/kg) and as contaminant activity per mass of soil for radionuclides (e.g., pCi/g).

The SSL for each COPC is computed (in the back-calculation step) as:

$$\mathrm{SSL} = aC_I \frac{WQS}{CPK} \qquad \text{Equation 1}$$

where,

SSL = soil screening level, expressed in units of contaminant mass or activity per unit mass of soil

a = constant selected to balance units

C_I = initial soil concentration, expressed as contaminant mass or activity per unit mass of soil (note this an arbitrary initial concentration used in STOMP in the forward calculation, applied uniformly over the appropriate soil depth range – see Section 3.2.4)

WQS = water quality standard, expressed as contaminant mass or activity per unit volume of water

CPK = peak groundwater concentration, expressed as contaminant mass or activity per unit volume of water (note this is the resulting peak groundwater concentration obtained as a result from STOMP in the forward calculation, based on the initial soil concentration C_I)

For SSL calculations with Equation 1, the *CPK* value is obtained from STOMP simulations using the conservative irrigation recharge scenario (see Section 3.2.1.2).

Similarly, the PRG for each COPC is computed (in the back-calculation step) as:

$$\text{PRG} = aC_I \frac{WQS}{CPK} \qquad \text{Equation 2}$$

For PRG calculations with Equation 2, the *CPK* value is obtained from simulations using the native vegetation recharge scenario (see Section 3.2.1.1).

The surface water quality standards are used as WQS values to compute SSLs and PRGs protective of surface water, whereas the groundwater quality standards as WQS values to compute SSLs and PRGs protective of groundwater. As seen from Equation 1 and Equation 2, the calculation of SSL and PRG values is the same: the difference between these is only that the results of the bounding irrigation recharge scenario are applied to the SSL calculation while the results of the native vegetation scenario are applied to the PRG calculation. If a WQS was not available for a COPC, then the corresponding SSL or PRG values were encoded "NA" to signify that there was no applicable water quality standard available.

SSL and PRG values calculated using Equation 1 and Equation 2 are compared to upper and lower thresholds described in the subsections that follow; SSL and PRG values that exceed these thresholds are handled as described.

2.5.1 Lower Threshold of Numerical Significance for Peak Groundwater Concentrations

Breakthrough is assumed not to occur in cases where the simulated peak groundwater concentration within the 1000-year limit does not exceed 0.0001 μg/L for non-radionuclide COPCs and 0.0001 pCi/m^3 for radionuclide COPCs. This breakthrough threshold is used to set a minimum level of numerical significance for groundwater peak concentrations reported by the numerical model. Use values less than this breakthrough threshold would result in extremely high SSL or PRG values that would not constitute a meaningful limit on residual soil contamination. Consequently, where breakthrough does not occur under this assumption, the SSL or PRG value is encoded "NR" to signify a non-representative result.

2.5.2 Lower Threshold of Estimated Quantitation Limit for Soil Screening Levels and Preliminary Remediation Goals

If the SSL or PRG calculated for a given COPC is below the estimated quantitation limit (EQL) for the soil concentration of that COPC, then the EQL is substituted for the SSL or PRG value as a lower bound. The soil EQL represents the lowest concentration that can be reliably measured within specified limits of precision and accuracy during routine laboratory operating conditions. EQLs are normally arbitrarily set rather than explicitly determined; for this calculation, EQLs are those specified in Appendix A of DOE/RL-2009-40 Rev. 0, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*.

2.5.3 Upper Threshold of Pore Space Maximum Contaminant Mass Capacity for Non-radionuclide Soil Screening Level and Preliminary Remediation Goal Values

SSL and PRG values were calculated from the peak groundwater concentrations using Equation 1 and Equation 2, respectively, and the applicable surface water and groundwater regulatory standards. Where simulated peak groundwater concentrations were very small, application of Equation 1 and Equation 2 would yield physically unrealistic soil concentrations, e.g., 10 kg of aluminum per 1 kg of soil. Listing such unphysical protection levels is not meaningful, so an upper physical bound for SSL and PRG values is specified here that is derived based on considering the extreme of total contaminant mass that can occupy the soil pore space within a unit mass (1.0 kg) of bulk soil. The bulk density (ρ_b) of 100 Area soils is 1930 kg/m^3, so the total volume (V_T) of this soil (sum of soil and pore space) is calculated as

$$V_T = \frac{m_{soil}}{\rho_b} = \frac{1\ \text{kg}}{1930\,\frac{\text{kg}}{\text{m}^3}} = 5.18 \times 10^{-4}\ \text{m}^3$$

At maximum, COPC mass is assumed to occupy the total porosity fully. Therefore, the maximum mass of COPC in the soil is calculated as

$$m_{max,p} = n_T \times V_T \times \rho_p \qquad \text{Equation 3}$$

where n_T is the total porosity and ρ_p is the particle density of the COPC. In the 100 Area, the highest total porosity of Hanford or Ringold is 0.28. The particle density of the COPC is assumed equal the highest particle density of the Hanford or Ringold, which is 2680 kg/m^3 for the Hanford formation (PNNL-18564). Substituting into Equation 3, the maximum mass of COPC in 1.0 kg soil is then calculated as

$$m_{max,p} = (0.28) \times \left(5.18 \times 10^{-4}\ \text{m}^3\right) \times \left(2680\ \frac{\text{kg}}{\text{m}^3}\right) = 0.389\ \text{kg} \times \left(\frac{1{,}000{,}000\ \text{mg}}{1\ \text{kg}}\right)$$
$$= 389{,}000\ \text{mg}$$

Thus, the maximum screening or PRG value for non-radionuclides is 389,000 mg per kg of soil. Therefore, SSL or PRG values that exceed this physical upper bound are truncated at physical upper bound value 389,000 mg/kg. Note that this physical upper bound is not applied to radionuclide SSL or PRG values because these are expressed in terms of activity rather than mass.

A similar threshold was presented for maximum radioactivity in soil in SGW-50776. However, it was redundant to apply that limit here because a value for that would exceed that limit would also exceed the lower threshold of numerical significance for peak groundwater concentrations (Section 2.5.1).

2.5.4 Upper Threshold for Hexavalent Chromium Soil Screening Level and Preliminary Remediation Goal Values based on Limitation of Sorption Data

Hexavalent chromium soil concentrations for which the conservative-basis K_d was derived had a maximum value of 6.0 mg/kg (ECF-Hanford-11-0165 Rev. 1). Therefore, there is no basis to infer greater PRGs for Cr(VI) based on these data. Hence, SSL and PRG values calculated for hexavalent chromium using this K_d are limited (truncated) to a maximum value of 6.0 mg/kg.

3 Assumptions and Inputs

A pair of sequential STOMP simulations was used to determine peak groundwater concentrations. The first simulation, called the historic (pre-2010) simulation, simulated water flow in the representative stratigraphic columns for a 2010-year period ending in the calendar year 2010. The purpose of this first long simulation period was to first to achieve equilibrium (steady state) in the flow conditions and moisture content in the model domain at long-term native vegetation conditions (by simulating for an arbitrarily long time) and then simulate subsequent flow conditions and moisture content resulting from changes in surface conditions through calendar year 2010. Review of the matric potential and volumetric water content values at the end of the arbitrarily long period simulated with native vegetation recharge rates were checked to confirm that equilibrium (steady state) conditions had been attained, confirming that the arbitrary period chosen was sufficiently long. Results from the historic (pre-2010) simulations provided the initial aqueous pressure conditions (and hence moisture content distribution) for the second

simulation, called the predictive (post-2010) simulation. This second simulation solved for water flow and for contaminant transport for 1000 years, using the initial moisture conditions from the first simulation and a bounding assumption for the initial distribution of COPC contaminant mass or activity in the soil profile. The predictive (post-2010) simulation was repeated for each COPC, using the appropriate distribution coefficient (K_d) and half-life (where applicable, for radionuclides) to predict the peak groundwater concentrations of each COPC resulting from its assumed bounding initial contamination levels, and to determine the year of occurrence of that peak groundwater concentration.

STOMP estimates of contaminant concentration depend on the model assumptions and inputs. Inputs to the models and supporting assumptions are divided into the following categories for discussion:

- Model domain
- Boundary and initial conditions
- Hydraulic parameters
- Contaminant transport parameters
- Simulation duration
- Uncertainties, assumptions, and conservatism

Each of these input categories are discussed in the sub-sections that follow.

3.1 Model Domain

Conceptually, the model represents a column of sediments comprised of a vadose zone underlain by an aquifer. Recharge-driven flow moves downward through the vadose zone, where it encounters contamination that is eventually transported to an underlying aquifer, across which a pressure gradient drives horizontal flow. At the start of each predictive (post-2010) simulation, the vadose zone comprises a cover of clean fill with constant thickness as well as contaminated and uncontaminated sediments of varying thickness. The aquifer constitutes the base of the column with a minimum thickness of 5 m so that a 5-m-long monitoring well screen could be simulated. Depending on source-area-specific geology, the vadose zone comprises either Hanford formation alone or a combination of Hanford and Ringold E, whereas the saturated zone can comprise only Hanford, a combination of Hanford and Ringold E, or only Ringold E. If present, the contact between the Ringold E and the Ringold upper mud (RUM) forms the bottom of the aquifer.

The model represents the vadose zone as a vertical one-dimensional column of evenly spaced grid blocks, each containing a node at the centroid. In STOMP, boundary conditions are specified at the faces of the grid blocks, so each grid block is assigned an arbitrary but constant length to avoid large grid Courant numbers in the aquifer grid blocks during transport simulations. Each grid block is 0.25 m in height and 10 m in length. A length of 10 m was chosen to reduce the Courant number below 1.0 to reduce numerical dispersion. The Courant number represents a simple guideline for selecting grid element and time step size to limit numerical dispersion in advection dominated problems (Huyakorn and Pinder, 1983). In practice, the time step is easier to control in a simulation because the grid is fixed in advance. STOMP provides an automatic Courant limitation scheme that automatically subdivides transport solution time steps within flow-solution time steps to ensure that the Courant limit was maintained throughout the computational mesh for partially saturated nodes; this feature of STOMP was used in this calculation. Following the simulation, the contaminant aqueous concentration output was scaled back to 1.0-m length by dividing the aqueous concentrations by 10. The accuracy of this methodology was verified through

simulation with varying grid dimensions (details not presented here). Grid block Courant numbers for the aquifer grid blocks, in which flow is horizontal under fully saturated conditions, was all less 1.0. Grid block Courant numbers for the vadose zone grid blocks, in which flow is vertical under variably saturated conditions, were all less 1.0 for both recharge scenarios.

The total column thickness and the thickness of the vadose zone vary according to the geology of each source area. Only the thickness of the clean backfill was held constant at 4.5 m (note: an evaluation of the sensitivity of clean backfill thickness is provided in Section 6.2.1). Thickness of the vadose zone, thickness of the saturated zone (that is, the aquifer), and the percentages of the different lithologic units in each were determined using borehole data from the Hanford Environmental Information System (HEIS) borehole database (Table 1 and Table 2). A conservative (thinner) estimate of vadose zone thickness was calculated by taking the difference between ground surface elevation and the June 2008 water table elevation, which is representative of the seasonal high water table elevation (conservatism here is with respect to minimizing the vadose zone travel distance for contaminants).

Because of natural variability in the thickness of various hydrostratigraphic units, it is impractical to calculate SSL and PRG values for all possible variations in thicknesses observed in the various boreholes. Instead, representative stratigraphic columns were identified to provide a representative range of stratigraphic conditions in these source OUs. The representative stratigraphic columns were identified by collecting and reviewing geologic data from 86 boreholes nearest to the waste sites in each geographic area (18 of these in 100-D, and 17 in 100-H geographic areas). All borehole data were taken from the HEIS borehole database. The representative stratigraphic columns include geologic material in both the vadose zone and the unconfined aquifer. Using water table elevations representing the annually occurring highest water table, a minimum thickness of the vadose zone was computed for each borehole (minimum thickness is conservatively selected to reduce contaminant transport time, thereby biasing peak groundwater concentrations higher). The borehole data also provided estimates of the thicknesses of each lithologic unit within the vadose zone and within the aquifer. The boreholes were divided into groups based on the proportion of each lithologic unit and total vadose zone thickness. This process yielded representative stratigraphic columns for each source area (Figure 1) derived from the borehole data using vadose zone thickness and lithologic composition (Table 1 and Table 2). Boreholes from each source area were divided into groups that represent the range of vadose zone thicknesses and lithologic composition. The objective was to create a limited, practical number of representative stratigraphic columns for each source area so that the number of STOMP simulations would be reasonable, while capturing the range of variability throughout each area. This was accomplished by dividing the boreholes for each source area into groups based on a range of vadose zone-thickness intervals and then identifying one or more representative lithologic compositions. For example, 100-D boreholes can be divided into three groups according to vadose zone thickness: 25, 20, and 15 m, whereas the 100-H boreholes can be divided into two groups with 12 and 8 m thicknesses, respectively.

Examination of all wells within the 100-D 25-m-thickness group reveals a range of compositions for the vadose zone, but the 12 boreholes in this group can easily be divided into three sub-groups (Table 1):

- 100% Hanford formation
- 75% Hanford formation – 25% Ringold E unit
- 60% Hanford formation – 40% Ringold E unit

A 5-m thickness of the saturated zone (aquifer) was used in STOMP simulations in accordance with WAC 173-340-747(5)(f)(i) and equation 747-4 for A, aquifer mixing zone. Figure 1 shows the

representative stratigraphic columns at each source area. Each column was assumed to include clean backfill in the uppermost 4.5 m of the column, representing conditions following interim remediation.

STOMP's inactive nodes feature was not used for this model.

Table 1. Determination of Vadose Zone Thickness and Geology for Source Area D at 100 Area

Representative Column Index	Representative Vadose Zone Thickness (m)	Representative Vadose Zone Composition	Thickness of Hanford in Vadose Zone (m)	Thickness of Ringold E in Vadose Zone (m)	Corresponding Wells	Actual Vadose Zone Composition	Actual Vadose Zone Thickness (m)	Actual Saturated Zone (Aquifer) Thickness (m)	Assigned Saturated Zone (Aquifer) Thickness (m)	Saturated Zone (Aquifer) Composition
100-D Column 1	25	100% Hanford	25	0	199-D4-83	100% Hanford	24.32	5.25	5	100% Hanford
					199-D5-17		25.40	6.15		
					199-D5-97		25.81	7.41		
					199-D5-99		26.09	7.29		
					199-D8-4		25.21	6.31		
100-D Column 2	20	100% Hanford	20	0	199-D2-5	100% Hanford	22.64	4.80	5	100% Hanford
					199-D8-97		23.14	5.06		
					199-D8-98		20.37	5.53		
100-D Column 3	25	75% Hanford 25% Ringold E	18.75	6.25	199-D4-101	76% Hanford 24% Ringold E	25.35	6.66	5	100% Ringold E
					199-D5-103	83% Hanford 17% Ringold E	25.69	8.05		
100-D Column 4	20	80% Hanford 20% Ringold E	16	4	199-D8-89	80% Hanford 20% Ringold E	19.76	4.01	5	100% Ringold E
100-D Column 5	25	60% Hanford 40% Ringold E	15	10	199-D4-25	63% Hanford 37% Ringold E	24.79	6.15	5	100% Ringold E
					199-D5-12	59% Hanford 41% Ringold E	25.96	1.17		
					199-D5-120	63% Hanford 37% Ringold E	25.76	7.16		
					199-D5-19	63% Hanford 37% Ringold E	24.14	4.66		
					199-D5-34	62% Hanford 38% Ringold E	26.60	5.40		
100-D Column 6	15	60% Hanford 40% Ringold E	9	6	199-D8-54B	63% Hanford 37% Ringold E	16.82	6.35	5	100% Ringold E
					199-D8-55	55% Hanford 45% Ringold E	16.70	4.33		

Table 2. Determination of Vadose Zone Thickness and Geology for Source Area H at 100 Area

Representative Column Index	Representative Vadose Zone Thickness (m)	Representative Vadose Zone Composition	Thickness of Hanford in Vadose Zone (m)	Thickness of Ringold E in Vadose Zone (m)	Corresponding Wells	Actual Vadose Zone Composition	Actual Vadose Zone Thickness (m)	Actual Saturated Zone (Aquifer) Thickness (m)	Applied Saturated Zone (Aquifer) Thickness (m)	Saturated Zone (Aquifer) Composition
100-H Column 1	12	100% Hanford	12	0	199-H3-1	100% Hanford	12.90	4.17	5	100% Hanford
					199-H3-25		11.31	5.75		
					199-H3-2A		11.39	5.37		
					199-H3-2B		11.26	6.11		
					199-H3-2C		11.36	5.40		
					199-H4-1		11.62	6.14		
					199-H4-11		10.82	7.16		
					199-H4-14		11.42	6.56		
					199-H4-2		11.66	8.15		
					199-H4-46		13.07	5.53		
					199-H4-49		13.36	3.40		
					199-H4-69		12.53	5.75		
					199-H4-70		12.97	4.10		
					199-H4-72		11.90	5.17		
					199-H4-9		11.34	2.83		
					199-H6-2		12.92	2.32		
100-H Column 2	8	100% Hanford	8	0	699-99-41	100% Hanford	8.35	3.84	5	100% Hanford

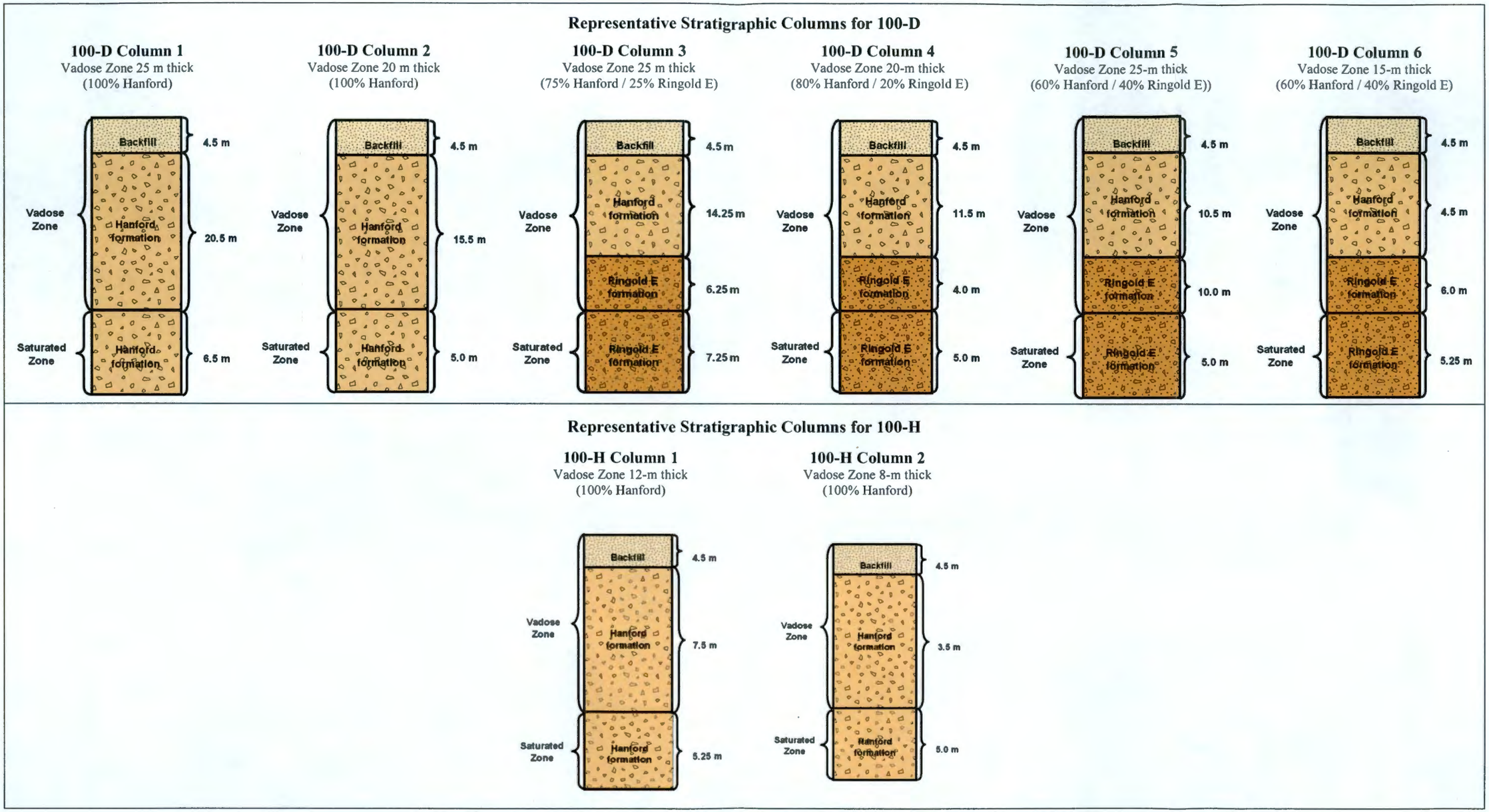

Figure 1. Representative Stratigraphic Columns for 100 D and 100-H Source Areas

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3.2 Boundary and Initial Conditions

Solving the governing equations for variably saturated flow and transport requires stipulation of boundary and initial conditions. A complete set of boundary and initial conditions must be stipulated for each governing equation for input to STOMP. The boundary condition specifications for this model discussed in this section are graphically summarized in Figure 2.

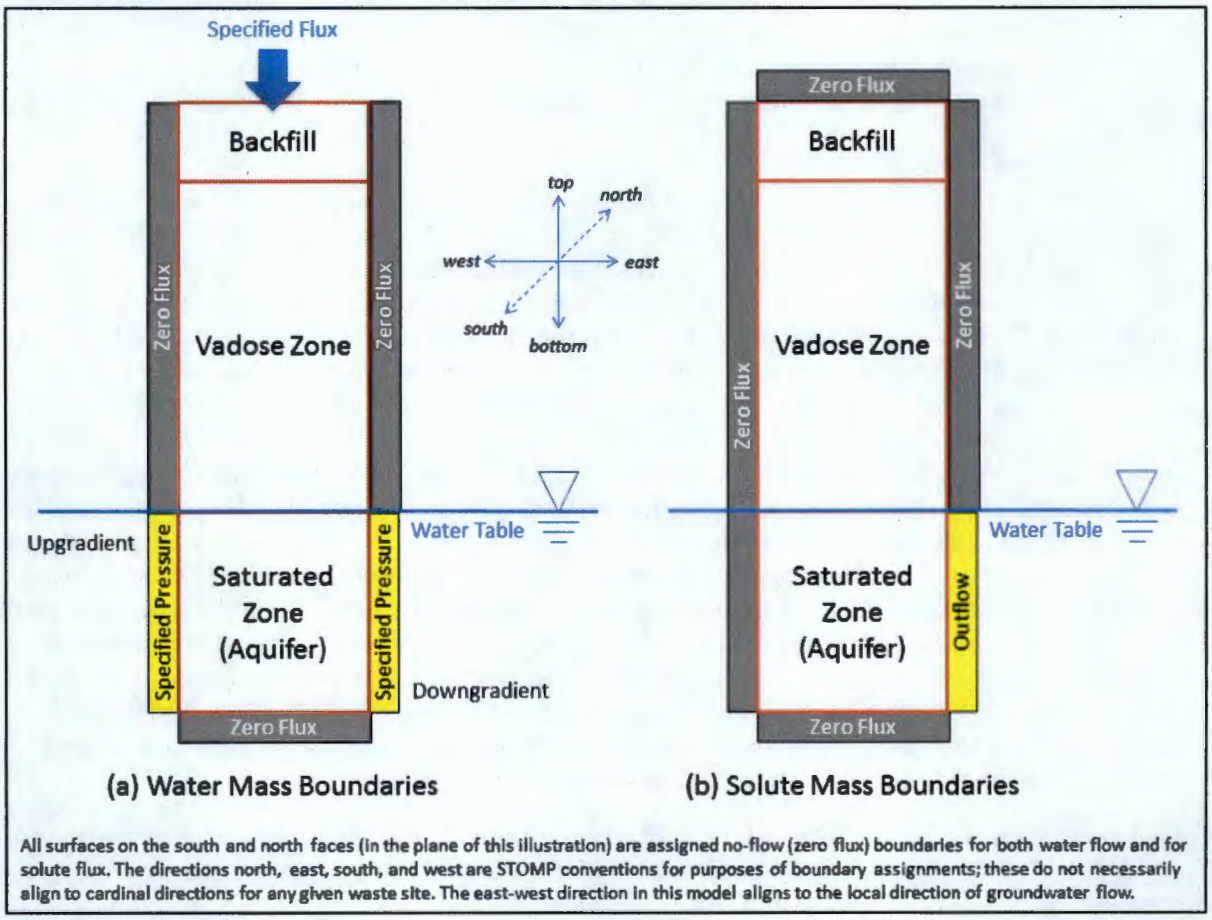


Figure 2. Boundary Conditions for (a) Water Mass and (b) Solute Mass Conservation Equations

For the water mass conservation equation, flow boundary conditions were specified to represent one-dimensional vertical flow in vadose zone resulting from recharge through the top boundary, and lateral flow in the saturated zone in response to the hydraulic gradient. A Neumann-type (specified flux) boundary condition was applied at the top surface to simulate effective recharge; the flux rate was varied, stepwise constant, to represent different recharge rates over time. Neumann-type boundary conditions with no flow (zero flux) were assigned to all the vertical boundaries (east, west, south, and north) of the vadose zone to maintain one-dimensional, vertical flow. The bottom boundary of the model domain was assigned a Neumann-type boundary condition with no-flow (zero flux) to constrain the aquifer to a 5-m thickness (Figure 2a). The east and west boundaries of the saturated zone portion of the domain was assigned a hydraulic gradient boundary condition to maintain the specified lateral flow rate in the aquifer, while the north and south boundaries were assigned Neumann-type boundary conditions with no flow (zero flux) to constrain the aquifer flow to a one horizontal direction. Note here that in discussing lateral boundaries, the directions east, west, north, and south are conventions used in the STOMP code. For this

model, these direction references do not (necessarily) align to cardinal directions for any given actual waste site. Rather, the east-west dimension in this STOMP representation is intended to represent (align to) the direction of groundwater flow for any waste site.

For the solute mass conservation equation, specified zero-flux boundaries were applied at the top of the model domain, along both edges of the vadose zone, along the upgradient edges of the aquifer grid blocks, and the bottom of the aquifer (Figure 2b). The downgradient edges of the aquifer grid blocks were assigned STOMP's outflow solute type boundary condition (see page 6.21 of PNNL-12030, and page 4.4 of PNNL-15782), which transports solute mass out of the domain according to the advective flux term in the solute mass conservation governing equation but does not allow solute to enter back into the domain.

3.2.1 Upper Boundary Conditions

For water flow, a time-varying Neumann-type (specified water flux) boundary condition was applied at the top surface (Figure 2a) to represent net infiltration (destined to become recharge). The net infiltration into the vadose zone, which is used in the model to represent the recharge into the aquifer, is driven by the competition between precipitation (including snow), potential evaporation, transpiration, run-off and run-on. In an arid or semi-arid climate, the net downward flux that results from these fluxes are episodic and usually infrequent. This effect is typically damped towards a nearly constant rate with increasing depth, however, as soil moisture variability with depth measured at Hanford Site lysimeters shows (PNNL-17841, *Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates*). This is the basis for representing recharge in the vadose zone model using a constant rate applicable to a given soil type and vegetation cover (DOE/RL-2011-50). A number of studies have been carried out at the Hanford Site to ascertain representative long-term averages of the episodic fluxes, i.e., recharge rates, such as those compiled by Pacific Northwest National Laboratory (PNNL) in PNNL-14702 Rev. 1, *Vadose Zone Hydrology Data Package for Hanford Assessments*) for the 100 Areas. The 100 Area specific recharge rates reported in PNNL-14702 Rev. 1 vary with surface soil type, providing an estimate of the range of possible recharge rates for various land uses. The three surface soil types were the Ephrata sandy loam or stony loam, Burbank sandy loam and Rupert sand. Additionally, PNNL-14702 Rev. 1 also provides recharge rates for disturbed soil conditions: the disturbed soil rates were selected for use in calculation of SSLs and PRGs for the 100-D and 100-H source OUs.

Each calculation of a SSL or PRG with STOMP requires a pair of simulations; the first is a simulation of water flow only for historic recharge conditions, needed to obtain the soil moisture conditions throughout the model domain at the start time for the second simulation. The second is a coupled simulation of water flow and contaminant transport, starting from the assumed initial contaminant distribution (100:0 or 70:30 models) and the initial moisture distribution provided by the first simulation. Calendar year 2010 was set as the time when the first, historic (pre-2010) simulation ends and the second, predictive (post-2010) simulation begins. Recharge rates were conservatively simulated in STOMP as a specified flux boundary condition applied to the top boundary of the model (Figure 2a) for each recharge scenario and each soil type. Rates were assumed to change over time in step function-fashion for each recharge scenario.

For the historic (pre-2010) simulations, land use and recharge rates were assumed to transition from native vegetation (mature shrub-steppe) during pre-settlement conditions, to a historic irrigation period for 1880 to 1944, to a Hanford Site operational period with bare soil from 1944 to 2010. The pre-settlement phase was assumed to begin in calendar year 0, an arbitrary date that was selected merely to ensure steady-state moisture conditions are achieved in the solution for the applicable recharge rate by the 1880 year of transition to historic irrigation (1880). Historic irrigation is included in the historic period because multiple land areas in the 100-D and 100-H area were used for irrigated agriculture prior to construction of the Hanford Site. The historic irrigation period is conservatively assumed to commence in 1880, and is further conservatively assumed applicable to all waste sites in the 100-D and 100-H source

OUs. The Hanford Site operational period is conservatively assumed to consist of bare soil conditions, maintained vegetation free, for all waste sites. The recharge rates for each historic phase (pre-settlement with native vegetation, historic irrigation, Hanford operations) are applied to the top boundary as a constant rate within each phase.

For the predictive simulations (post-2010), two different recharge scenarios were evaluated, representing different future land uses. The native vegetation recharge scenario represents DOE's planned land use with restoration and maintenance of a native shrub-steppe plant community. The irrigation recharge scenario represents a bounding condition of irrigated agriculture.

For solute transport, specified zero-flux boundaries were applied at the top of the model domain, along both edges of the vadose zone, along the upgradient edges of the aquifer grid blocks, and the bottom of the aquifer (Figure 2b). The downgradient edges of the aquifer grid blocks were assigned STOMP's outflow solute boundary condition (see page 6.21 of PNNL-12030, and also page 4.4 of PNNL-15782), which transports solute out of the domain according to the advective flux term in the governing equation and does not allow solute to enter back into the domain (Figure 2b).

3.2.1.1 Native Vegetation Recharge Scenario

The native vegetation recharge scenario (Table 3; Figure 3) is used for calculation of PRG values. This recharge scenario represents DOE's planned land use with restoration and maintenance of a native shrub-steppe plant community. The scenario is comprised of three historic phases discussed previously and four future phases that represent recharge rates changes corresponding to postulated future land use/cover transitions. The first future phase (2010 to 2015) represents the period of continued bare soil cover. The second future phase (2015 to 2020) represents an invasive cheatgrass cover. The third phase represents grasses and developing shrubs as vegetation matures during a 30-year transition (transition period duration from DOE/RL-2011-50). The final phase is mature shrub steppe that lasts for the remainder of the simulation. Recharge rates diminish in each successive phase for this scenario. Revegetation of waste sites following remediation is assumed in this scenario, consistent with revegetation that is occurring in the 100 Areas accordance with the *Hanford Biological Resources Management Plan* (DOE/RL-96-32 Rev. 1). Revegetation has been successfully conducted in the 100 Area following other remediation activities (for examples, refer to annual issues of the *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*, including WCH-299 (2008), WCH-362 (2009), WCH-428 (2010), WCH-512 (2011), and WCH-554 (2012).

3.2.1.2 Irrigation Recharge Scenario

The irrigation recharge scenario (Table 4; Figure 4) is used for calculation of SSL values. This recharge scenario represents an upper bound based on recharge rates from irrigated agriculture land use. This recharge scenario is comprised of transition from bare soil conditions to long-term irrigation farming. Although this recharge scenario is inconsistent with DOE land use plans, it is used here to represent an upper bound on recharge rates for screening purposes. The bounding nature of this recharge scenario is reinforced further by the assumption that irrigated agriculture commences five years in the future, much sooner than is reasonable given that Hanford Site remediation activities are expected to continue for decades to come and constrain land use accordingly.

Table 3. Native Vegetation Recharge Scenario Phases and Recharge Rates (mm/yr)

	Historic Simulation (pre-2010) (calculation of initial hydraulic conditions)			Predictive Simulation (post-2010) (calculation of peak groundwater concentration)			
Surface Soil Type	Pre-Settlement (< 1880)	Historic Irrigation [a] (1880-1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Cheatgrass (2015-2020)	Developing Shrub-Steppe (2020-2050)	Mature Shrub-Steppe (2050 >)
Hanford sand, disturbed	4.0 [b]	72.4 [c]	63.0 [d]	63.0 [d]	31.5 [e]	8.0 [f]	4.0 [g]

a. Irrigated agriculture was prevalent in the100-D/H Area prior to Hanford Site construction; irrigation therefore was conservatively assumed applicable to all 100-D/H sites from calendar years 1880 through 1944.

b. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; shrub steppe.

c. Recharge rates for historic irrigation phase is that from the long-term irrigation rate (Irrigation II) under the irrigation recharge scenario (Table 4).

d. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; no vegetation.

e. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; cheatgrass.

f. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; young shrub steppe.

g. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; shrub steppe.

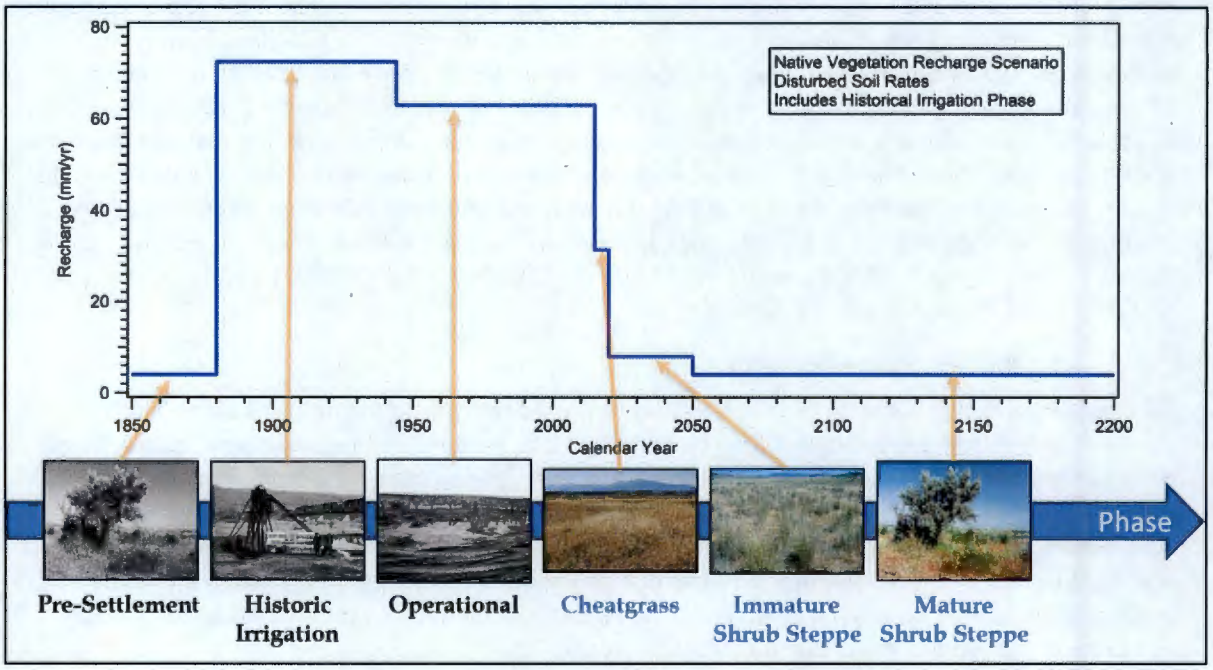


Figure 3. Native Vegetation Recharge Scenario

Recharge rates for the irrigation phases of this recharge scenario were estimated using the same approach used to assess interim remediation at 100 Area waste sites (DOE/RL-96-17 Rev. 6) following Washington Department of Health guidance (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). These previous site assessments used Remedial Action Goals (RAGs) calculated from RESRAD simulations that assumed total recharge was a combination of irrigation and native vegetation (base case) recharge scenario rates. As the base case rates used in the RESRAD simulations were differ from those adopted for the native vegetation recharge scenario (from PNNL-14702 Rev. 1), the RESRAD equation for total recharge was back-solved to ascertain the recharge rate attributable to irrigation alone.

According to the RESRAD manual, total recharge rate is a function of precipitation, evapotranspiration, run-off, and applied irrigation and is defined as:

$$I = (1 - C_e)[(1 - C_r)P_r + I_{rr}] \qquad \text{Equation 4}$$

where I = annual recharge rate (LT^{-1}), C_e = evapotranspiration coefficient (dimensionless), C_r = runoff coefficient (dimensionless), P_r = annual precipitation rate (LT^{-1}), and I_{rr} = annual irrigation rate (LT^{-1}). Using Equation 4 with the DOE/RL-96-17 Rev. 6 RESRAD values for these parameters, $C_e = 0.91$, $C_r = 0.2$, $P_r = 0.16$ m/yr, and $I_{rr} = 0.76$ m/yr, yielded a total recharge rate of 80 mm/yr. Solving Equation 4 again with $I_{rr} = 0$ yielded the non-irrigation total recharge rate of 11.6 mm/yr. Therefore, the recharge attributable to irrigation alone was 68.4 mm/yr. This rate was then added to the native vegetation recharge rates for undisturbed soils to determine a rate for the irrigation phases (Table 4).

3.2.2 Lower Boundary Conditions

The bottom of the model domain is assigned a constant zero-flux boundary condition for both water mass and contaminant mass (solute) transport (Figure 2). This boundary condition limits the aquifer representation in this model to the appropriate thickness.

3.2.3 Lateral Boundary Conditions

For the portion of the model domain in the vadose zone (Figure 2a), a constant zero-flux boundary condition for both water transport and solute transport is assigned to restrict (with respect to arrival time of peak solute concentration and peak magnitude) the representation in the vadose zone to one-dimensional vertical flow. This is a conservative representation with respect to the arrival time and the magnitude of the peak concentration.

For the portion of the model domain in the saturated zone (aquifer; refer to Figure 2a), a constant Dirichlet type (specified head) boundary condition is specified for water transport at opposite edges aligned to the hydraulic gradient to represent the water table at the desired elevation and impose the desired hydraulic gradient. The hydraulic gradients used for the simulations were based on Automated Water Level Network (AWLN) data obtained from HEIS. Hydraulic head data from 2004 to present were used to calculate the hydraulic gradient for the 100-D and 100-H areas. Triangulated irregular networks (TINs) were fitted to the wells using ArcGIS®[1] and hydraulic gradients were computed for each TIN (Table 5). The gradient magnitudes typically varied across two or more orders of magnitude, so the median, a measure of the central tendency of the computed gradients, was selected as a representative value, yielding hydraulic gradients of 0.0014 m/m for 100-D and 0.0035 m/m for 100-H. The details on the hydraulic gradient calculation are reported in ECF-Hanford-14-0028, *Median Hydraulic Gradient Calculation to Support Development of Soil Screening Levels and Preliminary Remediation Goals in the*

[1] ArcGIS is a registered trademark of registered trademarks, or service marks of ESRI in the United States, the European Community, or certain other jurisdictions.

100 Area. Note the median gradients were less than the arithmetic average, leading to less dilution in groundwater than if arithmetic average gradients were used.

Table 4. Irrigation Recharge Scenario Phases and Recharge Rates (mm/yr)

Surface Soil Type	Historic Simulation (pre-2010) (calculation of initial hydraulic conditions)			Predictive Simulation (post-2010) (calculation of peak groundwater concentration)		
	Pre-Settlement (< 1880)	Historic Irrigation [a] (1880-1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Irrigation I (2015-2045)	Irrigation II (2045 >)
Hanford sand, disturbed	4.0 [b]	72.4 [c]	63.0 [d]	63.0 [d]	76.4 [e]	72.4 [e]

a. Irrigated agriculture was prevalent in the100-D/H Area prior to Hanford Site construction; irrigation therefore was conservatively assumed applicable to all 100-D/H sites from calendar years 1880 through 1944.

b. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; shrub steppe.

c. Recharge rates for historic irrigation phase is that from the long-term irrigation rate (Irrigation II phase).

d. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; no vegetation.

e. Recharge rates for future irrigation phases represent incremental increases over corresponding undisturbed native vegetation recharge rates, based on WDOH guidance (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). The recharge increment attributable to irrigation alone is 68.4 mm/yr. This increment is added to the corresponding rate for immature shrub steppe (8.0 mm/yr) and mature shrub steppe (4.0 mm/yr) phases of the native vegetation recharge scenario (Table 3) to obtain the total recharge rate.

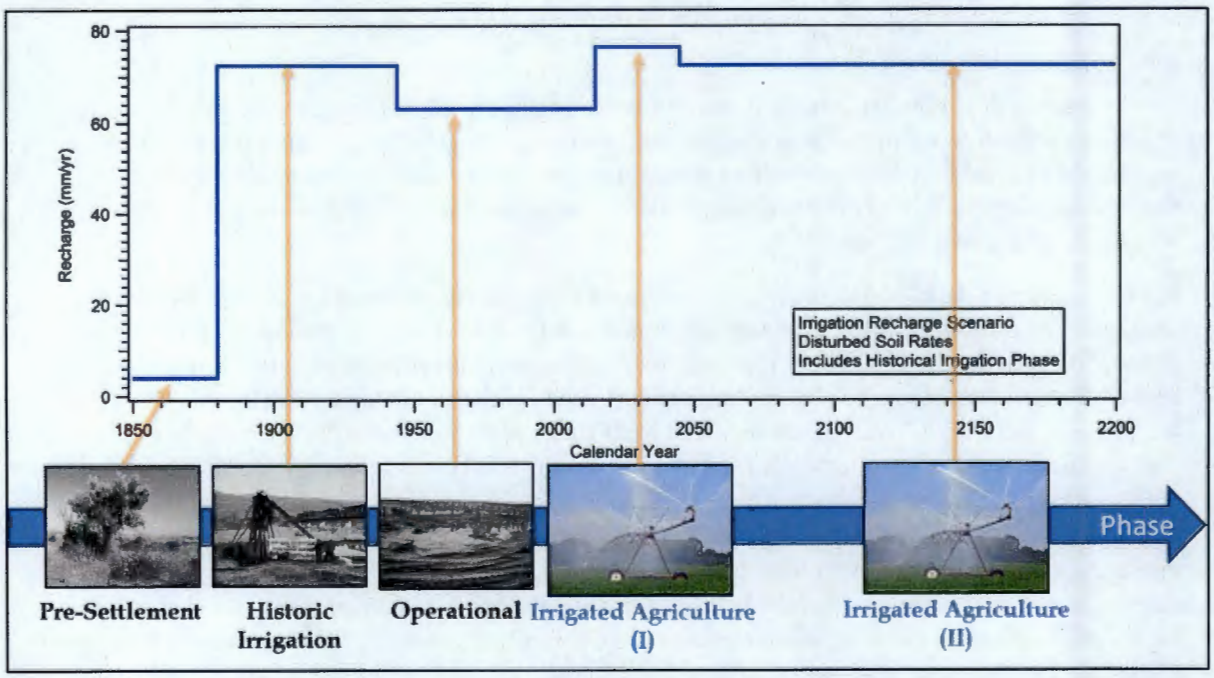


Figure 4. Irrigation Recharge Scenario

Aquifer conditions are dynamic in the 100 Area; the hydraulic gradient, thickness, and in many cases direction of flow vary throughout the year. The use of median gradients is intended to provide a broadly representative value for use in calculation of SSLs and PRGs that will be applicable for the range of locations in each geographic area. This gradient is applied to a model stratigraphy that is based on high-river stage conditions for the purpose of minimizing the vadose zone thickness as a bounding condition to bound (minimize) transport time.

Table 5. Hydraulic Gradients for 100-D and 100-H

Source Area	Number of Triangular Irregular Networks [a]	Hydraulic Gradient (m/m) [a]			
		Minimum	Maximum	Median	Arithmetic Average
100-D	28	0.00016	0.03730	0.00140	0.00234
100-H	19	0.00110	0.00856	0.00350	0.00365

a. Source: ECF-HANFORD-14-0028, *Median Hydraulic Gradient Calculation to Support Development of Soil Screening Levels and Preliminary Remediation Goals in the 100 Area.*

Three representative stratigraphic columns have that include aquifer thicknesses slightly less than 5 m: 100-D Column 5 (Table 1) and 100-H Column 2 (Table 2). It is the aquifer flow rate, rather the aquifer thickness, which determines the dilution rate for vadose zone releases. The aquifer flow rate is determined according to Q=KAI, where Q is aquifer flux, K is aquifer conductivity, A is the area perpendicular to flow, and I is the groundwater gradient. Areas for which the representative columns with less than 5-m aquifer thicknesses are representative are subject to the same aquifer flow rate as for upstream locations with greater aquifer thicknesses. Hence, the local hydraulic gradient at these locations must increase in order to maintain the same flux rate through the aquifer as the thickness diminishes. Thus, groundwater dilution rates are similar because the flux is similar. To evaluate this effect in a model would require a more sophisticated modeling effort to apply local hydraulic gradients with seasonal variability, along with seasonally variable aquifer thicknesses, to determine PRGs and SSLs on a waste site by waste site basis. Such refinement is deemed unnecessary to meet the modeling objectives to provide bounding values for SSLs and PRGs; the use of a slightly thicker than actual aquifer (5-m) for these representative stratigraphic columns is offset by the use of the median hydraulic gradient that is lower than it would be for the locations with thinner aquifers.

For solute transport, the upgradient edge of the portion of the model domain in the aquifer and all edges of the model domain in the vadose zone portion of the model domain are assigned zero-flux boundary conditions (Figure 2b). The downgradient edges (Figure 2b) of the aquifer grid blocks were assigned STOMP's outflow solute boundary condition (see page 6.21 of PNNL-12030 and page 4.4 of PNNL-15782). This boundary condition provides for transport of solute out of the domain according to the advective flux term in the governing equation, but does not allow solute to enter back into the domain.

3.2.4 Initial Conditions

For hydraulic initial conditions, an arbitrary value was assigned as the initial pressure for the historic (pre-2010) flow simulations. A value of 86,656.7 Pa, approximately equivalent to –1.5 m matric potential, was assigned to the nodes in the vadose zone whereas the aquifer grid blocks were assigned values that matched the boundary condition pressures. Final pressures from the historic (pre-2010) simulations were used as the initial pressures for the predictive (post-2010) coupled flow and transport simulations.

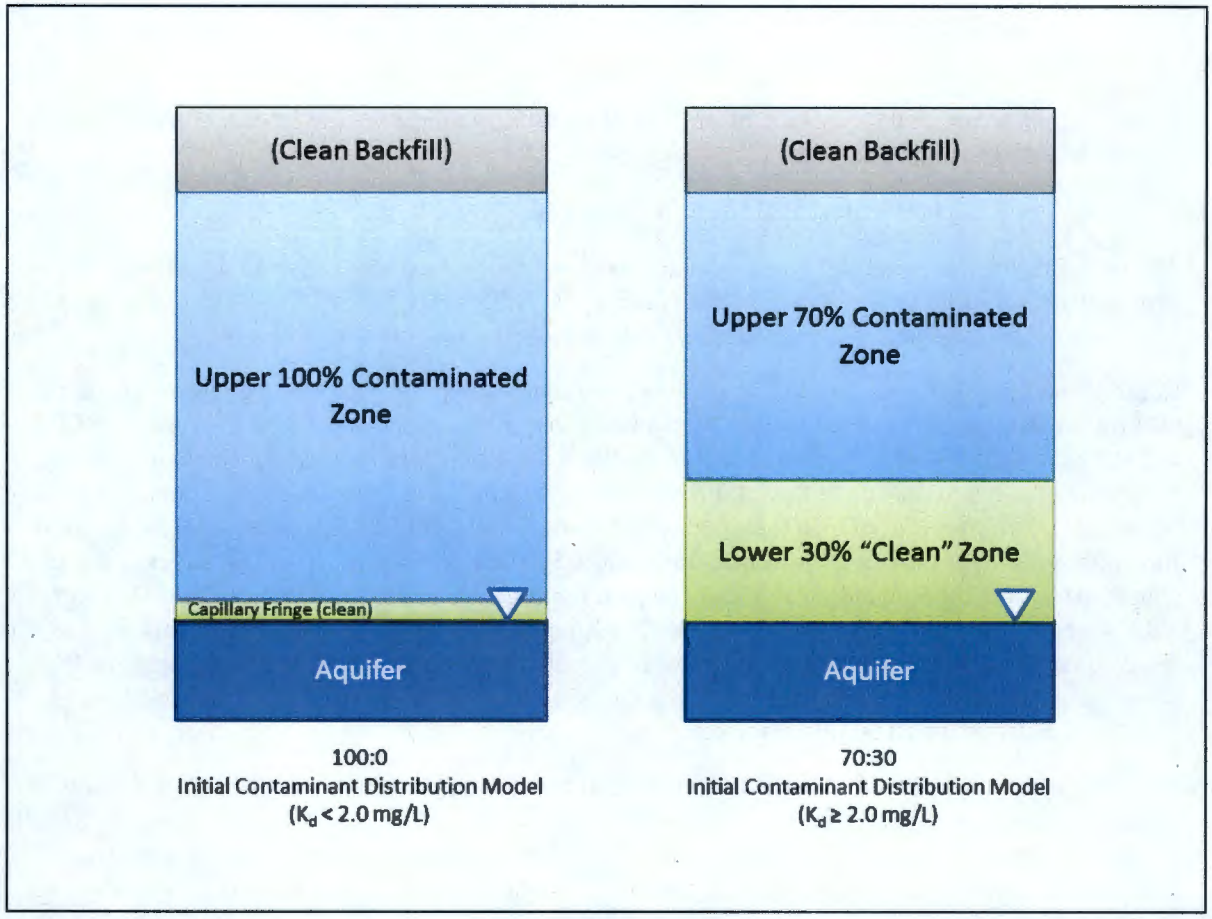
Contaminant initial conditions are imposed based on the objective and methodology of the calculation. Determination of SSL and PRG values is accomplished in a two-step calculation process: first, STOMP is used in a forward calculation step to calculate peak groundwater concentration resulting from an uniform initial concentration over an appropriate vertical depth range of the vadose zone. For this forward calculation step, the initial concentration applied is a unit concentration (1.0 mg/kg for nonradionuclide COPCs, or 1.0 pCi/kg for radionuclide COPCs). The second, back-calculation, step (represented by use of Equation 1 and Equation 2), is where the peak groundwater concentration resulting from the initial uniform unit concentration is scaled by the appropriate regulatory compliance criterion to determine the maximum initial soil concentration that could be present and not result in an exceedance of that criterion. The maximum value obtained from this back-calculation step is assigned as the SSL or PRG value (these differ only with respect to the recharge scenario used; irrigation for SSLs versus native vegetation for PRGs). As a measure of maximum allowable contaminant concentration in the soil, SSLs and PRGs are expressed as contaminant mass per mass of soil for non-radionuclides (e.g., mg/kg) and as contaminant activity per mass of soil for radionuclides (e.g., pCi/g). The use of a unit initial concentration in the forward-calculation step with STOMP is therefore only a convenience to support calculation of SSLs and PRGs in the back-calculation step. The peak groundwater concentration that is calculated with STOMP will be proportional to the initial soil concentration value. Hence, any initial value for soil concentration could be used in the forward-calculation step, and when scaled against the resulting peak groundwater concentration in the back-calculation step in Equation 1 or Equation 2 will yield the same SSL or PRG. The unit concentration, therefore, is not to be confused as constituting an actual observed waste site residual soil concentration. Further detail on this calculation approach is provided in SGW-50776.

Based on SGW-51818, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone*, and the analysis reported below (in Section 3.5), all contaminants were grouped into two groups, one with lower distribution coefficients in the range $K_d < 2$ mL/g, and other with the higher distribution coefficients in the range ≥ 2 mL/g.

For the lower K_d contaminants ($K_d < 2$ mL/g), a uniform concentration of 1.0 mg/kg was applied in the entire vadose zone, from below the clean backfill down to 0.5 m (two simulation grid blocks) above the water table. This is termed the 100:0 initial source distribution (Figure 5). Initial concentration in the 0.5-m-zone above the water table was not applied due to the presence of capillary fringe and water table movement in the periodically rewetted zone that would result from river stage fluctuations. Placing the initial mass at the water table can also result in unrepresentative large peak releases in the simulation start because of the extreme concentration gradients created by the application of this initial condition.

For the higher K_d contaminants ($K_d \geq 2$ mL/g), based on information presented in SGW-51818, the conservative assumption of contamination throughout the full thickness of the vadose zone is modified. For these contaminants, the upper 70% of the vadose zone below the clean backfill was assumed to be contaminated while the lower 30% is treated as uncontaminated; this is termed the 70:30 initial source distribution (Figure 5). The 70:30 initial source distribution assumption is deemed conservative for the high K_d contaminants, with respect to peak groundwater concentration, based on observed limited vertical extent of such contaminants. Where borehole measurements of deeper contamination of higher K_d contaminants but of limited vertical extent are found, this conservatism can be tested using those data.

A notable exception to the K_d based assignment of an initial source distribution was made for the COPC strontium-90. Because field data revealed that this COPC was found throughout the vadose zone at several sites, use of a 70:30 initial source distribution for this COPC would clearly be non-conservative. Accordingly, SSL and PRG values were calculated for strontium-90 using the 100:0 initial source distribution at all sites. Strontium-90 is distributed throughout the vadose zone despite its relatively high K_d value for reasons having to do with historic discharge practices that no longer dominate the subsurface.



Note: Strontium-90 (K_d = 25 mL/g) is an exception, simulated with 100:0 model; see text for explanation.

Figure 5. 100:0 and 70:30 Initial Contaminant Distribution Models

A complete discussion of this is provided in the nature and extent of contamination discussion found in Chapter 4 of the remedial investigation/feasibility study report for this OU. This exception might be considered as a site-specific treatment, but was applied to all sites for this COPC only in the first-level modeling under the graded approach (DOE/RL-2011-50).

3.3 Hydraulic Parameters

To the extent possible, source-area-specific hydraulic and transport parameter values were used in the STOMP simulations. Based on previous Hanford studies, and on the fact that all available measurements of hydraulic properties were made under the same assumption, the sediments were assumed to follow the van Genuchten (1980) moisture retention constitutive relation and the Mualem–van Genuchten relative permeability constitutive relation (Mualem, 1976), thus requiring values to be specified in STOMP for each lithologic unit for:

- K_s, saturated hydraulic conductivity (LT^{-1})
- n_T, total porosity (L^3L^{-3})
- θ_s, saturated volumetric water content, called diffusive porosity n_D in STOMP (L^3L^{-3})

- s_r, residual saturation (dimensionless), equal to the residual volumetric water content θ_r divided by the saturated volumetric water content θ_s
- α, van Genuchten fitting parameter (L^{-1}), proportional to the inverse of the air entry matric potential
- n, van Genuchten exponential fitting parameter (dimensionless)

The van Genuchten m parameter was assumed to be fixed and equal to $(n-1)/n$ and the Mualem β exponent was assumed to be fixed at 0.5 (Mualem, 1976; RPP-20621 Rev. 0, *Far-Field Hydrology Data Package for the Integrated Disposal Facility Performance Assessment*).

Hanford and Ringold E units are well to poorly sorted sandy gravels or sandy silty gravels whereas the backfill consists of poorly sorted sand and gravel with varying fractions of eolian loess and silt (RPP-20621; SGW-40781 Rev. 1; SGW-41213 Rev. 0, *100-KR-4 Remedial Process Optimization Modeling Data Package*; and SGW-46279 Rev. 0; PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*). Within the 100-D and 100-H source areas, the Hanford formation tends to be coarser grained than the Ringold E. The former tends to contain larger gravel clasts than the latter, but the Ringold E can locally contain significant amounts of gravel (SGW-40781 Rev. 1; SGW-41213 Rev. 0; and SGW-46279 Rev. 0). The Ringold E unit in the vadose zone is described as silty sandy gravel in 100-D and fluvial sandy gravel to silty sandy gravel in 100-H. Where present, the RUM was assumed to act as a lower bound (aquitard) for the aquifer (SGW-46279 Rev. 0) and so was not directly included in the STOMP simulations.

OU-specific values for several Mualem-van Genuchten hydraulic parameters were obtained for the Hanford formation from data packages SGW-40781 Rev. 1 (100-D and 100-H) and SGW-46279 Rev. 0 (entire 100 Area). The three data packages cite RPP-20621 Rev. 0 as the source of the unsaturated hydraulic properties of 15 samples of sandy gravels from the 100 Area areas (Table 6). These 100 Area sediments are dominated by the gravel fraction (> 2-mm size), with gravel clasts accounting for 43 to 75% of the total sample mass (Table 6; RPP-20621 Rev. 0). Moisture retention data were measured on the non-gravel sediment fraction (< 2mm size) and corrected for gravel fraction. The gravel correction was done using Equation 4 in WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area soils, Hanford Site:*

$$\theta_{(b,s)} = F_f \theta_{(f,s)} = (1 - F_g)\theta_{(f,s)} \qquad \text{Equation 5}$$

where $\theta_{(b,s)}$ is the volumetric moisture content of the bulk soil which includes gravel, $\theta_{(f,s)}$ is the volumetric moisture content of the fines (the fraction tested in the laboratory), F_f is the volumetric fraction of the bulk soil sample passing through the No. 10 sieve (< 2mm), and F_g is the volumetric gravel fraction (the complement of F_f). This is well-established procedure for soils with substantial aggregate such as the Hanford Site. In other cases, hydraulic conductivities were measured on the bulk samples that included the gravel fraction using the constant-head permeameter method for saturated hydraulic conductivity (K_s) and the unit gradient method for unsaturated hydraulic conductivity (Table 6; RPP-20621 Rev. 0). The K_s measurements were assumed to represent vertical hydraulic conductivity.

Table 6. Hydraulic Parameters for Sandy Gravels in the 100 Area Vadose Zone [a,b]

Sample	HSU [c]	Source Area	Well Number	Depth (m)	% Gravel	θ_s *Saturated Volumetric Moisture Content* (cm^3/cm^3)	θ_r *Residual Volumetric Moisture Content* (cm^3/cm^3)	α van Genuchten Inverse Air Entry Head Fitting Parameter (1/cm)	n van Genuchten Exponential Fitting Parameter (-)	Fitted K_s Fitted Saturated Hydraulic Conductivity [d,e] (cm/s)
2-1307	Ringold	100-HR-3	199-D5-14	18.90	43	0.236	0.0089	0.0130	1.447	1.29E-04
2-1308	Ringold	100-HR-3	199-D5-14	30.64	58	0.120	0.0208	0.0126	1.628	6.97E-05
2-1318	Hanford	100-HR-3	199-D8-54A	15.54	60	0.124	0.0108	0.0081	1.496	1.67E-04
2-2663	Hanford	100-BC-5	199-B2-12	8.20	61	0.135	0.0179	0.0067	1.527	6.73E-05
2-2664	Ringold	100-BC-5	199-B2-12	24.84	73	0.125	0.0136	0.0152	1.516	1.12E-04
2-2666	Hanford	100-BC-5	199-B4-9	21.49	71	0.138	0.00	0.0087	1.284	1.02E-04
2-2667	Hanford	100-BC-5	199-B4-9	23.93	75	0.094	0.00	0.0104	1.296	1.40E-04
3-0570	Hanford	100-KR-1	116-KE-4A	3.50	60	0.141	0.00	0.0869	1.195	2.06E-02
3-0577	Hanford	100-FR-3	199-F5-43B	7.16	66	0.107	0.00	0.0166	1.359	2.49E-04
3-0686	Hanford	100-FR-1	116-F-14	6.49	55	0.184	0.00	0.0123	1.600	5.93E-04
3-1702	Hanford	100-DR-2	199-D5-30	9.78	68	0.103	0.00	0.0491	1.260	1.30E-03
4-1086	Ringold	100-K	199-K-110A	12.77	65	0.137	0.00	0.1513	1.189	5.83E-02
4-1090	Hanford	100-K	199-K-111A	8.20	50	0.152	0.0159	0.0159	1.619	4.05E-04
4-1118	Hanford	100-K	199-K-109A	10.30	66	0.163	0.00	0.2481	1.183	3.89E-02
4-1120	Ringold	100-K	199-K-109A	18.90	63	0.131	0.0070	0.0138	1.501	2.85E-04

Table 6. Hydraulic Parameters for Sandy Gravels in the 100 Area Vadose Zone [a,b]

Sample	HSU [c]	Source Area	Well Number	Depth (m)	% Gravel	θ_s *Saturated Volumetric Moisture Content* (cm^3/cm^3)	θ_r *Residual Volumetric Moisture Content* (cm^3/cm^3)	α van Genuchten Inverse Air Entry Head Fitting Parameter (1/cm)	n van Genuchten Exponential Fitting Parameter (-)	Fitted K_s Fitted Saturated Hydraulic Conductivity [d,e] (cm/s)

a. Source: RPP-20621 Rev .0

b. Moisture retention data were measured on the non-gravel sediment fraction (< 2mm size) and corrected for gravel fraction.

c. HSU = hydrostratigraphic unit

d. Assumed to represent vertical hydraulic conductivity

e. Hydraulic conductivities were measured on the bulk samples that included the gravel fraction using the constant-head permeameter method for saturated hydraulic conductivity (K_s) and the unit gradient method for unsaturated hydraulic conductivity.

The Mualem-van Genuchten hydraulic properties for the Hanford formation in the vadose zone were estimated for each geographic area by averaging the individual parameter values for all samples collected from that geographic area. For example, two samples from borehole 199-D5-14 were selected to provide mean properties for 100-D and 100-H areas for the Ringold Formation, and two samples from boreholes 199-D5-30, and 199-D8-54A (Table 6) were selected to provide mean properties for the 100-D and 100-H areas for the Hanford formation (Table 7). Vertical saturated hydraulic conductivity of the Hanford formation was obtained by using the geometric mean of the applicable measurements, whereas the other parameters were averaged using the arithmetic mean of the applicable measurements. An exception is the saturated volumetric water content parameter [θ_s in the van Genuchten moisture retention relation, termed diffusive porosity (n_D) in STOMP]. The θ_s values listed in Table 6 were determined by applying a gravel correction factor to the values determined in the laboratory on the < 2 mm fraction. However, the θ_s values appear to be underestimated and are hard to reconcile with the high K_s values estimated. Therefore, the site-wide estimate of 0.247 was used for Hanford formation (PNNL-18564). There were cases where parameters were unavailable, and the following assumption was applied to provide needed hydraulic parameters:

- The document and database review did not yield geographic area-specific Mualem-van Genuchten parameter values for the backfill material. Therefore, in the absence of more site-specific data, Hanford site-wide mean parameter values for the backfill reported in Table A.12 of PNNL-18564 were assumed representative for the 100 Area OUs. Mean hydraulic parameters for six samples of backfill and 18 samples of Ringold E gravels that were collected across the Hanford Site (PNNL-18564) were selected to represent these units within the 100-D and 100-H Areas (Table 7).

Geographic area-specific values for Hanford and Ringold E saturated hydraulic conductivities were based on parameters reported in the following model data packages for saturated zone modeling: SGW-40781 Rev. 1, SGW-41213 Rev. 0, and SGW-46279 Rev. 0. Horizontal saturated hydraulic conductivity measurements from aquifer (pump) tests and slug tests for the several geographic areas presented in these model data packages were reviewed, and geometric means were calculated for each geographic area from aquifer test measurements only; these values are listed in Table 8.

Comparison of the aquifer horizontal K_s values in Table 8with the vertical K_s values in Table 6for the same units and source areas revealed differences of two or more orders of magnitude. For example, the aquifer horizontal K_s for the Hanford unit in 100-H is 0.113 cm/s (Table 8), whereas the vertical K_s values for the Hanford unit in 100-HR-3 is 2.0×10^{-4} cm/s (Table 6), a difference of more than two orders of magnitude. Similarly, the aquifer horizontal K_s for the 100-D Hanford equals 0.0642 cm/s (Table 8), whereas the vertical K_s for the sole sample from 100-DR-2 area is 0.0013 cm/s (Table 6). Vertical anisotropy is commonly assumed to be 0.1 for the Hanford formation (SGW-40781 Rev. 1; SGW-41213 Rev. 0; and SGW-46279 Rev. 0), but 0.1 is at least an order of magnitude larger than the differences that are described above. Possible explanations include:

- Differences in sample scale between the large-scale aquifer test relative to the small-scale Table 6 samples characterized in the laboratory
- Potential effects of sample disturbance or repacking prior to the Table 6 K_s measurements, and
- Limitations of the Mualem-van Genuchten relative permeability functions to represent hydraulic conductivity across the range of matric potential values adequately

Table 7. Hydraulic Parameters used for 100-D and 100-H Source Areas

Geographic Area	Zone	Unit	n_T Total Porosity (cm^3/cm^3)	n_D Diffusive Porosity (cm^3/cm^3)	α van Genuchten Air Entry Fitting Parameter (1/cm)	n van Genuchten Exponential Fitting Parameter (-)	s_r Residual Saturation (-)	$K_{s\|h}$ Horizontal Saturated Hydraulic Conductivity (cm/s)	$K_{s\|v}$ Vertical Saturated Hydraulic Conductivity (cm/s)
100-D	Backfill	Hanford	0.276 [a]	0.262 [a]	0.019 [a]	1.400 [a]	0.103 [a]	5.98E-04 [a]	5.98E-04 [a]
	Vadose	Hanford	0.280 [b]	0.247 [b]	0.029 [c]	1.378 [c]	0.022 [c]	4.66E-03 [d]	4.66E-04 [d]
	Vadose	Ringold E	0.293 [e]	0.267 [e]	0.013 [f]	1.538 [f]	0.057 [f]	9.48E-04 [g]	9.48E-05 [g]
	Saturated	Hanford	0.280 [b]	0.247 [b]	0.029 [c]	1.378 [c]	0.022 [c]	6.42E-02 [h]	6.42E-03 [h]
	Saturated	Ringold E	0.293 [e]	0.267 [e]	0.013 [f]	1.538 [f]	0.057 [f]	2.59E-02 [i]	2.59E-03 [i]
100-H	Backfill	Hanford	0.276 [a]	0.262 [a]	0.019 [a]	1.400 [a]	0.103 [a]	5.98E-04 [a]	5.98E-04 [a]
	Vadose	Hanford	0.280 [b]	0.247 [b]	0.029 [c]	1.378 [c]	0.022 [c]	4.66E-03 [d]	4.66E-04 [d]
	Vadose	Ringold E	0.293 [e]	0.267 [e]	0.013 [f]	1.538 [f]	0.057 [f]	9.48E-04 [f]	9.48E-05 [f]
	Saturated	Hanford	0.280 [b]	0.247 [b]	0.029 [c]	1.378 [c]	0.022 [c]	1.13E-01 [h]	1.13E-02 [h]
	Saturated	Ringold E	0.293 [e]	0.267 [e]	0.013 [f]	1.538 [f]	0.057 [f]	4.28E-03 [i]	4.28E-04 [i]

Table 7. Hydraulic Parameters used for 100-D and 100-H Source Areas

Geographic Area	Zone	Unit	n_T Total Porosity (cm^3/cm^3)	n_D Diffusive Porosity (cm^3/cm^3)	α van Genuchten Air Entry Fitting Parameter (1/cm)	n van Genuchten Exponential Fitting Parameter (-)	s_r Residual Saturation (-)	$K_{s\|h}$ Horizontal Saturated Hydraulic Conductivity (cm/s)	$K_{s\|v}$ Vertical Saturated Hydraulic Conductivity (cm/s)

a. Source: arithmetic mean of hydraulic parameters for backfill calculated for six samples that were collected within the Hanford Site (hydraulic conductivity assumed isotropic for backfill) reported in PNNL-18564, Table A.12 (these are also the site-wide values for backfill listed in PNNL-14702 Rev. 1, Table 4.5)

b. Source: PNNL-18564, Tables 6.3 and 6.4, values for total and effective porosity for Hanford gravelly sand (Hgs), site-wide. Note the saturated volumetric moisture content values listed in Table 6 were determined by applying a gravel correction factor to the values determined in the laboratory on the < 2 mm fraction. However, these values appeared to be underestimated and were inconsistent with the high K_s values estimated, so this site-wide estimate was used.

c. Source: computed arithmetic mean of values for two Hanford formation samples from 100-D and 100-H (Table 6, samples 2-1318 and 3-1702).

d. Source: computed geometric mean of values for two Hanford formation samples from 100-D and 100-H (Table 6, samples 2-1318 and 3-1702) for vertical value; horizontal value computed based on assumed anisotropic ratio of 0.1.

e. Source: PNNL-18564, Tables 6.3 and 6.4, values for total and effective porosity for Ringold gravel (Rg), site-wide.

f. Source: computed arithmetic mean of values for two Ringold Formation samples from 100-D and 100-H (Table 6, samples 2-1307 and 3-1308).

g. Source: computed geometric mean of values for two Ringold Formation samples from 100-D and 100-H (Table 6, samples 2-1307 and 3-1308); horizontal value computed based on assumed anisotropic ratio of 0.1.

h. Source: vertical saturated hydraulic conductivity for saturated zone units was calculated as the geometric mean of aquifer test measurements for the Hanford formation in the 100-D and 100-H areas of data reported in SGW-40781 Rev. 1, Table 7-1; see Table 8.

i. Source: vertical saturated hydraulic conductivity for saturated zone units was calculated as the geometric mean of aquifer test measurements for the Ringold formation in the 100-D and 100-H areas of data reported in SGW-40781 Rev. 1, Table 7-1; see Table 8.

Table 8. Source-area-specific Aquifer Horizontal Saturated Hydraulic Conductivity (K_s) Data

Source Area	Aquifer Formation	Number of Tests	*Minimum $K_{s,h}$* Minimum Horizontal Hydraulic Conductivity (m/day)	*Maximum $K_{s,h}$* Maximum Horizontal Hydraulic Conductivity (m/day)	*Geometric Mean $K_{s,h}$* Geometric Mean Horizontal Hydraulic Conductivity (m/day)	(cm/s)
100-D	Hanford	1	55.5	55.5	55.5	6.42E-02
	Ringold	23	8.5	560	22.4	2.59E-02
100-H	Hanford	18	15.2	1810.5	97.9	1.13E-01
	Ringold	3	0.04	106.7	3.7	4.28E-03

3.4 Contaminant Transport Parameters

The contaminant transport parameters required by STOMP are the particle density of each unit, dispersion coefficients, half-lives for each radiological COPC, and the distribution coefficient for each COPC.

The particle density (ρ_p) values of the backfill, Hanford, and Ringold units can be calculated using the bulk density (ρ_B) and porosity. Bulk density is needed for retardation scaling factor calculations. Estimates of bulk density for Hanford and Ringold units were obtained from PNNL-14702 Rev. 1, which gave 1.91 g/cm^3 for the Hanford and 1.90 g/cm^3 for the Ringold. The bulk density estimate of 1.94 g/cm^3 for backfill was obtained from PNNL-18564.

Hydrodynamic dispersion was conservatively assumed negligible, so dispersivity values were all set to zero. Setting dispersivity values to zero yields higher peak groundwater concentrations than would be obtained using non-zero values. This, therefore, is a conservative assumption with respect to SSL and PRG values. (Numerical dispersion is a separate consideration; steps taken to minimize numerical dispersion in the STOMP code calculations are discussed in Section 3.1.)

Distribution coefficient (K_d) values for all COPCs were obtained from ECF-Hanford-12-0023, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*. These values are listed for each COPC in the tables of SSL values listed in Attachment B, and of PRG values listed in Attachment C, of this ECF. One COPC's K_d value requires elaboration here, that for hexavalent chromium. A site-specific, bounding value is selected in ECF-Hanford-12-0023 for this COPC that was derived from the site-specific analysis for the 100 Area presented in ECF-Hanford-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area)*. The leach test data analyzed in ECF-Hanford-11-0165 included D/H area samples (Figure 6). The empirical cumulative distribution function for K_d estimates from these leaching tests are shown with respect to each reactor area within the River Corridor in Figure 7. This K_d value for Cr(VI) is considered bounding because it was selected on the basis that 90% of the K_d values in that analysis had higher sorption values. Thus, this value would not be appropriate to represent hexavalent chromium migration in a predictive model, but is appropriate for

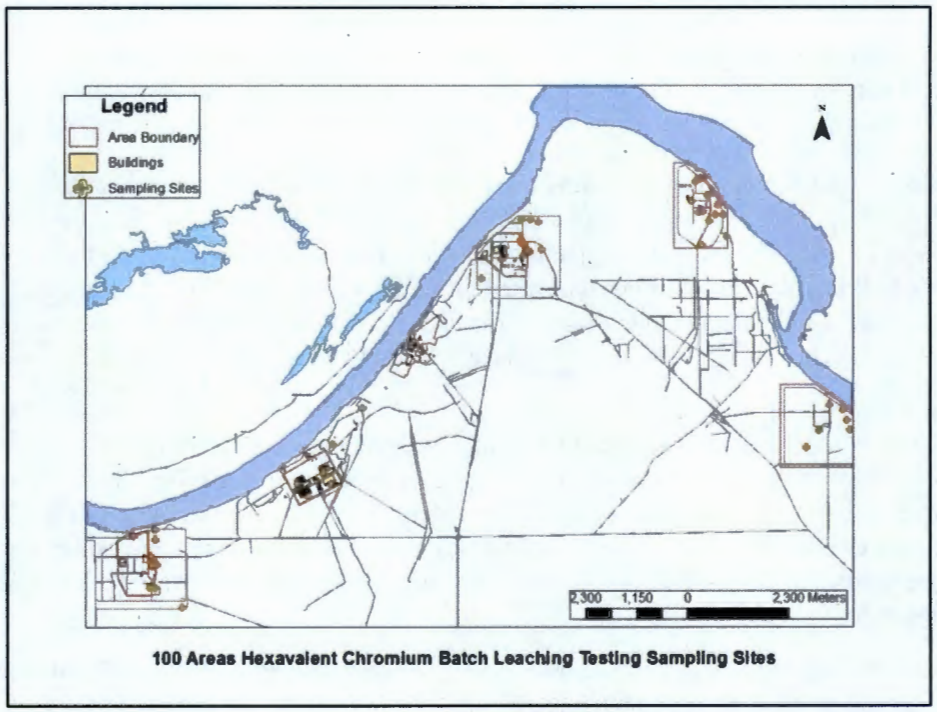
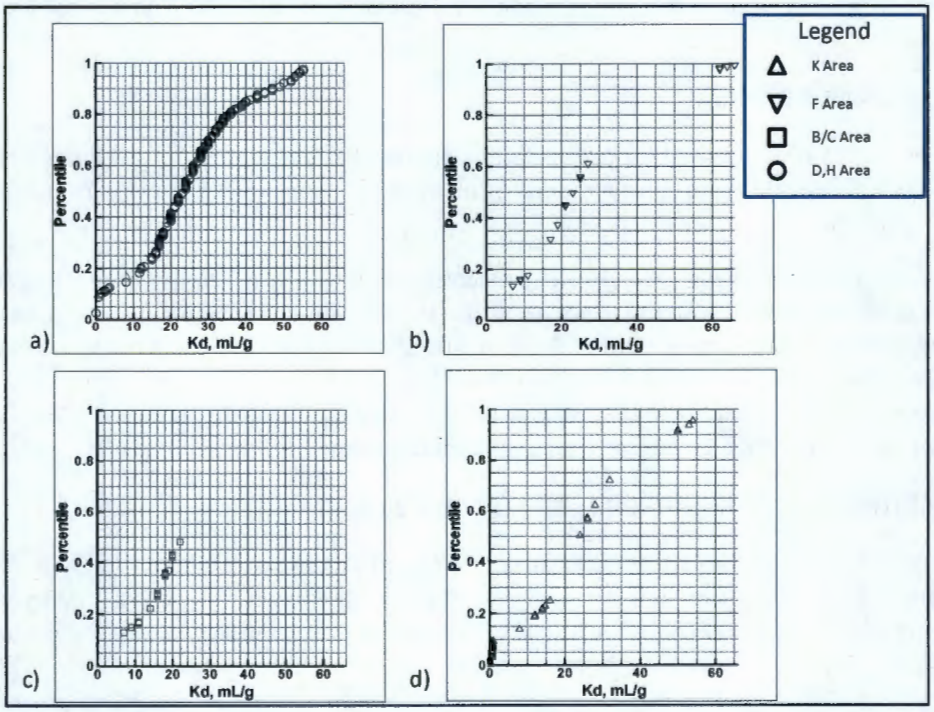


Figure 6. Location of Leach Test Data Samples Evaluated for Derivation of a Bounding, Site-specific K_d Value for Residual Hexavalent Chromium



Source: ECF-Hanford-11-0165 Rev. 1, Figure 3

Figure 7. Empirical Cumulative Distribution Function for K_d Estimates from Leaching Tests Symbolized to Indicate Reactor Area within the River Corridor

use in this bounding calculation of SSL and PRG values. Further, this value for K_d of hexavalent chromium is applicable only to the residual fraction of hexavalent chromium remaining in the vadose zone; it is inapplicable to the mobile fraction that migrated out of the vadose zone in the past.

STOMP accounts for contaminant first-order decay in the solute mass conservation equation (PNNL-12030). Half-life values ($t_{1/2}$) for radionuclide COPCs were obtained from ECF-Hanford-10-0429. These values are listed in those tables pertaining to radionuclides in Attachments B and C of this ECF for each radionuclide COPC. Chain decay is not accounted for in this calculation. No radionuclide COPC is simulated that has significant daughter products (no significant daughter/decay products associated with the alpha, beta, and gamma emitters that are present at 100-D/H; the gamma emitters do not have any decay products).

Biodegradation is neglected in this calculation, which is generally a conservative assumption because the result it to overstate the persistence of a COPC by neglecting its biodegradation. However, in some circumstances this may be nonconservative where biodegradation products are also COPCs. For example, COPCs such as chloroform can degrade to methylene chloride and chloromethane, which have higher cancer slope factors. Dichloroethylene can eventually degrade to vinyl chloride, which has a higher cancer slope factor than dichloroethylene.

Volatilization and gas phase transport is conservatively neglected in this calculation to maximize the peak groundwater concentration predicted by the model.

Predictive (post-2010) simulations of water flow and contaminant transport were run for 1000 years to produce peak groundwater concentrations for each COPC based on its K_d values, and accounting for radioactive decay for radionuclide COPCs, using the K_d values and half-lives listed in the tables in Attachments B and C of this ECF.

3.5 Simulation Duration

A 1000-year limit was established for purposes of SSL and PRG calculation by agreement with regulatory agencies. Accordingly, the peak concentration within the 1000-year predictive (post-2010) simulation was used to calculate the SSL and PRG values.

The time of occurrence for peak groundwater concentration may be after the 1000-year limit for contaminants subject to high sorption. Because of the 1000-yr limit, however, only the peak groundwater concentration within 1000 years is used as the basis for SSL or PRG values. Typically, breakthrough at numerically significant levels is not simulated within 1000 years for contaminants with high sorption values, although the threshold for breakthrough will depend on the recharge scenario used. These cases commonly result in an "NR" (non-representative) coding assigned for the SSL or PRG (Section 2.5.1).

3.6 Uncertainties, Assumptions, and Conservatism

Potential sources of uncertainty in risk assessments are primarily in the categories of (1) model uncertainties, (2) scenario uncertainties, and (3) parameter uncertainties. Model uncertainty pertaining to the equations used as numerical representations of the natural processes is expected to be relatively small (DOE/RL-2011-50).

STOMP has been shown through comparison to analytical solutions, benchmarking against other codes, and field validation to solve the governing equations it incorporates for flow and transport processes correctly, but that the representativeness of any given model implemented using STOMP is inherently

limited by the accuracy of the conceptual representation and the representativeness of the parameterization.

DOE/RL-2011-50 provides a summary evaluation of the comparisons of field data and field test results to corresponding model results obtained using the STOMP code, and the evaluation indicates that the equations used in STOMP adequately simulate the natural processes. The technical basis regarding scenario and parameter selection and the evaluation of uncertainty and variability is also documented in DOE/RL-2011-50. Documentation is provided in DOE/RL-2011-50 on (1) dominant model factors, (2) model parameter values and plausible ranges of parameter values, (3) model assumptions and effects on model results, and (4) model limitations.

Application of the PRG values calculated herein requires an understanding of which assumptions and modeling choices were conservative and which were not. Conservative assumptions and modeling choices include:

- Recharge was represented in the numerical model by uniform flux rates specified over particular periods so that vadose zone flow is always downward. In contrast, recharge in an arid vadose zone occurs only as often as the combination of precipitation and antecedent moisture conditions allow, i.e., sporadically or infrequently, so that there can be long periods when shallow vadose-zone pore water movement is controlled more by evaporation and transpiration near the surface than gravity, resulting in upward movement or reduced downward seepage velocity.
- The one-dimensional simulations force all contamination through the vadose zone down to the aquifer, whereas infiltrating water and solutes tend to migrate laterally as the wetting front redistributes following an infiltration event.
- The recharge rates for the native vegetation scenario used to calculate PRGs uses bounding native vegetation rates based on numerous lysimeter and tracer recharge studies (PNNL-17841).
- The SSL values to be used for screening calculated for bounding recharge rates postulated in the irrigation recharge scenario. This is not the expected land use, and the irrigation is assumed to commence much sooner than is reasonable.
- The initial condition (either the 100:0 or 70:30 model) represents a bounding initial condition that effectively assumes the maximum residual soil contamination level is uniformly present over the entire applicable vadose zone thickness (a peak concentration would not be expected to occur over the entire depth range).
- The vadose zone thicknesses for the representative stratigraphic columns were minimized by using water tables from a typical high-water month when developing the stratigraphic columns for use in an average annual model; this minimizes contaminant transport time, thereby resulting in higher and earlier groundwater peak concentrations.
- Dilution upon mixing of groundwater with Columbia River water is assumed negligible.
- Dispersion is assumed negligible, which leads to larger peak concentrations than if dispersion had been included.
- Volatile organic compounds are assumed to have negligible volatilization so that the resulting peak concentrations are larger than if volatilization had been included.

- Geometric means of measured aquifer horizontal hydraulic conductivity values are lower, and thus more conservative, than arithmetic means because the values typically span several orders of magnitude.

Assumptions that may or may not be conservative include:

- The median hydraulic gradient value for each source area may be too large by several-fold for waste sites near the Columbia River and may be several times too large for waste sites that are far inland from the river.
- The assumption of a 5-m-thick aquifer may or may not be conservative for those 100 Area locations with aquifer thicknesses less than 5 m.

4 Software Applications

STOMP was the primary software used for this calculation; as approved software, the information required is provided in this section.

Microsoft Excel® spreadsheets were used to calculate contaminant inventory values and approximate contaminant solute concentrations, back-calculate PRG values, and evaluate the results produced by STOMP. These calculations were performed on a desktop with ID INTERA-00465. The hardware is a Dell®[2] Precision E7200 with a 3.07-GHz Intel® Core2™ i7 processor and 6.0 GB of RAM loaded with the Windows®[3] 7 64-bit operating system.

4.1 Approved Software

The vadose zone fate and transport calculations are performed using CHPRC Build 4 of the STOMP software, registered in the Hanford Information System Inventory (HISI) under identification number 2471. STOMP use by CHPRC is managed under the following software lifecycle documents: CHPRC-00222, STOMP *Functional Requirements Document*; CHPRC-00176, *STOMP Software Management Plan*; CHPRC-00211, *STOMP Software Test Plan*; CHPRC-00515, STOMP *Acceptance Test Report*; and CHPRC-00269, STOMP *Requirements Traceability Matrix*.

4.1.1 Description

The following required information for the STOMP software package used for this calculation is provided here:

- Software Title: STOMP
- Software Version: CHPRC Build 4
- HISI Identification Number: 2471
- Workstation type and property number (from which software is run): STOMP was executed on the INTERA Richland GREEN Linux®[4] Cluster that is owned and managed by INTERA, Inc., a pre-selected subcontractor to CHPRC. The computer property tag for the front-end node is #469 at INTERA's office in Richland, Washington. This node is a Dell® PowerEdge® R510 with two

[2] Dell® and PowerEdge® are registered trademarks of Dell Products, Inc.

[3] Excel® and Windows® are registered trademarks of Microsoft Corporation in the U.S. and other countries.

[4] Linux® is the registered trademark of Linus Torvalds in the U.S. and other countries.

6-core Intel®[5] Xeon X5660 processors @ 2.80GHz and 48 GB of RAM. As given by the command :"uname –a", the operating system details are

```
Linux green 3.2.0-54-generic #82-Ubuntu SMP Tue Sep 10 20:08:42 UTC
2013 x86_64 GNU/Linux
```

4.1.2 Software Installation and Checkout

A copy of the *Software Installation and Checkout Form* for the STOMP installation used for this calculation is provided in Attachment D to this ECF.

4.1.3 Statement of Valid Software Application

DOE/RL-2011-50 contains a summary of the main model attributes and code selection criteria that serve as the basis for the demonstration of the adequacy of the STOMP code for use in vadose zone modeling at Hanford. The results of the evaluation in DOE/RL-2011-50 show that the STOMP code is capable of meeting or exceeding the identified attributes and criteria. The comparison of the code selection criteria to the STOMP code capabilities indicates the STOMP code is capable of simulating all of the necessary FEPs, and that STOMP meets all of the other required code selection criteria. Section 6.4.1 of DOE/RL-2011-50 addresses code selection criteria, including quality assurance documentation of verification studies for specific model attributes (e.g., unsaturated flow, solute transport, infiltration, and drainage), and includes a discussion of other code related criteria (i.e., inter-code comparisons, hardware requirements, solution methodology, dimensionality, and output capability).

The results of CHPRC acceptance testing (CHPRC-00515) demonstrate that the STOMP software is acceptable for its intended use by the CHPRC. Installations of the software are operating correctly, as demonstrated by the INTERA Linux® Cluster system producing the same results as those presented for selected problems from the STOMP application guide (PNNL-11216) in accordance with the software test plan (CHPRC-00211).

5 Calculation

STOMP simulations were created and run using the representative stratigraphic columns, boundary conditions, initial conditions, and parameter values described in Section 3. A description of the calculation of SSL and PRG values is described in Section 5.1. Site-specific modeling evaluations are described in Section 5.2.

5.1 Calculation of Soil Screening Levels and Preliminary Remediation Goals

The source-area-specific SSL values for 100-D and 100-H OUs are presented in Attachment B of this ECF. The source-area-specific PRG values are presented for 100-D and 100-H OUs in Attachment C of this ECF. Details of this calculation are provided below.

5.1.1 Time Step and Solution Control

The STOMP simulator solves a wide variety of nonlinear, single- or multiphase flow and transport problems for variably saturated geologic media. Partial differential conservations equations for component mass, energy, and solute mass comprise the fundamental equations for the simulator. STOMP solves flow and transport problems in the subsurface environment in one, two, or three dimensions.

[5] Intel® is a registered trademark of Intel Corporation.

STOMP solves the fundamental equations for flow using an integral volume finite difference approach with the nonlinearities in the discretized equations resolved through Newton-Raphson iteration. The fundamental equation for solute transport are discretized to algebraic form following the integrated finite difference method of Patankar (1980) that is implicit using backward Euler time differencing, or by other techniques available in STOMP (e.g., TVD). STOMP solves the linear systems of equations that result from the Newton-Raphson linearization or the solute transport solution using either a direct, banded matrix solver or an indirect conjugate gradient-based solver.

For this calculation, the STOMP-W operational mode (solving for water mass and solute mass conservation) with the direct, banded matric solver was used for all simulations. The Patankar (1980) technique was used for solute transport simulation. Details of the software quality assurance requirements met for use of STOMP are in Section 4.

For solution control, the maximum time step permitted was 0.01 years. The grid dimension of 10.0 m in the horizontal direction by 0.25 m in the vertical direction was deliberately specified to maintain grid Courant numbers below the threshold of 1.0 to minimize numerical dispersion in the saturated zone. STOMP's automatic Courant limitation feature was used to control numerical dispersion in the unsaturated nodes.

The aqueous concentrations calculated using STOMP was scaled down unit horizontal grid length (1.0 m) by dividing the aqueous concentrations by 10. The accuracy of this methodology was verified through simulation of varying grid dimensions (details not presented in this ECF).

5.1.2 Peak Groundwater Concentration Calculation

STOMP was used to simulate groundwater concentration for each model time step along a portion of the domain's downgradient boundary corresponding to the top 5 m of the aquifer for the following set of simulations:

- → Two recharge scenarios, each for:
  - → Eight stratigraphic columns (Figure 1), each for:
    - → All COPCs with their respective K_d values and decay half-lives (Attachments B and C of this ECF)

Fluxes through the downgradient boundary were written to a surface flux file, one of STOMP's standard output options. For each time step, STOMP writes the water mass and solute mass flux rates passing through the surface as well as the cumulative water and solute mass that have passed through the surface. Groundwater concentration within the 5-m-long surface was conservatively estimated by calculating it at the aquifer edge beneath the downgradient edge of the waste site footprint. The solute mass flux per unit time was divided by the water volume flux per unit time to yield a groundwater concentration at each time step.

5.1.3 Dilution Factor

Dilution of vadose zone contaminant release in the aquifer is directly accounted for within the STOMP simulation because the aquifer is directly represented in the model domain as a function of the aquifer thickness and the hydraulic gradient. Consequently, an aquifer dilution factor is not applied to scale the concentrations reported by STOMP, but rather it is implicit in the concentrations reported by STOMP in this formulation. For comparison purposes, the effective dilution factor in this model can be calculated. The dilution factor is as the ratio of the combined aquifer and vadose zone water fluxes to the vadose zone water flux (WAC 173-340-747):

$$DF = \frac{Q_{VZ} + Q_A}{Q_{VZ}} \qquad \text{Equation 6}$$

where DF is the dilution factor (dimensionless), Q_{VZ} equals the volumetric flux from the vadose zone into the aquifer (L^3T^{-1}) and Q_A represents the volumetric flux through the topmost 5 m of the aquifer (L^3T^{-1}).

The effective dilution factors calculated using Equation 6 for recharge rates for each recharge phase in the predictive period (treated as steady-state values) are listed in Table 9. These factors are calculated using the recharge rates for each scenario and phase (Table 3; Table 4), median hydraulic gradients (Table 5), and aquifer saturated hydraulic conductivities (Table 7), along with dimensions of the STOMP model domain (Section 3.1). The dilution factors are substantially higher where the aquifer is comprised of Hanford formation than where the aquifer is comprised of Ringold Formation because the higher hydraulic conductivity in the Hanford formation results in greater fluxes for a similar gradient. The dilution factors presented in Table 9 provide an indication of the magnitude of dilution calculated by STOMP. It is emphasized here, however, that these factors were not explicitly applied to STOMP results. Rather, dilution is actually calculated within the STOMP solution using the calculated instantaneous water fluxes in the model domain, time step by time step. Thus, dilution is implicitly accounted for within the model results, rather than applied explicitly in a post-calculation step to model results.

Table 9. Effective Dilution Factors[a]

Area	Aquifer Formation	Effective Dilution Factors by Recharge Scenario Phase			
Native Vegetation Recharge Scenario		Bare Soil (2010-2015) 63 mm/yr	Cheatgrass (2015-2020) 31.5 mm/yr	Developing Shrub-Steppe (2020-2050) 8.0 mm/yr	Mature Shrub-Steppe (2050 >) 4.0 mm/yr
100-D	Hanford	226	451	1,770	3,550
	Ringold	91.8	182	726	1,430
100-H	Hanford	991	1,980	7,800	15,600
Irrigation Recharge Scenario		Bare Soil (2010-2015) 63 mm/yr	Irrigation I (2015-2045) 76.4 mm/yr		Irrigation II (2045 >) 72.4 mm/yr
100-D	Hanford	226	187		197
	Ringold	91.8	75.9		80.0
100-H	Hanford	991	818		863

a. Dilution factors calculated per Washington Administrative Code (WAC 173-340-747); calculation of dilution is for the steady-state recharge rate in each recharge phase. Instantaneous dilution in STOMP varies as a function of the instantaneous water flux from the vadose zone entering the aquifer at the water table, which changes in response to time-varying recharge rates.

For context, if the default fixed parameter three-phase partition model (WAC 173-340-747(3)(a)) were used to establish soil concentrations for groundwater protection, the default groundwater dilution factor is 20 for unsaturated zone soil. However, this default is not applicable to this calculation, because it uses alternative fate and transport models (WAC 173-340-747(8)) and not the default parameter three-phase

partition model. Where alternative fate and transport models are used, however, the WAC requires that dilution "be based on site-specific measurements or estimated using a model incorporating site-specific characteristics". This requirement is met in this calculation by using STOMP to model the aquifer with the appropriate aquifer thickness and a median hydraulic gradient based on site-specific measurements.

The WAC requires the following with regard to the dilution factor where upgradient contamination is present for use of alternative fate and transport models:

> **WAC 173-340-747 (8)(b)(vi)**: Dilution. Dilution shall be based on site-specific measurements or estimated using a model incorporating site-specific characteristics. If detectable concentrations of hazardous substances are present in upgradient groundwater, then the dilution factor may need to be adjusted downward in proportion to the background (upgradient) concentration.

Adjustments to the dilution factor are not warranted in this case because these values were applied to establish soil contamination levels protective of groundwater for the post-remedy period. There is no natural background level of Cr(VI) contamination in groundwater in the 100-D/H area; the present plume is anthropogenic in origin and is being addressed by an interim remedy that will address any vadose zone sources that leach to groundwater during the remedy implementation period. The interim or final remedy will continue until contamination levels in groundwater have achieved cleanup levels. Hence, the SSLs and PRGs protective of groundwater and of surface water that were calculated without adjustment for upgradient (background) concentration are protective for the post-remedial period.

Other groundwater contaminants of concern (COCs) are strontium-90, nitrate, and tritium. These COCs were evaluated by mapping locations with vadose zone exceedances of these contaminants against current extent of groundwater plumes. These plots (Figure 8 through Figure 13) indicate the plumes are downgradient of waste sites with detections of the corresponding contaminants with one exception. This exception is nitrate, which is present upgradient of several sites in 100-D with exceedances. However, results from groundwater modeling of nitrate (presented in the 100-DH RI/FS, DOE-RL-2010-95) indicate this plume will also be downgradient of these sites within a short timeframe (approximately 5 years).

The Cr(VI) groundwater plume present in the 100-D/H area is already being remediated through an interim pump-and-treat system. The RI/FS and PP propose a preferred alternative that includes continued remediation using an enhanced pump-and-treat system. Groundwater model predictions show this COC will be remediated by the remediation system to levels below groundwater and surface water protection standards within about ten years (see ECF-100HR3-11-0114 for details). Consequently, groundwater Cr(VI) contamination is not a permanent characteristic of the groundwater resource.

PRG values were calculated to determine the residual soil contamination levels protective of groundwater for post-remedial conditions, when any background levels would persist, but not to protect against present contamination levels in groundwater of the groundwater COCs identified in the RI/FS that are being remediated. If a waste site leaches additional Cr(VI) mass to the groundwater during the remedy implementation period, the groundwater remedy will address the contamination issue.

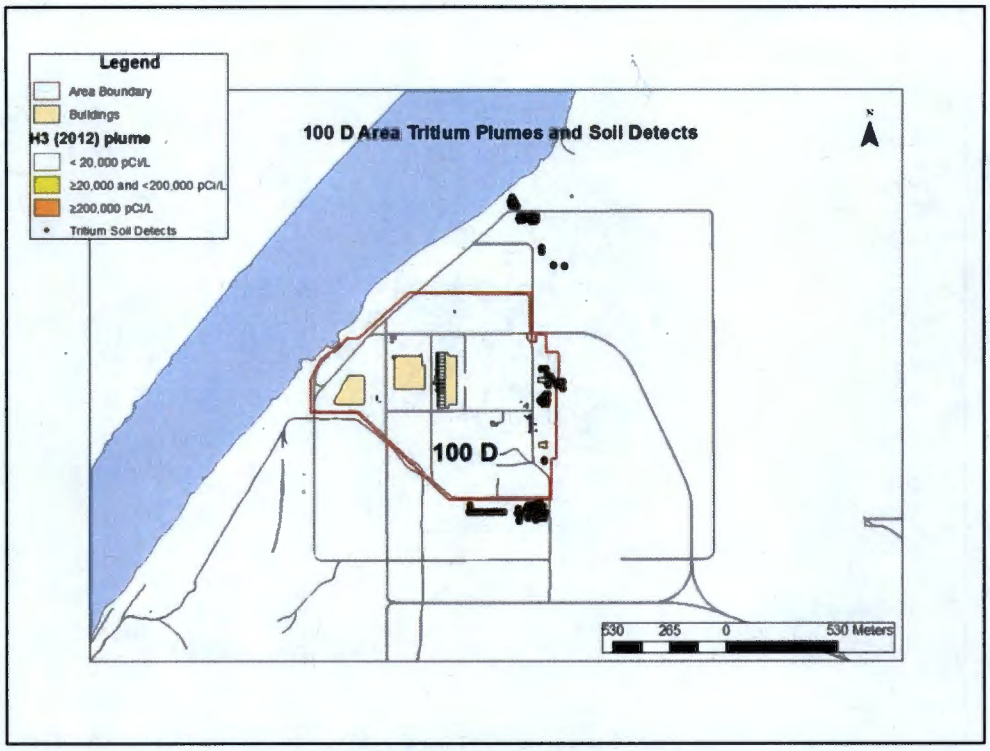


Figure 8. 100-D Area Tritium Plumes and Soil Detects

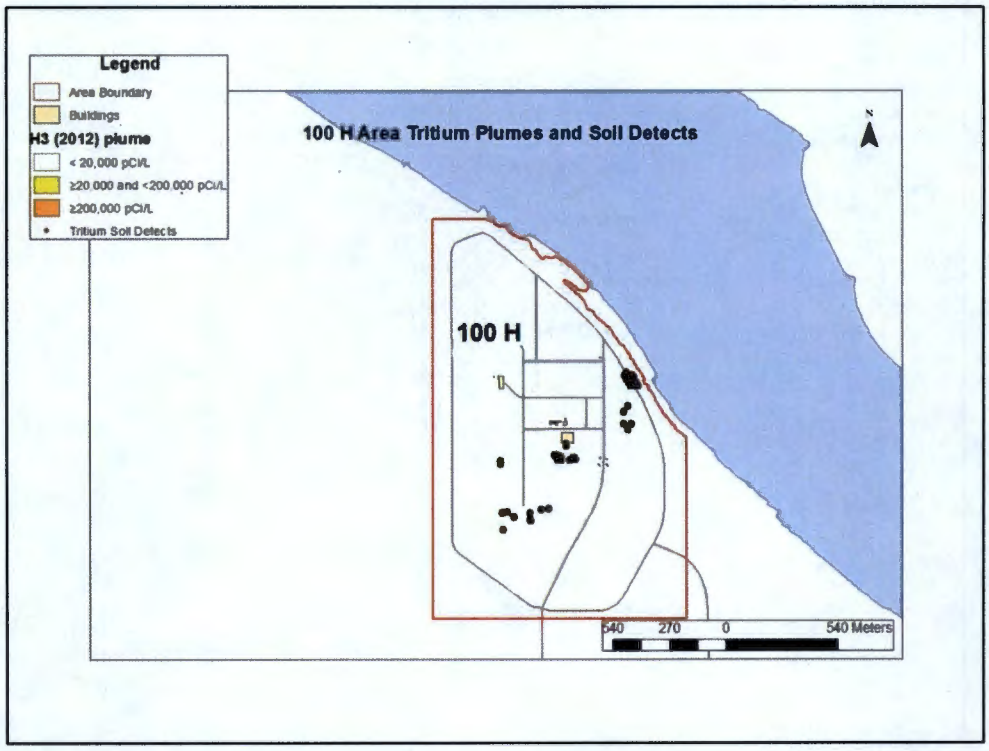


Figure 9. 100-H Area Tritium Plumes and Soil Detects

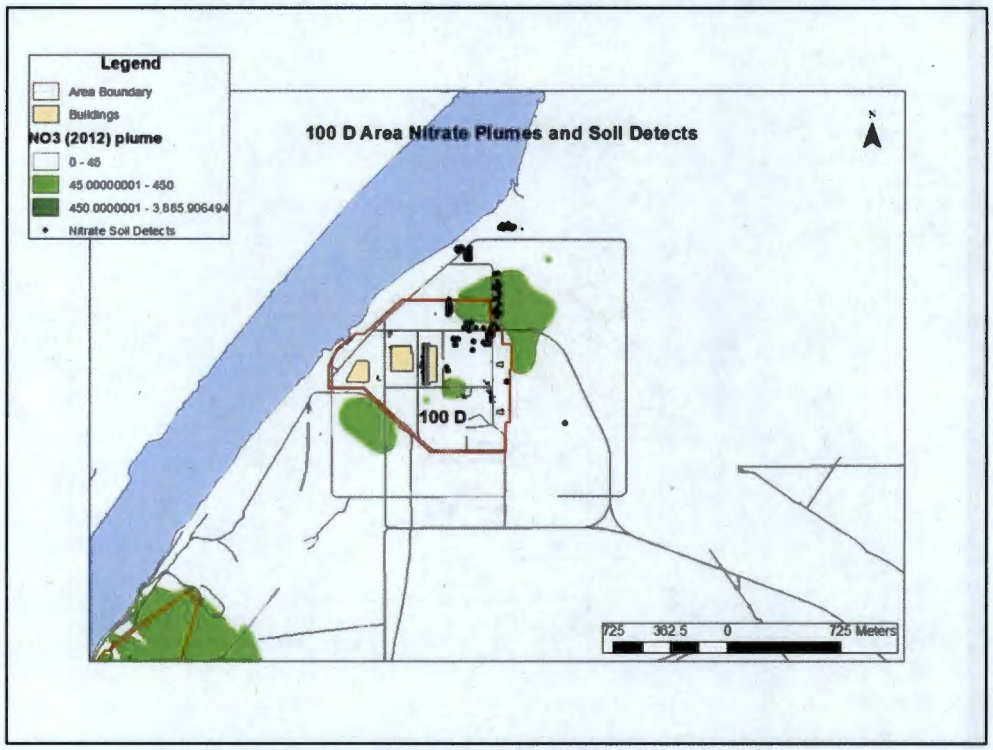


Figure 10. 100-D Area Nitrate Plumes and Soil Detects

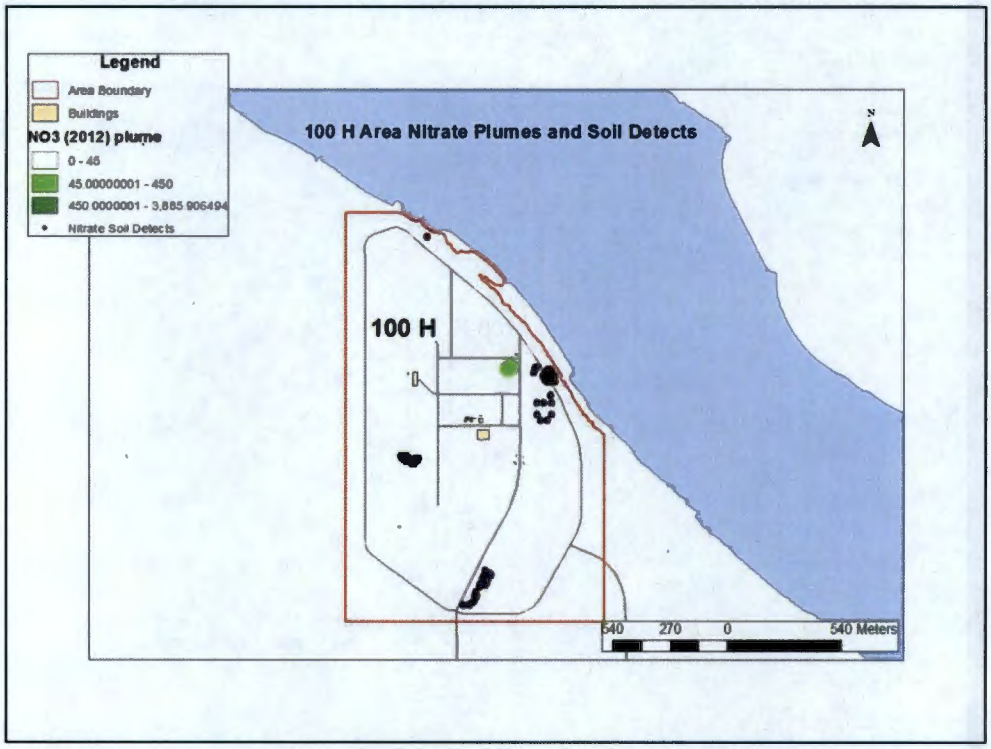


Figure 11. 100-H Area Nitrate Plumes and Soil Detects

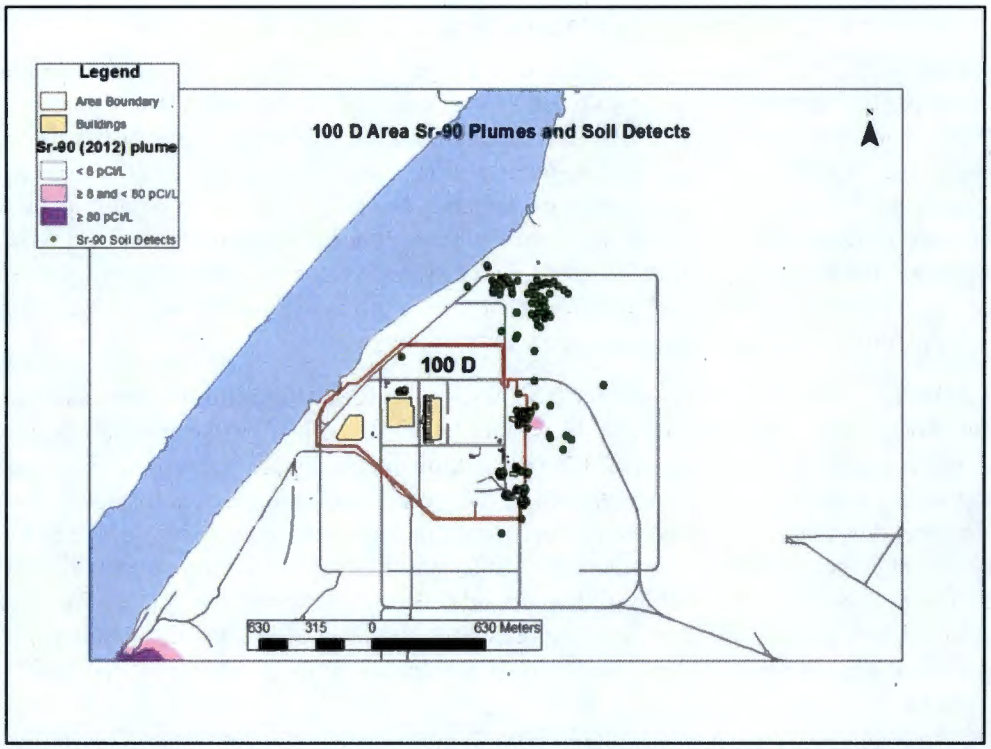


Figure 12. 100-D Area Strontium-90 Plumes and Soil Detects

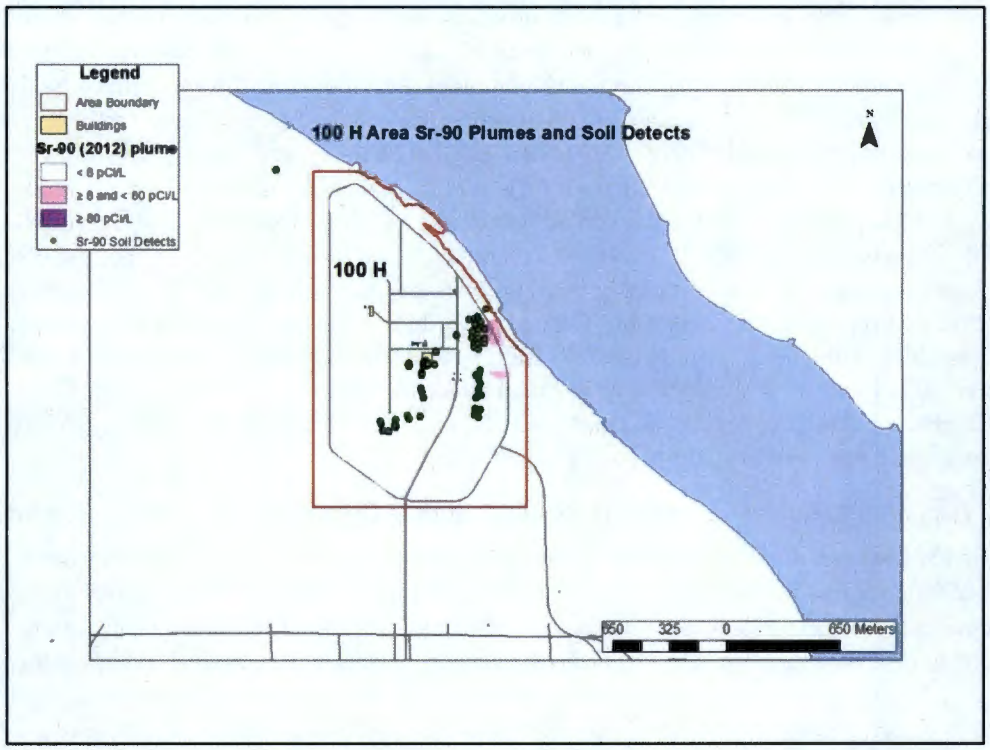


Figure 13. 100-H Area Strontium-90 Plumes and Soil Detects

5.1.4 Calculation of Soil Screening Levels and Preliminary Remediation Goals

In post-processing of the STOMP surface flux files, the peak groundwater concentration within 1000 years for the predictive simulations (Section 5.1.2) was identified for each simulation. For each COPC, and for each source area (100-D or 100-H), the maximum of the peak concentrations simulated for the representative stratigraphic columns for that source area (Figure 1) was selected as the basis for calculation of the SSL (if the irrigation recharge scenario) or PRG (if the native vegetation recharge scenario). This process of using the maximum groundwater concentration result provided an additional bounding aspect to this calculation, because SSL and PRG values for all waste sites in a given source area are based on results for the stratigraphic column that is least protective for the range of stratigraphic columns representative of that source area.

Evaluation of SSL and PRG calculations for the full set of representative stratigraphic columns developed for all 100 Area source OUs indicates that the K_d threshold value (the K_d value at which the peak groundwater concentration does not exceed the breakthrough concentration threshold) is strongly influenced by the vadose zone thickness as well as the recharge scenario. Generally, for 70:30 initial source distributions, thicker vadose zone columns result in smaller K_d threshold values. The K_d threshold is denoted in Attachments B and C tabulations of SSL and PRG values that are presented in ascending K_d order (Tables B-1, B-2, and B-3; Tables C-1, C-2, and C-3), by a bold red line at the point where "NR" values result in each geographic area. Note the same SSL and PRG values are also tabulated in analyte-name ascending order for lookup convenience in Attachments B and C (Tables B-4, B-5 and B-6; Tables C-4, C-5 and C-6).

5.2 Site-Specific Modeling

DOE-RL/2011-50 provides a graded approach for calculation of SSL and PRG values. Under this graded approach, for which the first-level, generalized model is non-representative, or in cases where the bounding assumptions merit reconsideration for specific site conditions, may be evaluated further using a site-specific modeling approach. This approach combines the efficiency of a generalized modeling approach (first level) with the judicious use of site-specific modeling (second level) only where the additional modeling is merited. There were instances where a non-representative condition was potentially present regarding contamination for $K_d \geq 2.0$ mL/g contaminants in the deep vadose zone, which could signal that the 70:30 initial contaminant concentration model was unrepresentative for these sites. The conservatism of the 70:30 model was therefore tested (see Section 5.2.1, below) with the result that the conservatism was validated and no need for site-specific modeling was identified. No other instances of non-representative conditions were identified for 100-D and 100-H waste sites evaluated in this calculation (although six "special consideration" waste sites that were not included in the list of 100-D and 100-H waste site evaluation were examined separately; refer to Section 5.3). None of the waste sites exceeded the screening level (SSL values). Therefore, site-specific modeling was not necessary for any waste sites in the 100-D or 100-H sources OUs.

5.2.1 Validation of Conservative Basis for 70:30 Source Distribution for High K_d Contaminants

SGW-51818, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone*, recommends that for higher K_d contaminants ($K_d \geq 2$ mL/g) the most conservative assumption that contamination is uniformly distributed throughout the full thickness of the vadose zone can be considerably relaxed with respect to soil cleanup decisions at waste sites in the 100 Areas. Based on this conclusion, for higher K_d contaminants the upper 70% of the vadose zone below the clean backfill was assumed to be contaminated while the lower 30% was assumed uncontaminated. This is termed the 70:30 initial source distribution assumed for higher K_d contaminants, in contrast with the 100:0 initial source distribution assumed for lower K_d contaminants. However, the possibility that contaminant of higher K_d

contaminants could be present in the deeper portions of the vadose zone was recognized, and such case could be addressed if appropriate using site-specific modeling under the graded approach (DOE/RL-2011-50).

RI borehole data collected in the 100-D/H area provided several indications that some higher K_d contaminants ($K_d \geq 2$ mL/g) were present in the lower portion of the vadose zone, leading to the need to evaluate the appropriateness of the 70:30 initial contaminant distribution in these locations. The process for identifying specific waste sites and COPCs that merit further consideration is found in Attachment E to this ECF, and excluded cases for which:

- boreholes did not sample the lower 30 percent of the vadose zone
- COPCs had no background values
- reported concentrations in the lower 30 percent of the vadose zone were within the range of background
- COPCs had $K_d > 25$ mL/g
- COPC was strontium-90

The reason for the $K_d > 25$ mL/g exclusion basis was that results from preliminary vadose zone modeling to develop PRGs indicated that COPCs with K_d values higher than this value result in non-representative (NR) values (i.e., do not breakthrough to groundwater at numerically significant levels), based on peak groundwater concentrations simulated within 1000 years. (Note: the lowest K_d value screened out under this exclusion was 49 mL/g). Strontium-90 was excluded because it was decided to assign the 100:0 initial concentration distribution to this constituent throughout the D/H area based on its prevalence throughout the vadose zone in many locations, presence in groundwater, and recognition that this contaminant is a recognized risk driver in the 100 Area.

Based on the evaluation above, the following waste sites and COPCs were identified as potential cases for which the 70:30 initial distribution representations may be non-conservative:

- 116-D-1A (trench), neptunium-237 (Figure 14)
- 116-D-7 (retention basin), antimony (Figure 15)
- 116-DR-9 (retention basin), acenaphthene (Figure 16)
- 116-H-1 (trench), phenanthrene and antimony (Figure 17 and Figure 18, respectively)
- 116-H-4 (pluto crib), antimony (Figure 19)
- 116-H-6 (solar evaporation basin), antimony (Figure 20)
- 116-H-7 (retention basin), antimony and molybdenum (Figure 21)
- 118-H-6 (reactor fuel storage basin), neptunium-237 (Figure 22)

For each case on the above list, the conservatism of the 70:30 initial concentration representations requires testing because the 70:30 initial source distribution was not intended to exclude the possibility of any deep contamination being present, but rather, to serve as a conservative (bounding) representation for higher K_d contaminants with respect to predicted peak groundwater concentration. Therefore, the conservatism of the cases identified in Attachment E was tested to determine if any of these cases were

non-conservative and therefore necessary to promote to a site-specific evaluation. For this conservatism testing, simulations are performed in pairs: once with the actual vertical contamination profile reported for the RI borehole (CDM1), and again using the 70:30 representation with the uniform concentration equal to the peak observed concentration in the RI borehole (CDM2; matching the essential function of the 70:30 representation relative to SSL and PRG values). The peak groundwater discharge predicted by these models were obtained from in each case in these pairs of simulations and compared. The conservatism of the 70:30 initial concentration distribution was considered validated if:

- Validation Criteria 1: the simulated peak groundwater concentration obtained from observed contaminant distribution (CDM1) within 1000 years was less than the peak groundwater concentration obtained from the 70:30 distribution (CDM2), or
- Validation Criteria 2: the simulated peak groundwater concentration within 1000 years did not exceed the applicable water quality standards for groundwater and surface water (e.g., applicable regulations and requirements [ARARs], maximum contaminant levels [MCLs], or applicable water quality standards [AWQLs]) values) for each contaminant for both CDM1 and CDM2.

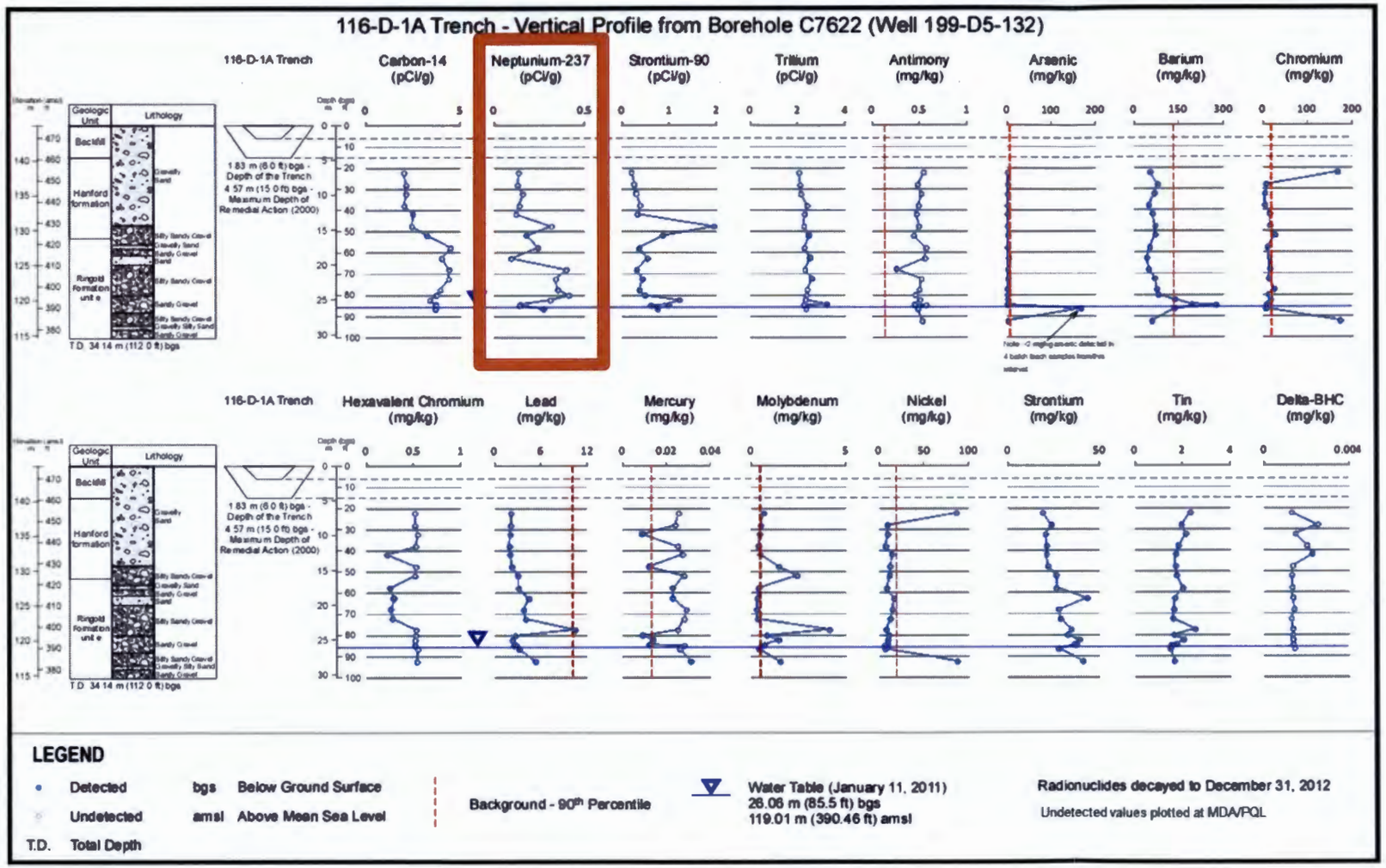
Figure 23 illustrates the two conceptual models, using the example of neptunium-237 vertical borehole measurements at waste site 116-D-1A.

For each of the waste sites evaluated, for the purpose of testing conservatism a single representative soil column was selected that most closely matched the site-specific stratigraphy for the site being evaluated for use in CDM1 evaluation. This is contrast to CDM2 (the general approach) in which the range of representative columns for a geographic area are simulated and the most conservative result from the range is selected in order to provide a bounding result applicable to all waste sites in that geographic area.

The specific surface soil identified for each waste site location is used to select the most site-specific appropriate recharge rates, which depend on surface soil type (Table 1). The irrigation recharge rates corresponding to the surface soil type was applied in the model. The representative column and surface soil type used in these site specific modeling is presented in Table 10.

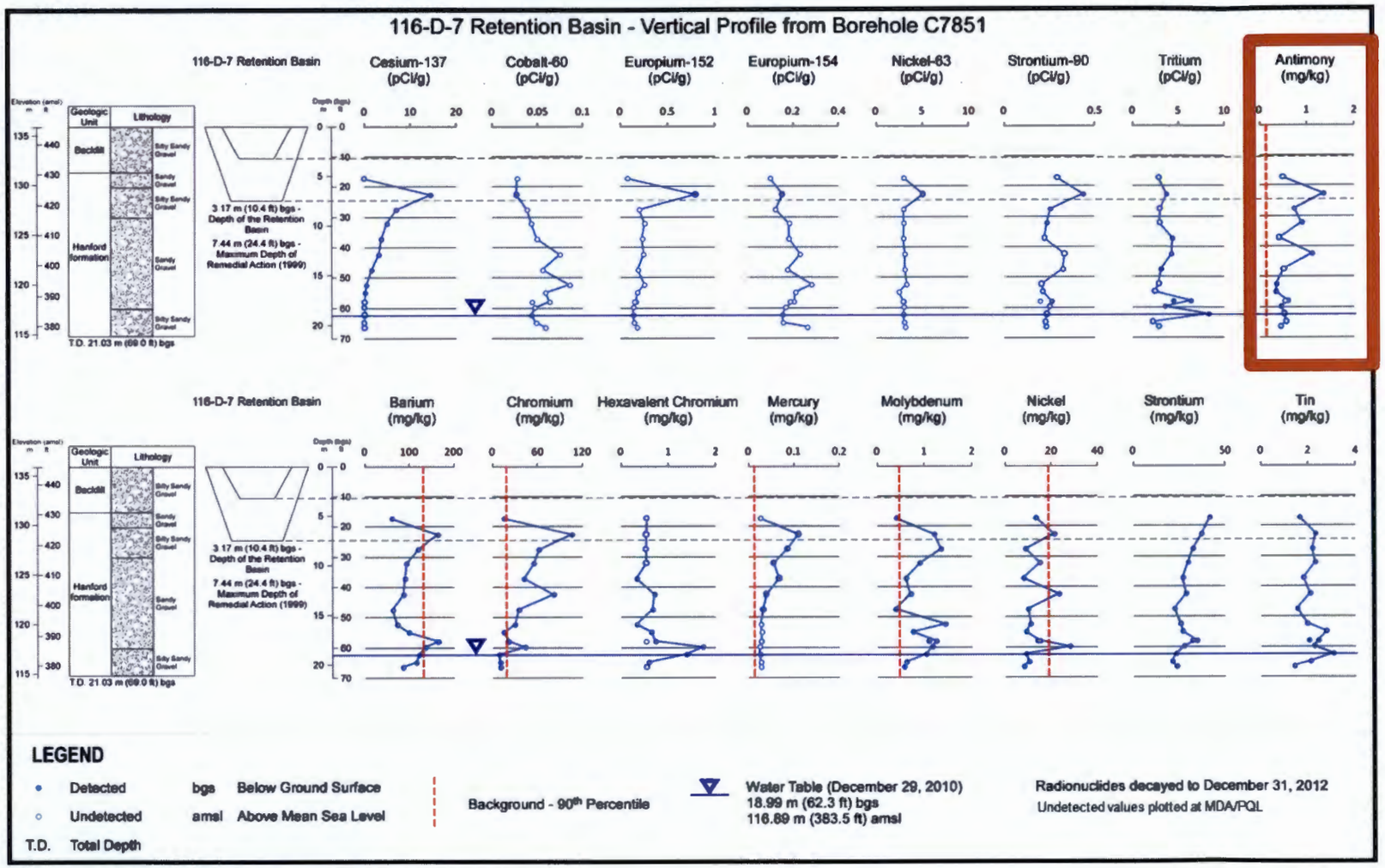
For CDM1 (actual contaminant distribution) the vertical distribution of contaminant observed in the borehole was input to the STOMP model. Concentration in the STOMP model nodes were interpolated using Excel "FORECAST" function from the vertical distribution of the observed data. The concentration was distributed along the entire 10m width of the waste site. Concentration was not applied in the 0.5-m zone above the water table for reasons discussed in Section 3.1. For CDM2 (the default 70:30 distribution), the maximum concentration used in CDM2 was applied uniformly over the upper 70% of the vadose zone below backfill. The lower 30% of the vadose zone was assigned zero concentration.

Results for the conservatism test modeling are presented in Table 10. For the 70:30 distribution (labeled CDM2) peak groundwater concentrations are higher than the actual distribution (labeled CDM1) in all cases evaluated when the 1000-year limit is not considered, indicating that the 70:30 distribution model (CSM2) is more conservative than the actual distribution model (CSM1) for every case evaluated for purposes of calculating SSL and PRG values. However, within the 1000-year period, four cases do not meet validation criteria 1 because CDM1 results in a higher peak groundwater concentration within 1000 years than CDM2 does. However, these cases all meet validation criteria 2 (well below respective applicable water quality standards for groundwater and surface water values for each contaminant for both CDM1 and CDM2.



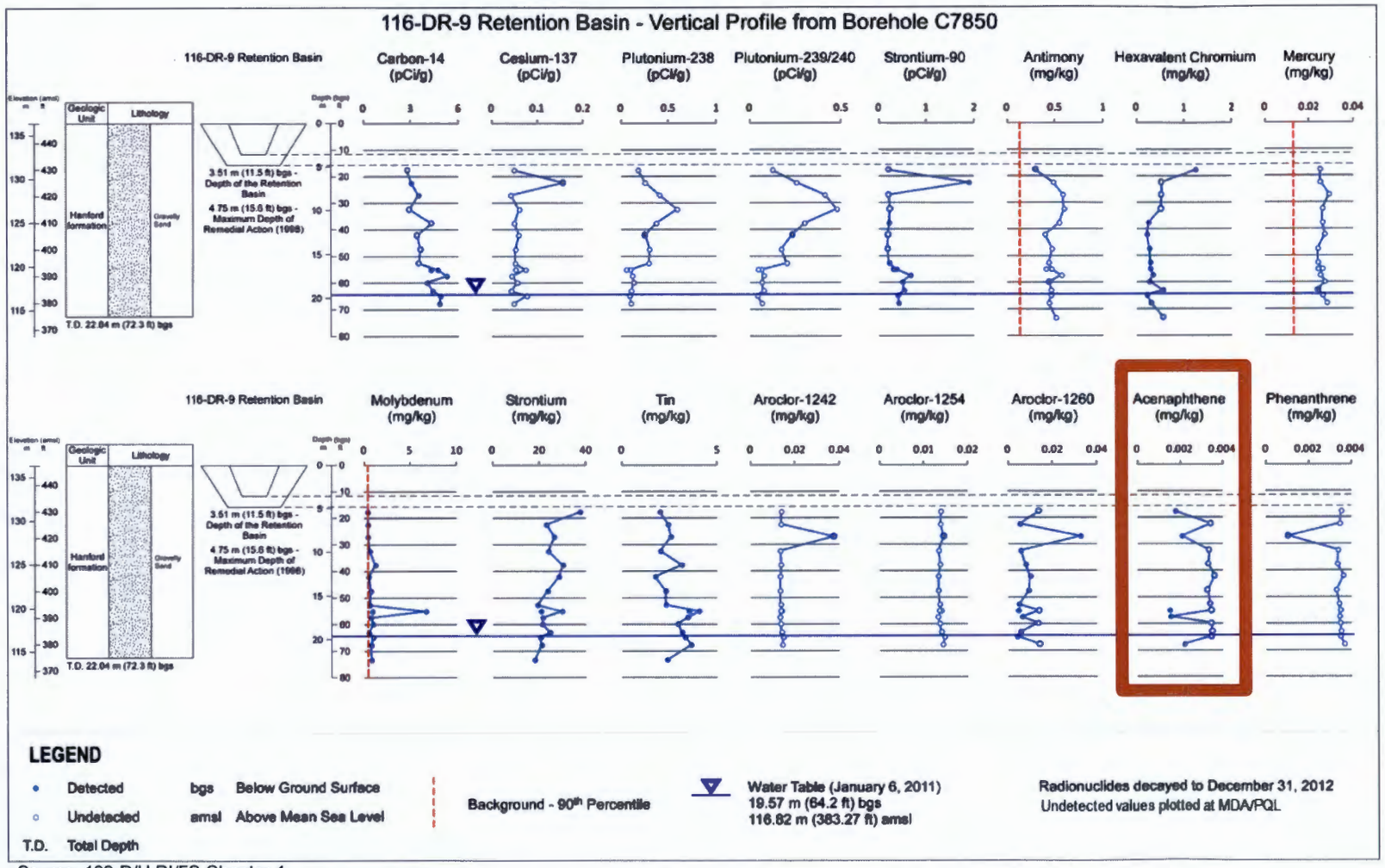
Source: 100-D/H RI/FS Chapter 4

Figure 14. Observed Contaminant Distribution in the Vadose Zone (116-D-1A, Borehole C7622, Neptunium-237)



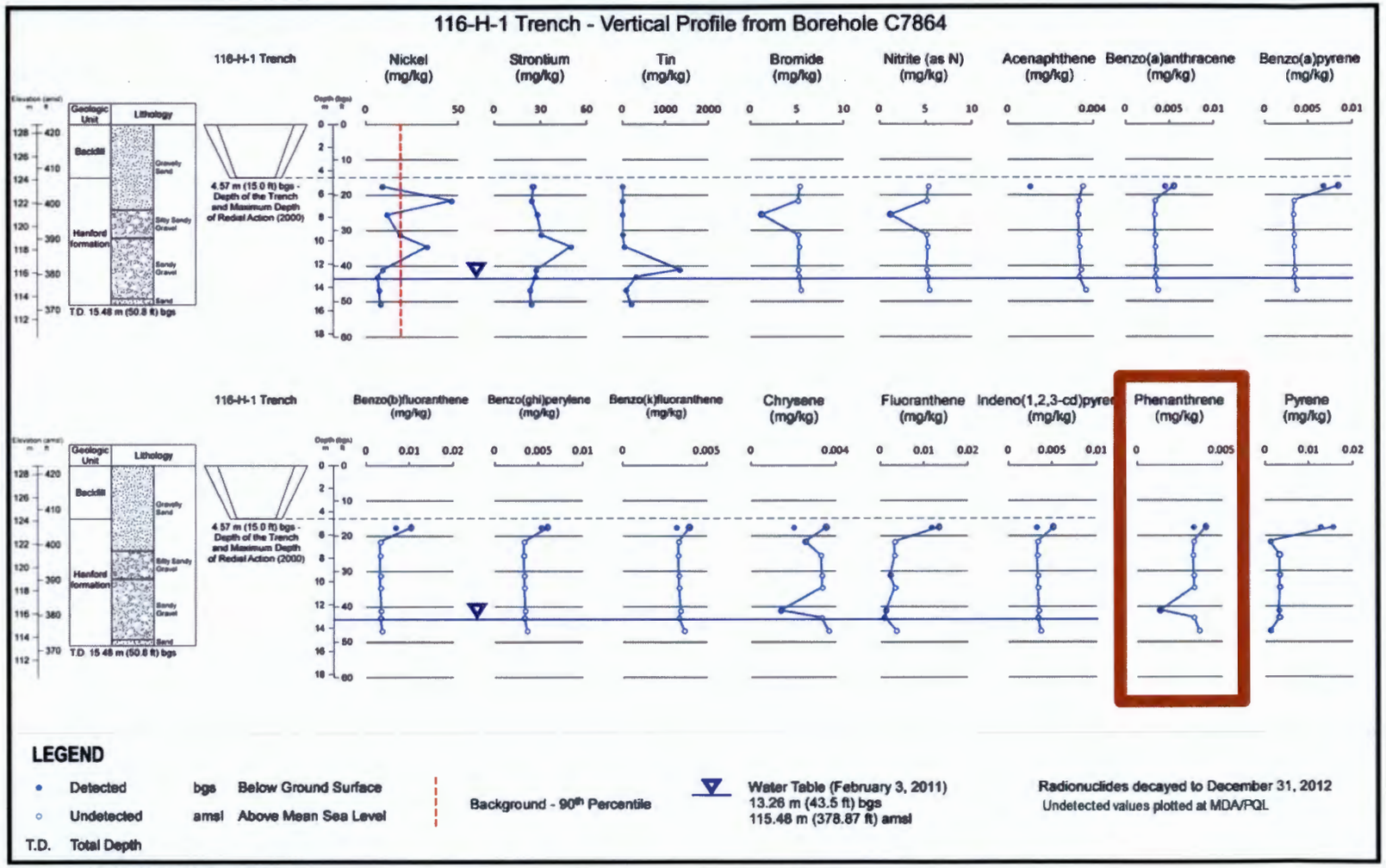
Source: 100-D/H RI/FS Chapter 4

Figure 15. Observed Contaminant Distribution in the Vadose Zone (116-D-7, Borehole C7851, Antimony)



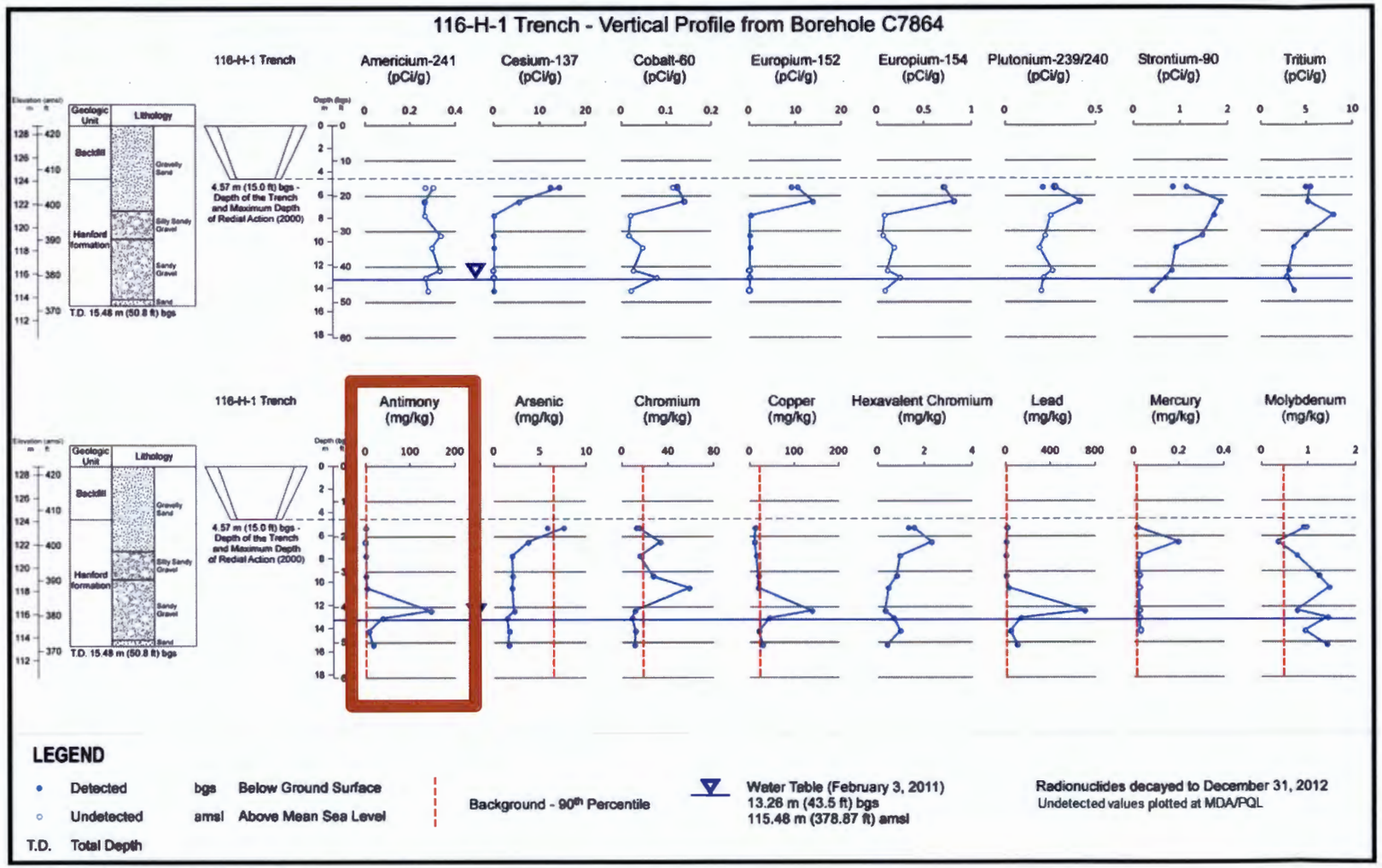
Source: 100-D/H RI/FS Chapter 4

Figure 16. Observed Contaminant Distribution in the Vadose Zone (116-DR-9, Borehole C7850, Acenapthene)



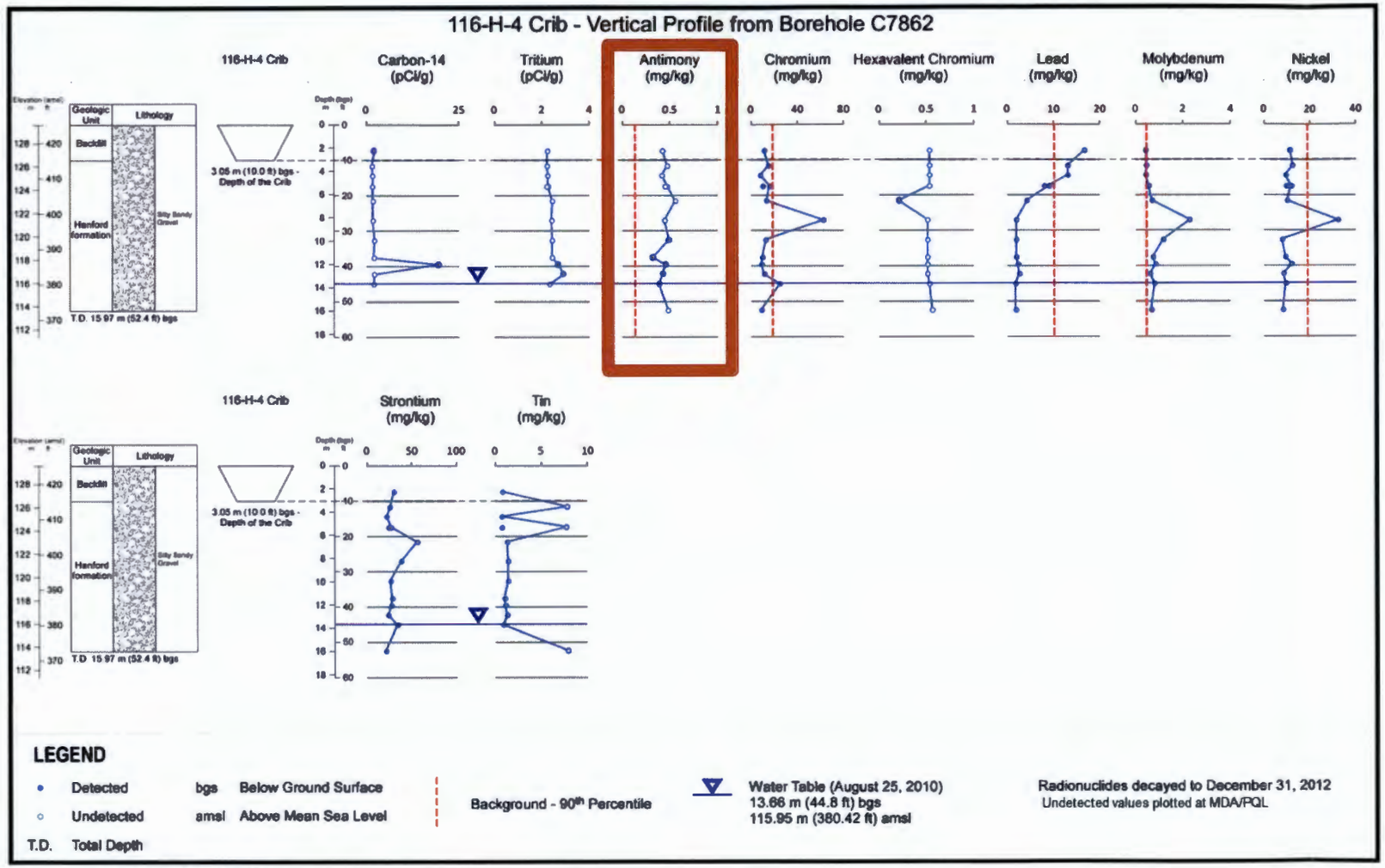
Source: 100-D/H RI/FS Chapter 4

Figure 17. Observed Contaminant Distribution in the Vadose Zone (116-H-1, Borehole C7864, Phenanthrene)



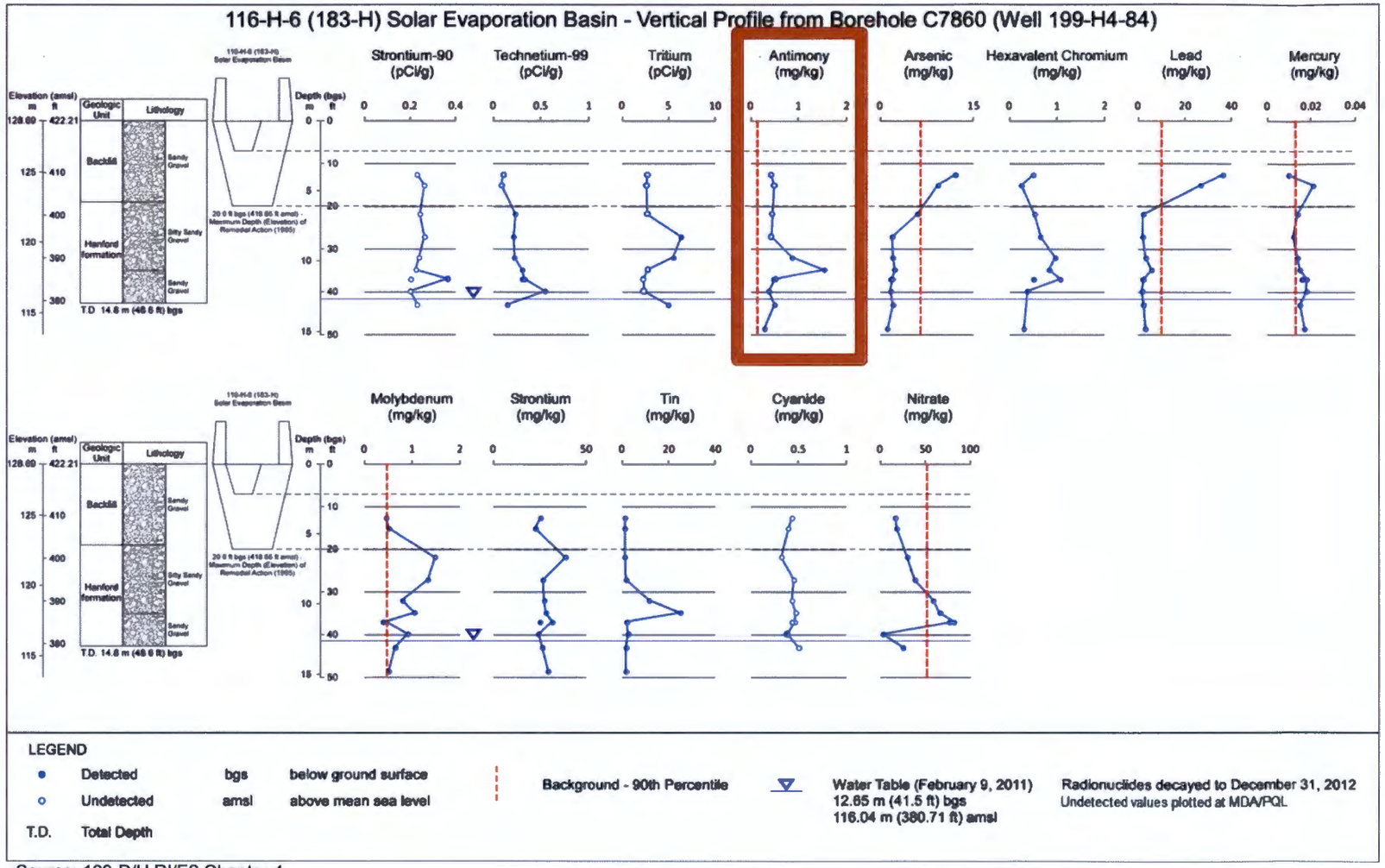
Source: 100-D/H RI/FS Chapter 4

Figure 18. Observed Contaminant Distribution in the Vadose Zone: (116-H-1, Borehole C7864, Antimony)



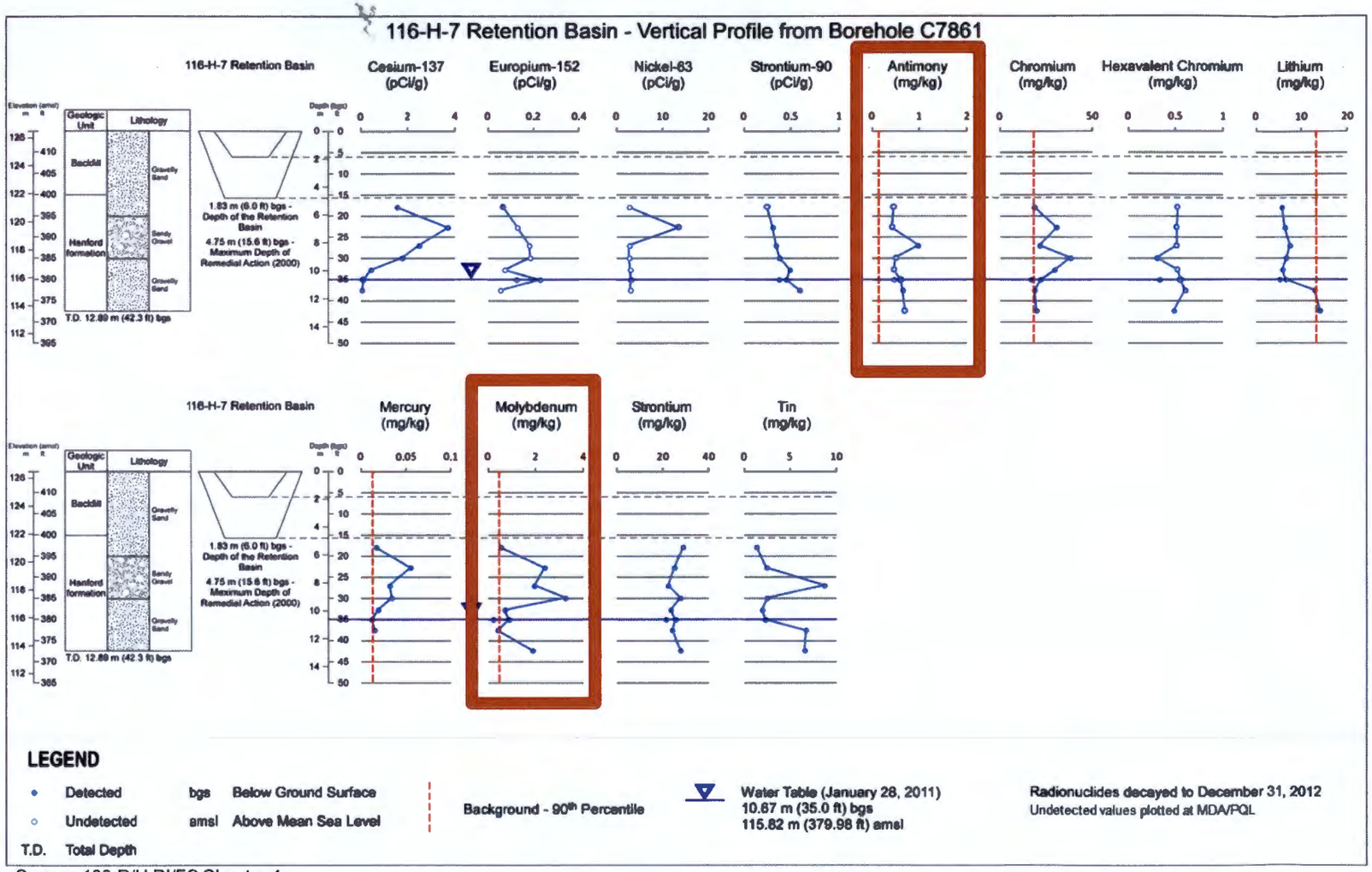
Source: 100-D/H RI/FS Chapter 4

Figure 19. Observed Contaminant Distribution in the Vadose Zone (116-H-4, Borehole C7862, Antimony)



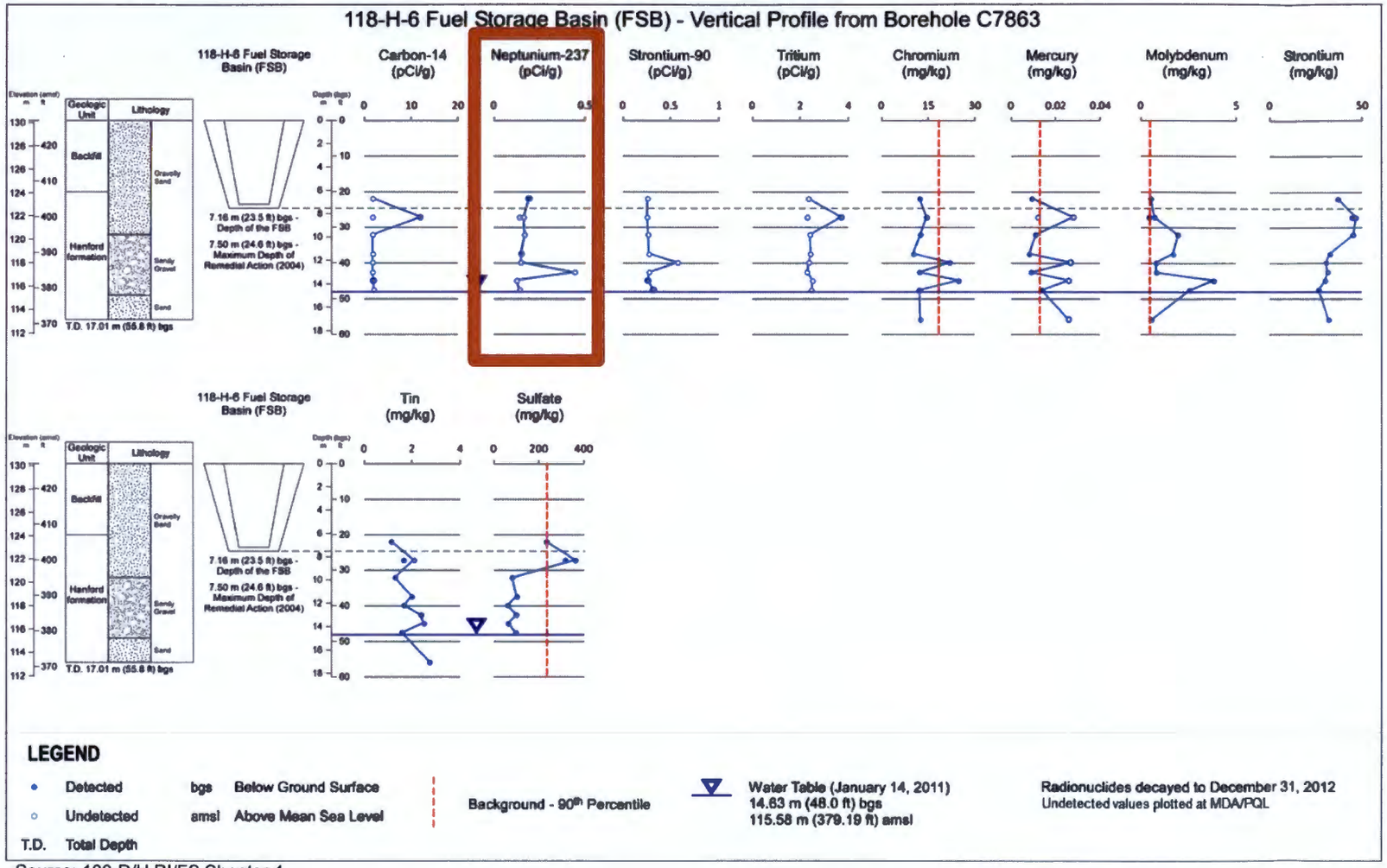
Source: 100-D/H RI/FS Chapter 4

Figure 20. Observed Contaminant Distribution in the Vadose Zone (116-H-6, Borehole C7860, Antimony)



Source: 100-D/H RI/FS Chapter 4

Figure 21. Observed Contaminant Distribution in the Vadose Zone (116-H-7, Borehole C7861, Antimony and Molybdenum)



Source: 100-D/H RI/FS Chapter 4

Figure 22. Observed Contaminant Distribution in the Vadose Zone (118-H-6, Borehole C7863, Neptunium-237)

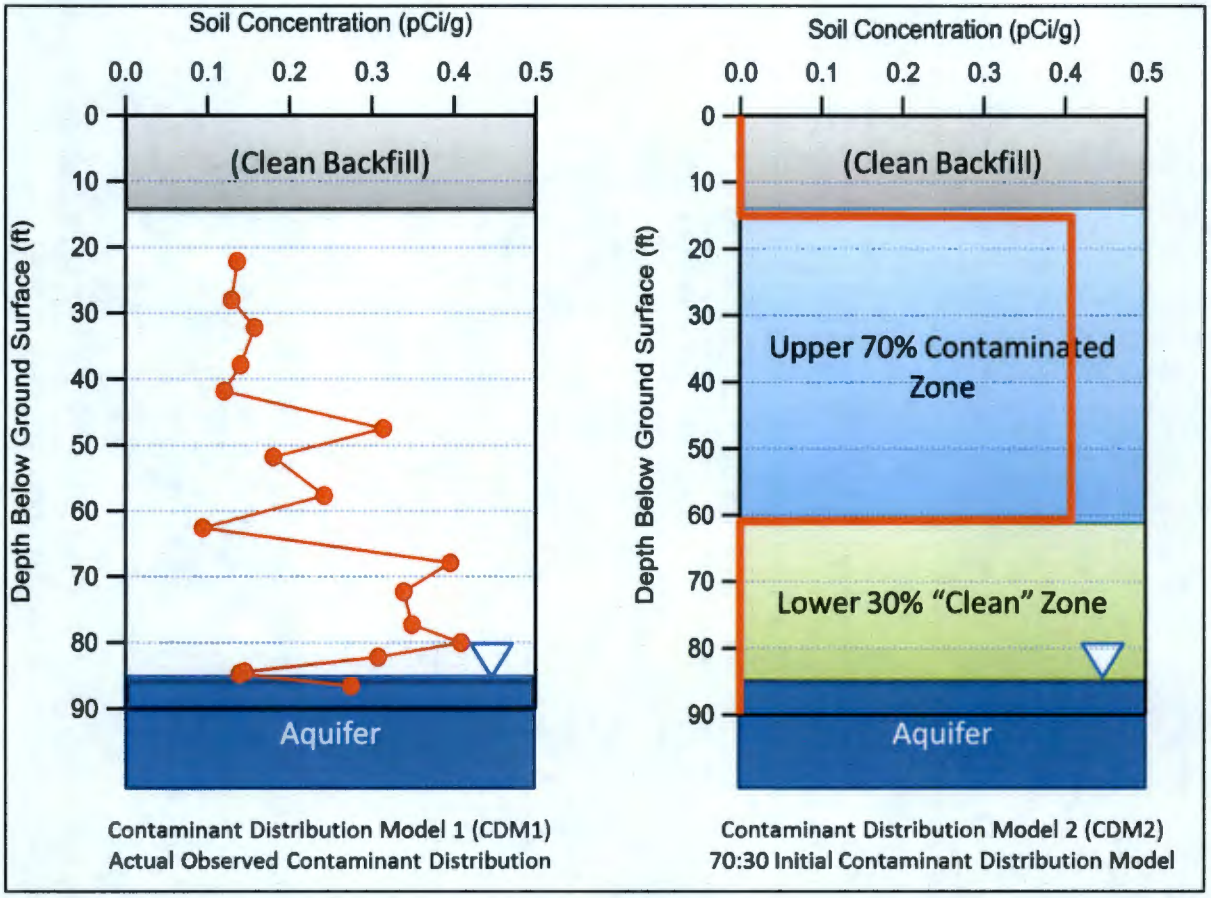


Figure 23. Illustrative Comparison (Neptunium-237 at 116-D-1A) of Initial Contaminant Distribution Models for CDM1 (Actual) and CDM2 (70:30) Cases Evaluated for Conservatism Testing of the 70:30 Distribution

Table 10. Results for the 70:30 Concentration Distribution Model Conservatism Testing Simulations

Waste Site	RI Borehole	Contaminant of Potential Concern	Representative Stratigraphic Column [b]	Surface Soil Type [c]	K_d (mL/g)	Ground-water Standard (µg/L)[a]	Peak Concentration (µg/L or pCi/L) [a]		Peak Concentration within 1000 years (µg/L or pCi/L) [a]	
							CDM1 [d] Actual Distribution	CDM2 [e] 70:30 Distribution	CDM1 [d] Actual Distribution	CDM2 [e] 70:30 Distribution
116-D-1A	199-D5-132	Neptunium-237	100-D Column 5	ESL	15	15	3.59E-01	4.17E-01	3.59E-01	< 1E-04
116-D-7	C7851	Antimony	100-D Column 6	ESL	3.76	6	3.64E-03	5.40E-03	3.64E-03	5.40E-03
116-D4-9	C7850	Acenaphthene	100-D Column 1	RS	6.12	960	9.01E-03	9.32E-03	1.11E-03	9.45E-04
116-H-1	C7864	Phenanthrene	100-H Column 1	BSL	16.7	No Value	3.71E-04	4.46E-04	3.71E-04	2.32E-04
116-H-1	C7864	Antimony	100-H Column 1	BSL	3.76	6	1.44E-02	3.01E-02	1.44E-02	3.01E-02
116-H-4	C7862	Antimony	100-H Column 1	BSL	3.76	6	2.52E-04	2.67E-04	2.52E-04	2.67E-04
116-H-6	C7860	Antimony	100-H Column 1	BSL	3.76	6	5.20E-04	7.38E-04	5.20E-04	7.38E-04
116-H-7	C7861	Antimony	100-H Column 1	BSL	3.76	6	3.24E-04	4.67E-04	3.24E-04	4.67E-04
116-H-7	C7861	Molybdenum	100-H Column 1	BSL	20	80	2.07E-04	2.97E-04	2.07E-04	2.97E-04
118-H-6	C7863	Neptunium-237	100-H Column 1	BSL	15	15	2.00E-02	2.30E-02	2.00E-02	1.50E-02

a. Neptunium-237 values are expressed as activity concentrations (pCi/L); all other contaminants of potential concern are expressed as mass concentrations (µg/L).

b. Representative stratigraphic column (see Figure 1) identified as the most closely approximating the stratigraphy at this waste site.

c. Surface soil type identified from soil maps as prevalent at the specific waste site: ESL = Ephrata silty loam or stony loam; RS = Rupert sand; BSL = Burbank silty loam) are determinant for effective recharge rates (SGW-50776).

d. CDM1 = contaminant distribution model 1, which uses the actual vertical contaminant distribution from RI borehole measurements.

e. CDM2 = contaminant distribution model 2, which uses the assumed bounding 70:30 uniform contaminant distribution.

Figure 24 presents an example pair of breakthrough curves, in this case for neptunium-237 at waste site 116-D1-A, for both the actual and 70:30 initial conditions, illustrating the impact of the two initial conditions as well as the higher peak groundwater concentration for the 70:30 contaminant distribution model of initial conditions.

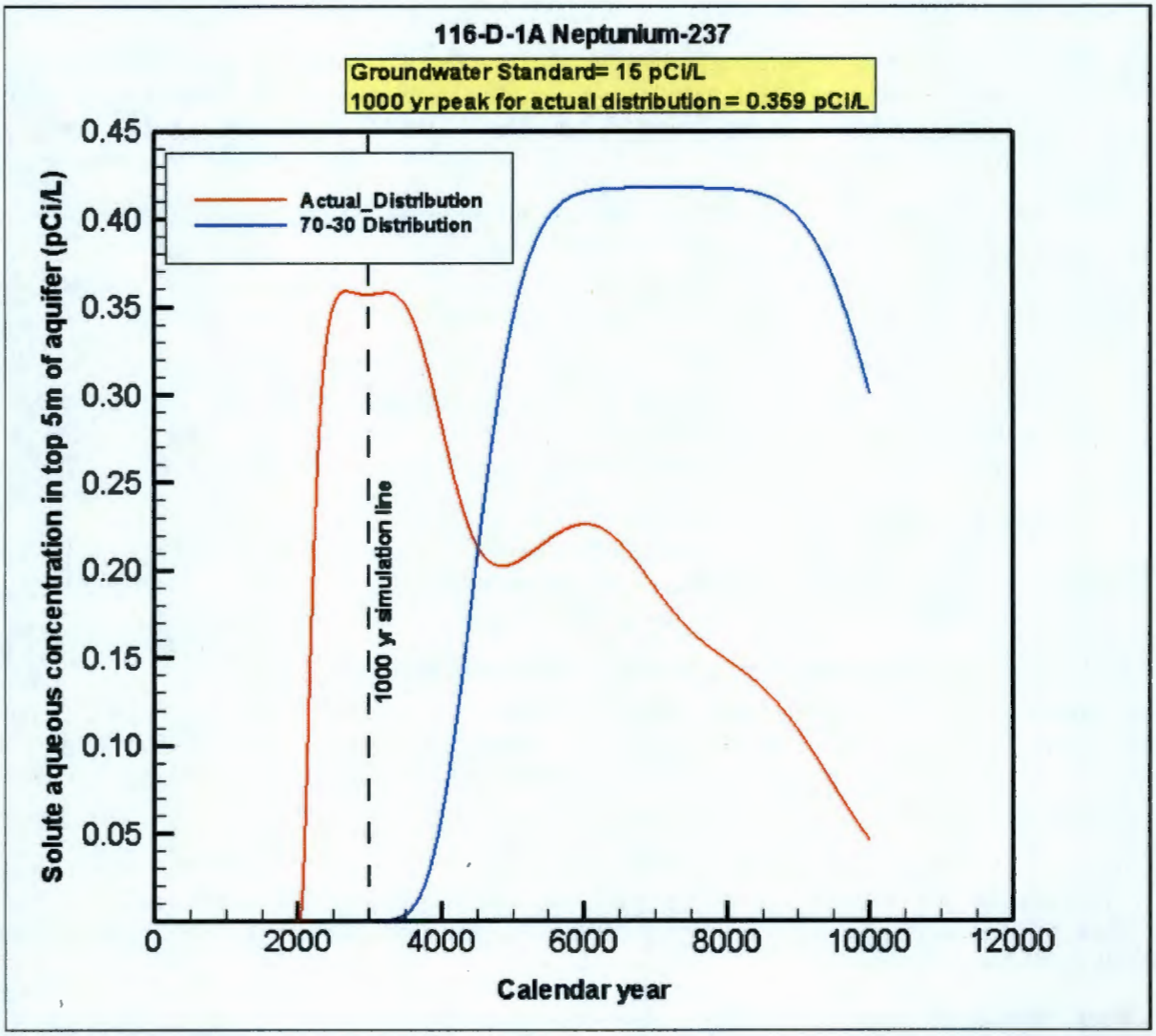


Figure 24. Breakthrough Curves for Neptunium-237 Simulated in Conservatism Testing for 70:30 Representation

5.3 Special Consideration Waste Sites

Six "special consideration" waste sites were identified for site-specific evaluation, for the following reasons:

- 128-H-1 – burn pit, excavated below groundwater level; hence, the SSL/PRG model is not representative where clean backfill extends below the water table. However, verification samples from the sides of the excavation require evaluation to demonstrate groundwater and surface water protection standards are met by residual contamination at the edges of the excavated waste site.

- 132-H-3 – effluent pumping station site, excavated below groundwater level; hence, the SSL/PRG model is not representative where clean backfill extends below the water table. However, verification samples from the sides of the excavation require evaluation to demonstrate groundwater and surface water protection standards are met by residual contamination at the edges of the excavated waste site.
- 116-H-5 – outfall structure, river-shore site, excavated below river level; hence, the SSL/PRG model is not representative. Cleanup verification samples from the upland side of the excavation, above the river inundation level, require evaluation to demonstrate groundwater and surface water protection standards are met by residual contamination at the edges of the excavated waste site.
- 100-D-8 – process sewer outfall site, near-river site; hence, the SSL/PRG model is not representative. Cleanup verification samples from the excavated surface, above the river inundation level, require evaluation to demonstrate groundwater and surface water protection standards are met by residual contamination at the edges of the excavated waste site.
- 100-D-65 - process sewer outfall site, near-river site; hence, the SSL/PRG model is not representative. Cleanup verification samples from the excavated surface, above the river inundation level, require evaluation to demonstrate groundwater and surface water protection standards are met by residual contamination at the edges of the excavated waste site.
- 100-D-66 - process sewer outfall site, near-river site; hence, the SSL/PRG model is not representative. Cleanup verification samples from the excavated surface, above the river inundation level, require evaluation to demonstrate groundwater and surface water protection standards are met by residual contamination at the edges of the excavated waste site.

5.3.1 Conceptual Representation of Special Consideration Waste Sites

A simplified conceptual representation of these waste sites, and projection of site structure and sample data onto a STOMP 1-D model domain, is shown in Figure 25 for waste sites 128-H-1 and 132-H-3, in Figure 26 for waste site 116-H-5, and in Figure 27 for waste sites 100-D-8, 100-D-65, and 100-D-66, respectively.

Portions of the near-river waste sites (100-D-8, 100-D-65, 100-D-66, and 116-H-5) that are below the ordinary high water level (OHWL) are not evaluated in the site-specific models presented in this ECF. These portions of these waste sites below the OHWL are evaluated as river sediment samples in the RI/FS (DOE/RL-2010-95, Appendix L, Tables L-72 and L-74).

5.3.2 STOMP 1D Model for Special Consideration Waste Sites

The generalized STOMP model used to calculate SSL and PRG values (which assume 70:30 initial source distribution model for $K_d \geq 2$ mL/g; see Section 3.2.4) could not be used for these waste sites because the residual contamination of concern in the margins of the excavated area is located near the water table. A site-specific STOMP 1D model was constructed to represent the abstractions shown in Figure 25, Figure 26, and Figure 27 to evaluate if groundwater and surface-water protection standards would be exceeded by residual contamination levels sampled at the edges of the excavated waste site.

The three 100-D waste sites (100-D-8, 100-D-65, and 100-D-66) have a very similar geologic stratigraphy, as interpreted from 100 Area Geologic Framework Model (ECF-Hanford-13-0020, *Process for Constructing a Three-dimensional Geologic Framework Model of the Hanford Site's 100 Area*). The average vadose zone thickness of these three waste sites is about 5 m. The ordinary high water level (OHWL) of 120 m was used to calculate the vadose zone thickness of these three 100-D waste sites.

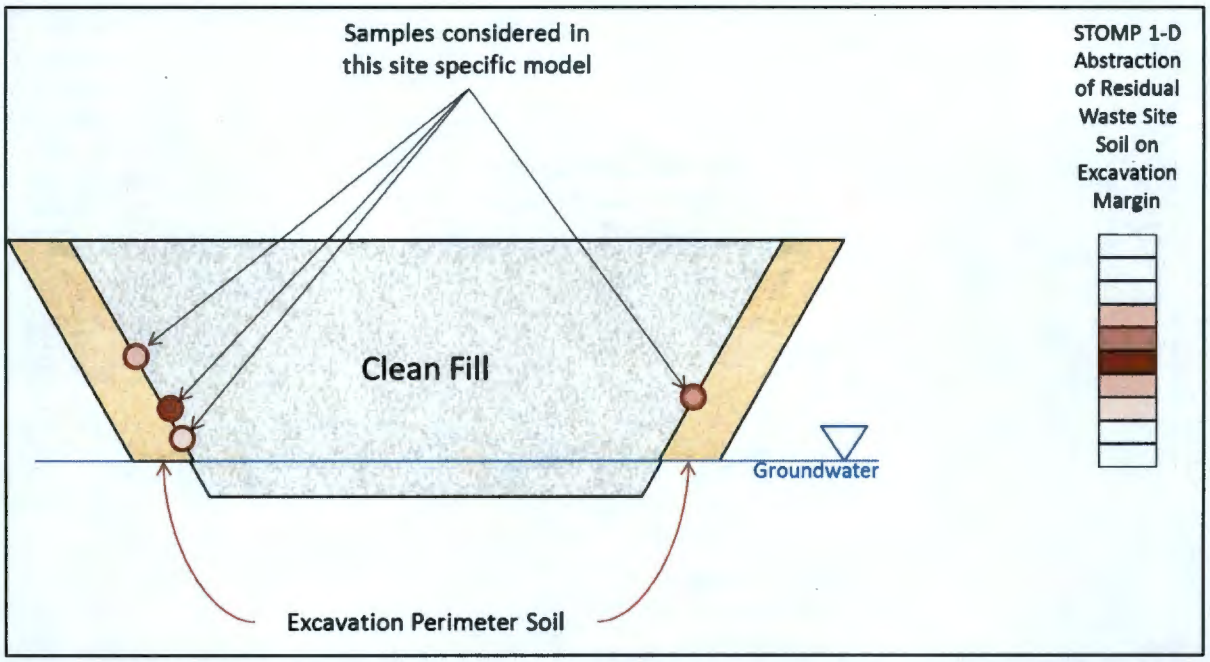


Figure 25. Conceptualization and Abstraction to STOMP 1-D Site-Specific Model for Special Consideration Waste Sites 128-H-1 and 132-H-3

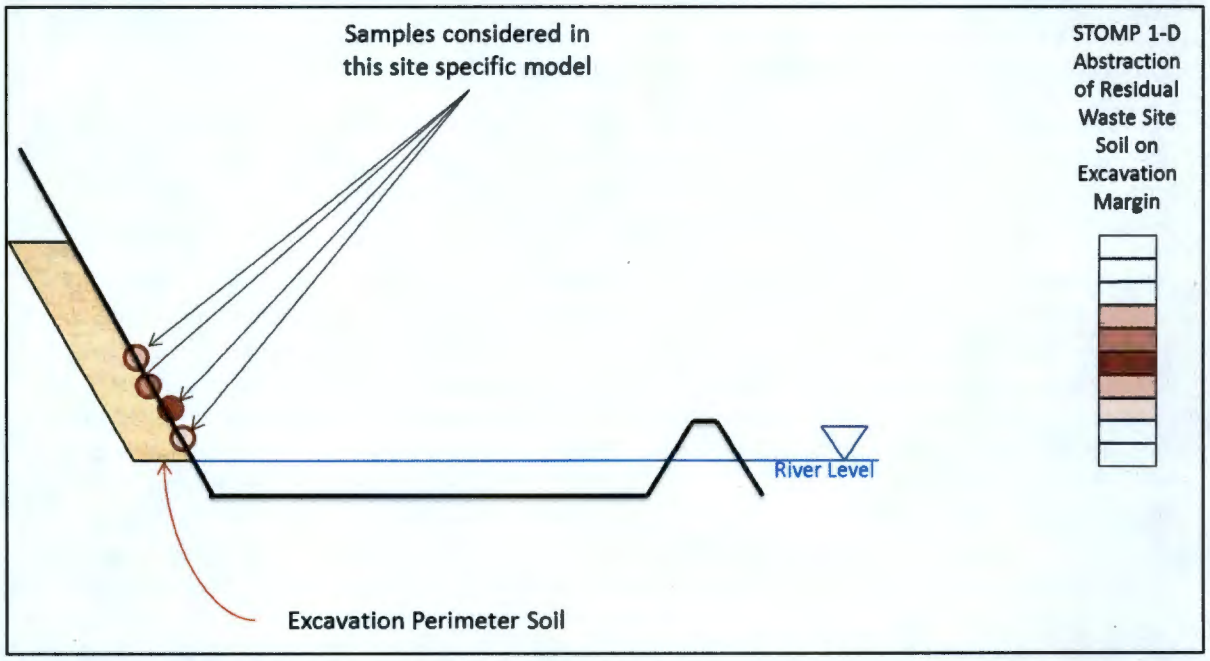


Figure 26. Conceptualization and Abstraction to STOMP 1-D Site-Specific Model for Special Consideration Waste Site 116-H-5

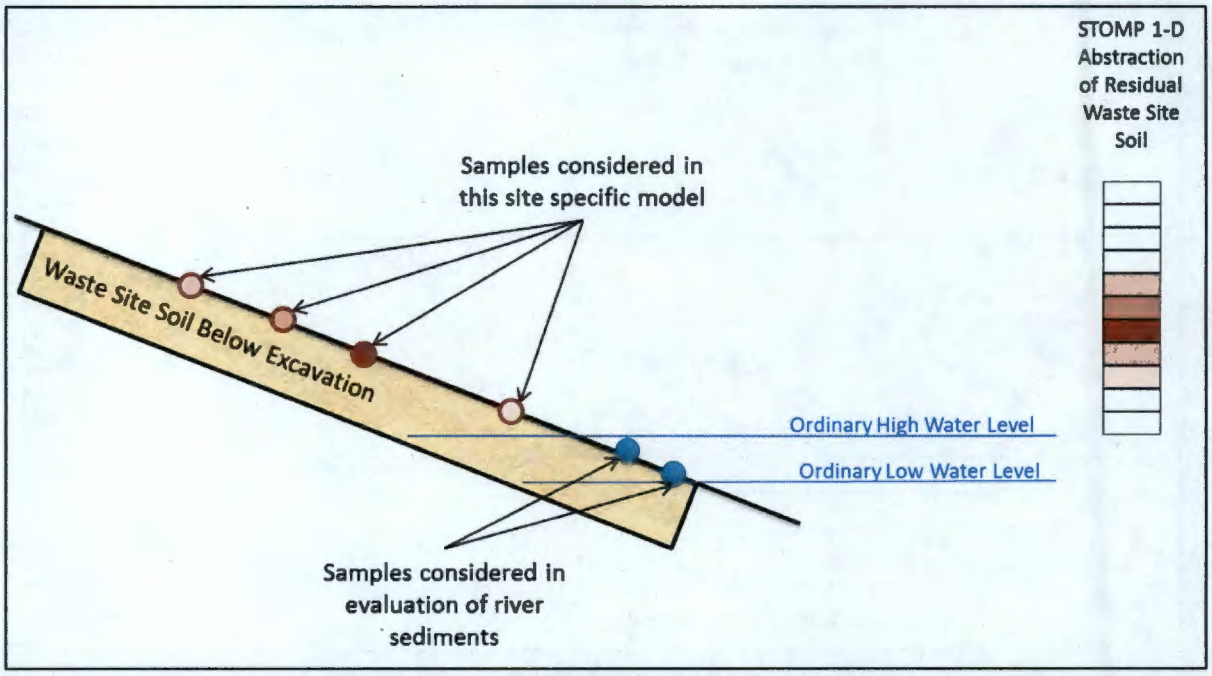


Figure 27. Conceptualization and Abstraction to STOMP 1-D Site-Specific Model for Special Consideration Waste Sites 100-D-8, 100-D-65, and 100-D-66

Based on the 100 Area geologic framework model, the only formation present in the vadose zone and top 5 m of the aquifer in these waste sites is the Ringold E unit.

For the three waste sites in 100-H area (128-H-1,132-H-3, and 116-H-5), a water table elevation of 117 m observed during verification sample collection was used to calculate the vadose zone thickness. An average vadose zone thickness of 10 m was calculated for these three waste sites and only geologic formation present in these locations is Hanford formation, based on the 100 area geologic model.

Based on this information, two stratigraphic soil columns were constructed: one to represent the 100-D special consideration waste sites, and another to represent the 100-H special consideration waste sites. These columns are depicted in Figure 28. Both the native vegetation recharge scenario (Section 3.2.1.1) and irrigation recharge scenario (Section 3.2.1.2) were evaluated using these site-specific models. All input parameters used for flow and transport simulations were consistent with values presented in Section 3.0, except for the initial contaminant source distribution. The full thickness of the vadose zone (except the bottom two nodes above the water table; Section 3.2.4) was assigned a unit concentration (1 mg/kg for chemicals and 1.0 pCi/m^3 for radionuclides) for the forward calculation step with STOMP (Section 2.5). That is, the 100:0 initial contaminant distribution was used for all COPCs evaluated (without regard to K_d) because of the very short vadose zone thickness and the fact that measurements of concern are located

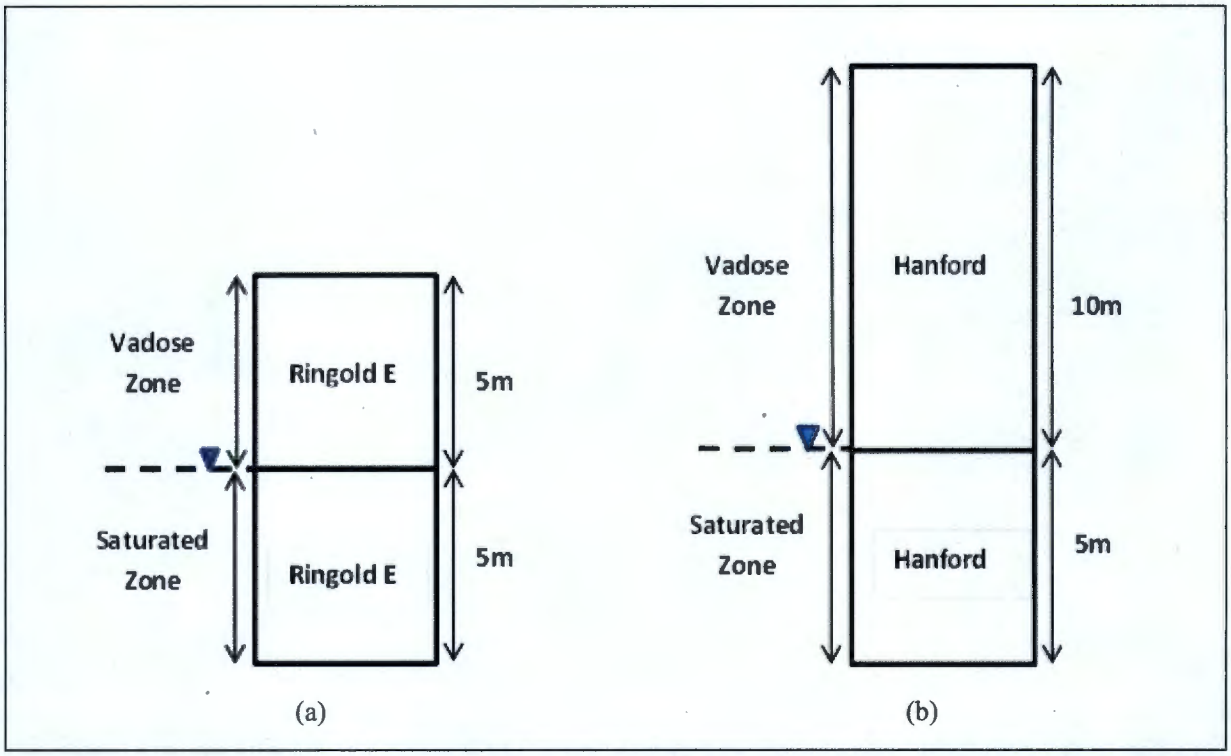


Figure 28. Stratigraphic Columns for (a) 100-D and (b) 100-H Source Areas Special Consideration Waste Sites

near the water table. A waste site width of 10 m was assumed to as the upper bound of the lateral extent of the contamination represented by the samples collected at the margins of these excavated sites. Site-specific SSL and PRG values were calculated in the back-calculation step using the methodology described in Section 2.5 using the peak groundwater concentration within 1000 years to calculate the SSL and PRG values using Equation 1 and Equation 2, respectively.

Verification samples data collected from these waste sites were extracted from HEIS to compare with the calculated SSL and PRG values. Any COPC that lacked a K_d value, and/or that lacked a surface water and groundwater protection value, was excluded from this evaluation. Because of the high volume of the resulting data set, full results of the evaluation for all COPCs are not presented here. Only a relatively few COPCs had verification sample concentrations that exceeded the calculated SSL value: the results of these cases are reported in Table 11 (for 100-D special consideration waste sites) and in Table 12 (for 100-H special consideration waste sites). Note the comparison results for the full set of COPCs evaluated is preserved in CHPRC's Environmental Model Management Archive (EMMA) along with other model input and output files used in the preparation of this ECF. As presented in Table 11, arsenic, copper and mercury concentrations in some of the samples from the 100-D waste sites exceeded the SSL for 100-H sites only. No COPC soil concentration exceeded the groundwater or surface water PRG values at either 100-D or 100-H special consideration waste sites.

Table 11. Comparison of Verification Data for Special Consideration Waste Sites 100-D-8, 100-D-65, and 100-D-66 to Site-Specific SSL and PRG Values for those Cases with SSL Exceedances

Site	Analyte	CAS#	Units	Number of Results	Number of Detects	Min Detect	Max Detect	Mean Detect	Median Detect	Max Detect Sample #	GW_SSL	No. of Detects > GW_SSL	SW_SSL	No. of Detects > SW_SSL	GW_PRG	No. of Detects > GW_PRG	SW_PRG	No. of Detects > SW_PRG
100-D-65_focused_concrete__Focused	Arsenic	7440-38-2	µg/kg	1	1	33300	33300	33300	33300	J1MM46	1.09E+02	1	2.81E+05	None	4.58E+04	None	1.18E+08	None
100-D-65_focused_concrete__Focused	Copper	7440-50-8	µg/kg	1	1	33300	33300	33300	33300	J1MM46	8.78E+05	None	1.23E+04	1	2.30E+08	None	3.23E+06	None
100-D-65_shallow_>OHWM	Arsenic	7440-38-2	µg/kg	11	11	1940	3030	2471.82	2540	J1PVL8	1.09E+02	11	2.81E+05	None	4.58E+04	None	1.18E+08	None
100-D-65_shallow_>OHWM	Copper	7440-50-8	µg/kg	11	11	11600	15200	13136.36	12800	J1PVL5	8.78E+05	None	1.23E+04	8	2.30E+08	None	3.23E+06	None
100-D-66_shallow_>OHWM	Mercury	7439-97-6	µg/kg	10	3	38.3	274	118.767	44	J1PXJ6	8.76E+03	None	5.26E+01	1	8.88E+06	None	5.33E+04	None
100-D-8_shallow_>OHWM	Arsenic	7440-38-2	µg/kg	10	10	1500	3200	2100	2000	J1MXX2	1.09E+02	10	2.81E+05	None	4.58E+04	None	1.18E+08	None
100-D-8_shallow_>OHWM	Copper	7440-50-8	µg/kg	10	10	9500	16400	12950	12800	J1MXX2	8.78E+05	None	1.23E+04	7	2.30E+08	None	3.23E+06	None

Table 12. Comparison of Verification Data for Special Consideration Waste Sites 128-H-1, 132-H-3, and 116-H-5 to Site-Specific SSL and PRG Values for those Cases with SSL Exceedances

Site	Analyte	CAS#	Units	Number of Results	Number of Detects	Min Detect	Max Detect	Mean Detect	Median Detect	Max Detect Sample #	GW_SSL	No. of Detects > GW_SSL	SW_SSL	No. of Detects > SW_SSL	GW_PRG	No. of Detects > GW_PRG	SW_PRG	No. of Detects > SW_PRG
116-H-5_Deep	Arsenic	7440-38-2	µg/kg	24	24	1100	17700	5091.66	4740	J19YD5	9.31E+02	24	2.39E+06	None	3.52E+05	None	9.06E+08	None
116-H-5_Shallow	Arsenic	7440-38-2	µg/kg	12	12	1100	7650	4398.33	4535	J19YC7	9.31E+02	12	2.39E+06	None	3.52E+05	None	9.06E+08	None
128-H-1_Deep	Arsenic	7440-38-2	µg/kg	12	12	1700	6000	3133.33	2800	J1JCV1	9.31E+02	12	2.39E+06	None	3.52E+05	None	9.06E+08	None
128-H-1_Shallow_AreaC	Arsenic	7440-38-2	µg/kg	13	13	2500	18600	7209.23	4380	J1B8B2	9.31E+02	13	2.39E+06	None	3.52E+05	None	9.06E+08	None
128-H-1_Shallow_AreaD	Arsenic	7440-38-2	µg/kg	12	12	2260	10700	4060	3310	J1B8C6	9.31E+02	12	2.39E+06	None	3.52E+05	None	9.06E+08	None
128-H-1_Shallow_AreaD	Mercury	7439-97-6	µg/kg	12	6	8	1070	198.5	27.5	J1B8B7	7.09E+04	None	4.26E+02	1	6.35E+07	None	3.81E+05	None

6 Results/Conclusions

The results of this calculation include tabulated SSL and PRG values (described in Section 6.1) and sensitivity studies on model results (described in 6.2).

6.1 Soil Screening Value and Preliminary Remediation Goal Results

As described in Section 5.1, the maximum of the peak groundwater concentrations calculated with STOMP for the range or stratigraphic columns for each source area (100-D or 100-H) using the irrigation recharge scenario was used in Equation 1 to compute the SSL value for each COPC. The resulting SSL values protective of surface water and of groundwater are reported for each COPC in Attachment B to this ECF.

Similarly, the maximum of the peak groundwater concentrations from the range of stratigraphic columns simulated for each source area (100-D or 100-H) using the native vegetation recharge scenario was used in Equation 2 to compute the PRG value for each COPC. The resulting PRG values protective of surface water and groundwater are reported for each COPC in Attachment C to this ECF.

Note the following provisions apply with regard to SSLs and PRGs reported in Attachments B and C to this ECF, respectively:

- For COPCs for which an applicable water quality standard is not available, the "NA" symbol was applied to the SSL and PRG values (Section 2.5).
- Breakthrough was assumed not to occur if the simulated peak concentrations in groundwater within the 1000-year limit did not exceed 0.0001 μg/L for non-radionuclide COPCs or 0.0001 pCi/m^3 for radionuclide COPCs, in at least one representative stratigraphic columns simulated (Section 2.5.1). In these instances, the "NR" symbol was applied for these COPCs to designate a non-representative result, signifying that the results were below a level of numerical significance.
- If the calculated value for any SSL or PRG was less than the estimated quantitation limit (EQL) for soil concentration for a given COPC, then the SSL or PRG value was set equal to the EQL for that COPC (Section 2.5.2).
- If the calculated SSL or PRG value for any COPC exceeded the physical upper bound (389,000 mg/kg), then that SSL or PRG value was truncated at 389,000 mg/kg (Section 2.5.3).
- SSL and PRG values for Cr(VI) were limited to a maximum value of 6.0 mg/kg (Section 2.5.4) because the K_d value used in the model was derived from experiments with soil concentration less than that value. Thus, there is no basis to infer greater PRGs for Cr(VI) based on these data (ECF-Hanford-11-0165).

The SSL and PRG values reported in this calculation are applicable only to sites and COPCs where the conditions and assumptions underpinning this calculation is representative. Some waste sites may require a more rigorous investigation of site-specific conditions than those underlying the SSL and PRG values listed in Attachments B and C to this ECF.

6.2 Sensitivity Analyses

Results for sensitivity analyses performed are reported and evaluated in the sub-sections that follow.

6.2.1 Sensitivity Analysis: Backfill Depth Influence on Peak Groundwater Concentration

The assumed thickness of the backfill (15 ft) is considered in this sensitivity analysis to evaluate if the impact on SSL and PRG values that would result from varying this assumed thickness. The greater the thickness of the backfill, which is simulated as having a zero initial concentration (clean backfill), the less contaminant mass is present in the vadose zone profile. At one extreme, if backfill extended to the water table, then there would be no residual contaminant mass in the profile (and SSL and PRG values would be irrelevant). At the other extreme, if no backfill were present at all (backfill thickness of 0 m), then the maximum contaminant mass would be present in the soil profile under either the 100:0 or 70:30 contaminant distribution model (as appropriate).

Mitigating this is the fact that the backfill is located at the top of the profile. It is observed that the SSL and PRG values developed in this ECF, being derived from peak groundwater concentration predicted within 1000 years by the STOMP model, are strongly a function of the proximity of the bottom of the uniform concentration profile relative to the water table and the mobility of the COPC being evaluated. The contaminant mass distributed in the upper portion of the profile is observed not to affect the magnitude of the peak groundwater concentration, but may extend the duration of that peak groundwater concentration. Because only the peak groundwater concentration is used to derive the SSL or PRG (not the duration), it is reasonable to expect that assuming even no clean backfill (an extreme case) may have little or no affect on the value of the groundwater peak concentration. Therefore, the most efficient evaluation is to simulate the same model used to develop SSL and PRG values but with the contaminated zone extending to the ground surface (i.e., no clean backfill) and compare the resulting model-predicted groundwater concentration from this sensitivity case to the base result that includes 15 ft of clean backfill. If the results indicate similar groundwater peak concentrations, then it is shown that the results are insensitive to the assumed backfill thickness.

Two sensitivity cases were run for this direct evaluation, using 100-H representative stratigraphic column 1.In the first case, a 100:0 initial source distribution for an unsorbed COPC (K_d = 0 mL/g) was simulated with and without clean backfill present. In the second case, a 70:30 initial source distribution for a sorbed COPC with K_d = 2.04 mL/g was simulated with and without clean backfill present. Higher K_d values than 2.04 mL/g were not evaluated here because the transport time for such retarded COPC mass from in the upper part of the soil profile would not reach groundwater in 1000 years. The results for the K_d = 0 mL/g case is shown in Figure 29 and for the K_d = 2.04 mL/g case in Figure 30. These results indicate that the peak groundwater concentration (and hence, the SSL and PRG values derived from it) are insensitive to the value of the assumed backfill thickness.

6.2.2 Sensitivity Analysis: Evaluation of an Alternative Conceptual Model for Initial Distribution and Mobility of Hexavalent Chromium

The conceptual model for the initial distribution of hexavalent chromium in the vadose zone followed that used for other low-K_d COPCs, namely, the 100:0 initial contamination distribution model (Section 3.2.4) with a conservative based estimated K_d value of 0.8 mL/g for residual hexavalent chromium, based on the analysis of batch leach test results presented in SGW-51818. An alternative conceptual model is evaluated in this sensitivity analysis in which the hexavalent chromium is:

- Distributed according to the 70:30 initial contaminant distribution model (Section 3.2.4)
- Assigned a K_d value of 0.8 mL/g in the contaminated portion of the model domain
- Assigned a K_d value of 0 mL/g (no sorption) in the uncontaminated portion of the domain (the lower 30 percent and the aquifer portion of the model domain).

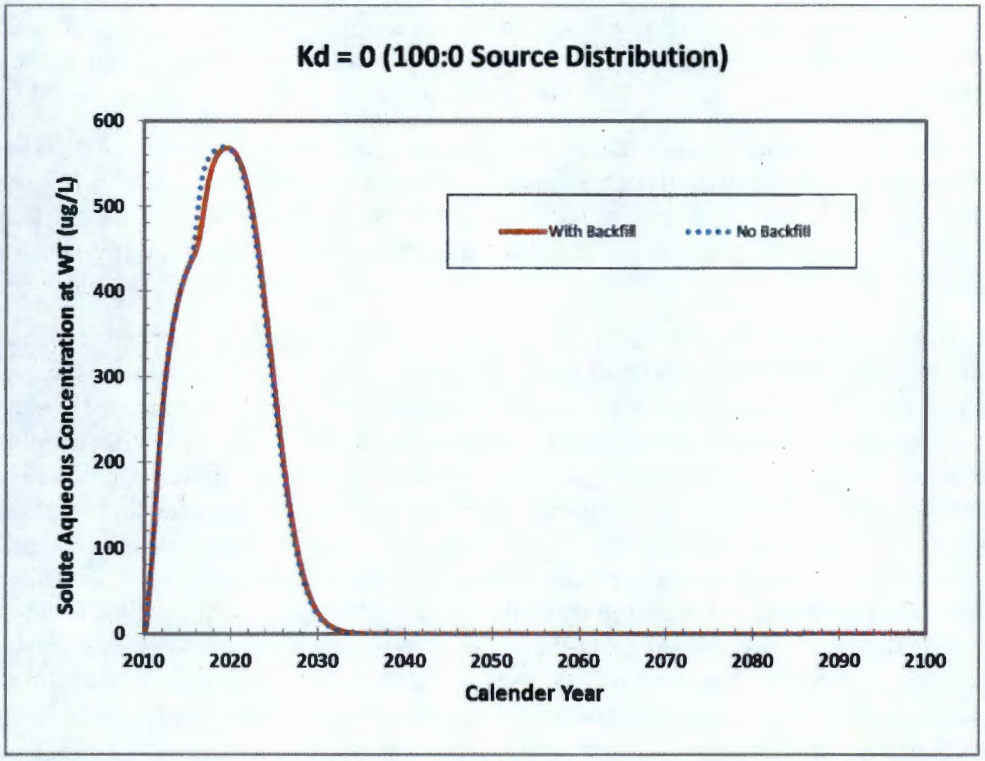


Figure 29. Results of Backfill Sensitivity Case (no backfill) Compared to Base Case for K_d = 0 mL/g

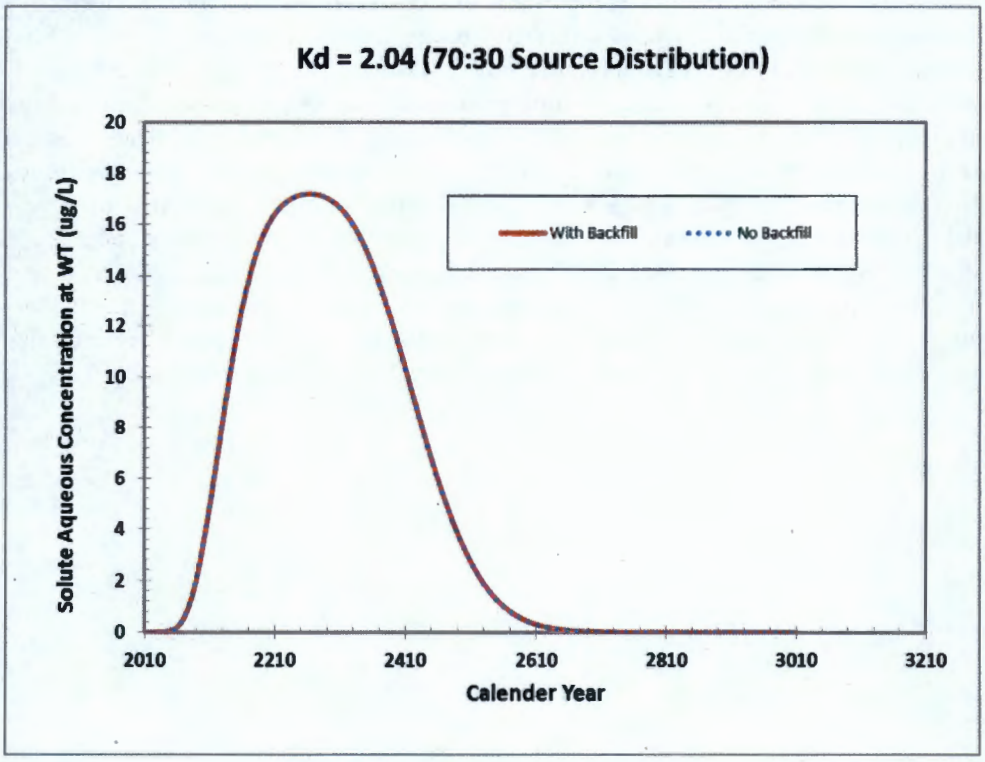


Figure 30. Results of Backfill Sensitivity Case (no backfill) Compared to Base Case for K_d = 2.04 mL/g

The peak groundwater concentration resulting from both the original model (100:0, K_d = 0.8 mL/g throughout) and this one-off analysis (70:30, K_d = 0.8 mL/g in contaminated region and K_d = 0 elsewhere) are calculated and compared to determine if the original model is bounding.

The comparison is performed for both the native vegetation recharge scenario (basis of PRG values) and the irrigation recharge scenario (basis of SSL values). For the sensitivity case, the specific stratigraphic column was identified that was selected as the basis for the PRG or SSL value (i.e., the one that yielded the most restrictive result from the set of results for all the stratigraphic columns in 100-D or 100-H areas).

For the native vegetation recharge scenario (PRG basis) case, the original model yielded a peak groundwater concentration of Cr(VI) of 50.2 g/m^3. It was this value that, used in the back-calculation (Equation 1), formed the basis for the PRG (unless truncated by the 6.0 mg/kg limit; see Section 2.5.4). In contrast, for sensitivity case with alternative 70:30 initial distribution and K_d dependent on location, the peak groundwater concentration of Cr(VI) predicted was 46.7 g/m^3. The resulting groundwater concentration over time is shown for both models in Figure 31. Note that the peak for the original model is not only higher, but occurs much sooner. This is a function of the original distribution of contamination used in each model. The original model places Cr(VI) mass very near the water table, and thus produces the earlier peak in groundwater concentration while the alternative model requires time for the Cr(VI) mass to transit the clean lower 30 percent of the soil column (even though it is unretarded in this part of the domain for this model). Thus, for the PRG case (native vegetation recharge scenario), the original model yields a more restrictive PRG (because it is based on a higher peak groundwater concentration than the alternative model produced).

The same test was repeated for the SSL values (based on irrigation recharge rates). As expected for the much higher recharge rates applied under the irrigation recharge scenario, peak groundwater concentrations are higher as Cr(VI) mass is flushed through the soil column more rapidly. The peak for groundwater concentration of Cr(VI) the original model was 815 g/m^3 compared to 831 g/m^3 for the alternative model (sensitivity case). The resulting groundwater concentration over time is shown for both models in Figure 32. Note the peak for the sensitivity case occurs earlier in this instance, because the high recharge rate associated with irrigation causes rapid transport of unretarded Cr(VI) mass through the lower (initially uncontaminated) 30 percent of the soil column. Both cases show that all of the Cr(VI) is transported to groundwater by calendar year 2700, in contrast to the slower release under the PRG case where lower recharge rates do not result in full mass transport to groundwater within 1000 years. Given the SSL or PRG value is based on the peak groundwater discharge, the inference is that the resulting SSL value would not differ meaningfully under the alternative model because the peak groundwater concentrations differed by only 0.2 percent between the original and sensitivity cases.

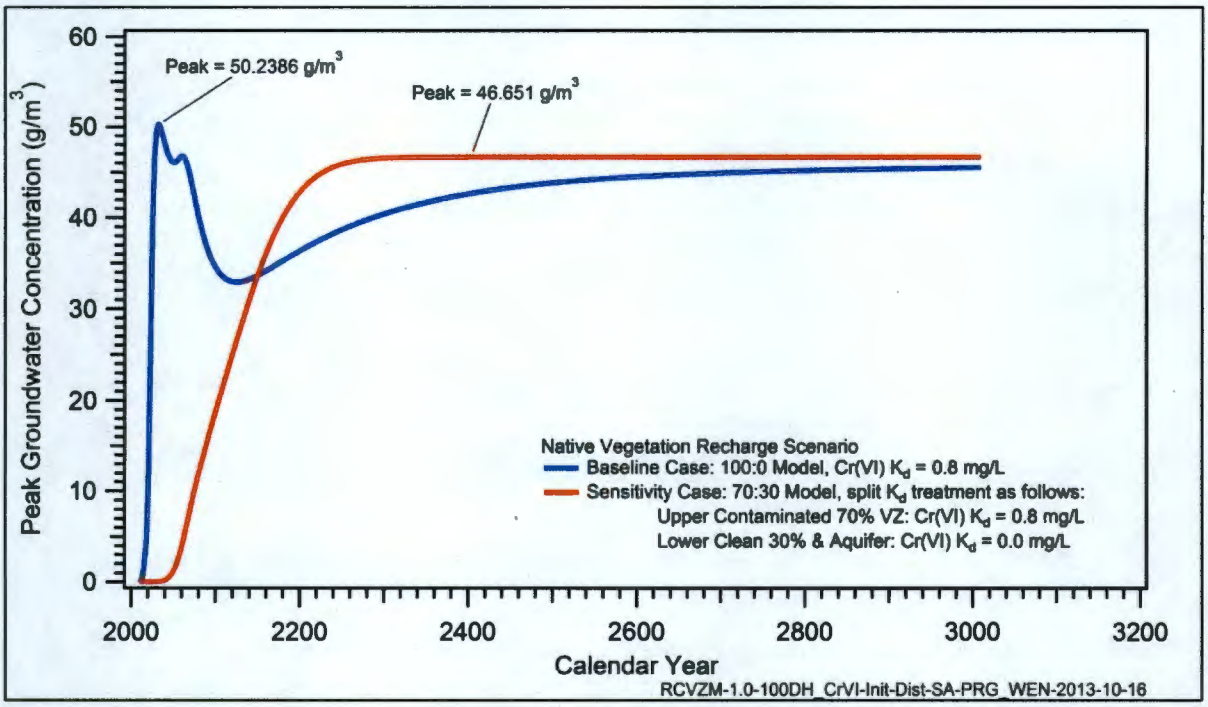


Figure 31. Sensitivity Analysis Results for Alternative Conceptual Model for Distribution and Mobility of Hexavalent Chromium (PRG Case based on Native Vegetation Recharge Scenario)

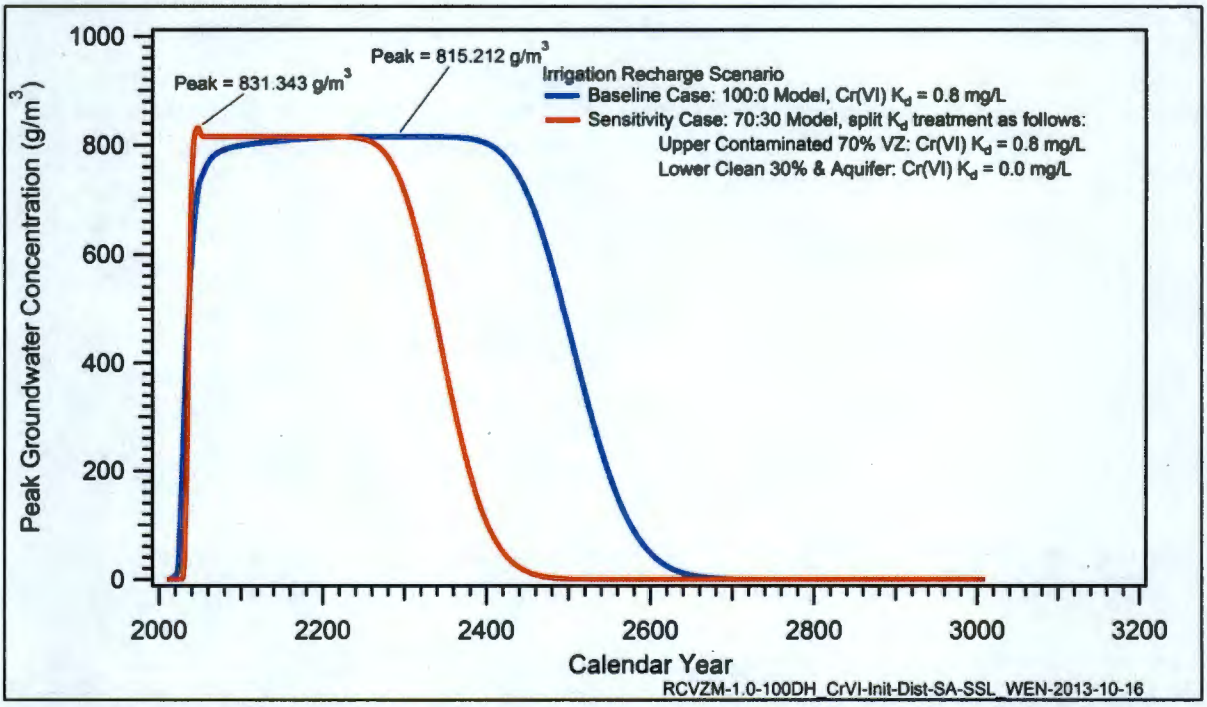


Figure 32. Sensitivity Analysis Results for Alternative Conceptual Model for Distribution and Mobility of Hexavalent Chromium (SSL Case based on Irrigation Recharge Scenario)

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Attachment A

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-D/H Remedial Investigation / Feasibility Study

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-D/H Remedial Investigation / Feasibility Study

This crosswalk demonstrates how the WAC 173-340-747(8) requirements for use of alternative fate and transport modeling are met in the use of STOMP modeling to derive soil screening level (SSL) and preliminary remediation goal (PRG) values for 100-D/H. Each requirement is listed in tabular form with a simple response, followed by an explanation, justification, and cross reference to where the information is found elsewhere in this RI/FS. Focus is on the parameterization of the alternative fate and transport model. Demonstration of the suitability of the STOMP code itself for use in alternative fate and transport modeling to meet WAC requirements is provided in DOE/RL-2011-50 Rev. 1.

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-D/H Remedial Investigation / Feasibility Study

WAC	Requirement	Response
8(b)	**Assumptions.** When using alternative models, chemical partitioning and advective flow may be coupled with other processes to predict contaminant fate and transport, provided the following conditions are met:	
8(b)(i)	Sorption. Was approach (4)(c) or (5)(b) used? Go to correct entry and meet all requirements.	**Both**
	Explanation: • Both Approach (4)(c) and 5(b) were used, depending on the COPC evaluated, for the 201 non-radionuclide, and 32 radionuclide, COPCs evaluated using the alternative fate and transport model of the vadose zone. Justification: • For radionuclides, K_d values are selected from Appendix E of DOE/RL-96-17 Rev. 6, which provided a compilation of Hanford-Site-specific values derived from scientific literature, with the exception of one radionuclide, Silver-108m, which is a generic value from scientific literature. • For organic analytes, K_d values are calculated using Equation 747-2. The K_d calculations assume a value of 0.001 g/g for the soil fraction of organic carbon (f_{oc}), as specified in Equation 747-2. Analyte-specific soil organic carbon-water partitioning coefficient (K_{oc}) values used in the K_d calculations are obtained from the following sources, in order of preference (i.e., if values available in higher preference source, those are used): 1. **Washington State Department of Ecology's "Cleanup Levels and Risk Calculations (CLARC)" online database application** (Ecology, 2014) (https://fortress.wa.gov/ecy/clarc/CLARCOverview.aspx) 2. **EPA's "Regional Screening Levels for Chemical Contaminants at Superfund Sites" web site (EPA, 2012)** (http://www.epa.gov/reg3hscd/risk/human/rb-concentration_table/) 3. **Oak Ridge National Laboratory's (ORNL) Risk Assessment Information** System (RAIS) (ORNL, 2014) (http://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chem_spef) • For inorganic analytes, K_d values are obtained directly from tabulated sources in the same order of precedence shown above for organic analytes. • Exception: for hexavalent chromium, the K_d value selected for use in modeling the residual fraction remaining in the vadose zone following remediation is 0.8 mL/g. This value is obtained from ECF-HANFORD-11-0165.	

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-D/H Remedial Investigation / Feasibility Study

WAC	Requirement				Response
	• Exception: for total petroleum hydrocarbons (TPH), the K_d value selected for use in modeling the residual fraction of TPH remaining in the vadose zone following remediation is 4 mL/g. This value is obtained from ECF-100NR2-12-0053. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety) • DOE/RL-96-17, 2009, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 6 (in its entirety). Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0095436 • Appendix F, ECF-HANFORD-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area* (in its entirety) • ECF-100NR2-12-0053, 2012, *Saturated Zone Flow and Transport Modeling in Support of 100-N RI/FS Document*, Rev. 6, Section 4.6.2.3 "K_d for TPH"; note this document is part of the 100-N RI/FS, and hence is not included the 100-D/H RI/FS.				
8(b)(i)	4(c)	**4(c) Distribution coefficient (K_d).** The default K_d values for organics and metals used in Equation 747-1.			
8(b)(i)	(4c)	(i)	**(i) Organics.** For organic hazardous substances, was the K_d value derived using Equation 747-2? (required)		**Yes**
			Explanation: • K_d values were derived under Method (4)(c)(i), using Equation 747-2 from WAC 173-340-747 for the following organics using analyte-specific soil organic carbon-water partitioning coefficient (K_{oc}) values from the sources indicated: ○ K_d values derived using K_{oc} values from CLARC tables (Ecology 2014): 1,1,1-Trichloroethane, 1,1,2,2-Tetrachloroethane, 1,1,2-Trichloroethane, 1,1-Dichloroethane, 1,1-Dichloroethene, 1,2,4-Trichlorobenzene, 1,2-Dichlorobenzene, 1,2-Dichloroethane, 1,2-Dichloropropane, 1,4-Dichlorobenzene, 2,4,5-Trichlorophenol, 2,4,6-Trichlorophenol, 2,4-Dichlorophenol, 2,4-Dimethylphenol, 2,4-Dinitrophenol, 2,4-Dinitrotoluene, 2,6-Dinitrotoluene, 2-Chlorophenol, 2-Methylphenol (cresol, o-), 3,3'-Dichlorobenzidine, 4,4'-DDD (Dichlorodiphenyldichloroethane), 4,4'-DDE (Dichlorodiphenyldichloroethylene), 4,4'-DDT (Dichlorodiphenyltrichloroethane), 4-Chloroaniline, Acenaphthene, Acetone, Aldrin, Alpha-BHC,			

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WAC	Requirement	Response
	Alpha-Chlordane, Anthracene, Aroclor-1016, Aroclor-1260, Benzene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC), Bis(2-chloroethyl) ether, Bis(2-ethylhexyl) phthalate, Bromodichloromethane, Bromoform, Bromomethane, Butylbenzylphthalate, Carbazole, Carbon disulfide, Carbon tetrachloride, Chlordane, Chlorobenzene, Chloroform, Chloromethane, chrysene, cis-1,2-Dichloroethylene, cis-1,3-Dichloropropene, Dibenz[a,h]anthracene, Dibromochloromethane, Dieldrin, Diethylphthalate, Di-n-butylphthalate, Di-n-octylphthalate, Endosulfan I, Endosulfan II, Endrin, Ethylbenzene, Fluoranthene, Fluorene, Gamma-BHC (Lindane), Heptachlor, Heptachlor epoxide, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Indeno(1,2,3-cd)pyrene, Isophorone, Methoxychlor, Methylene chloride, m-Xylene, Naphthalene, Nitrobenzene, n-Nitrosodi-n-dipropylamine, n-Nitrosodiphenylamine, o-Xylene, Pentachlorophenol, Phenol, Pyrene, Styrene, Tetrachloroethene, Toluene, Toxaphene, trans-1,2-Dichloroethylene, trans-1,3-Dichloropropene, Trichloroethene, Vinyl chloride, Xylenes (total). ○ <u>K_d values derived using K_{oc} values from EPA (2012)</u>: 1,2-Dichloroethene (Total), 2-(2-methyl-4-chlorophenoxy) propionic acid, 2,4,5-T(2,4,5-Trichlorophenoxyacetic acid), 2,4,5-TP(2-(2,4,5-Trichlorophenoxy)propionic acid)Silvex, 2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid), 2,4-Dichlorophenoxyacetic acid, 2-Butanone, 2-Butoxyethanol, 2-Chloronaphthalene, 2-Hexanone, 2-Methylnaphthalene, 2-Nitroaniline, 4,6-Dinitro-2-methylphenol, 4-Amino-3,5,6-trichloropicolinic acid, 4-Chloro-3-methylphenol, 4-Methyl-2-pentanone, 4-Methylphenol (cresol, p-), 4-Nitroaniline, Acrylamide, Acrylonitrile, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254, Bis(2-chloro-1-methylethyl)ether, Bis(2-Chloroethoxy)methane, Chloride, Chloroethane, Co-elution of Aroclor 1242 and Aroclor 1016, Cyanide, Dalapon, Dibenzofuran, Dicamba, Diethyl ether, Dinoseb(2-secButyl-4,6-dinitrophenol), Ethyl acetate, Ethylene glycol, Isopropylbenzene, Methanol, Nitrate, Nitrite, Nitrogen in Nitrate, Nitrogen in Nitrite, Nitrogen in Nitrite and Nitrate, Tributyl phosphate, Trichloromonofluoromethane. ○ <u>K_d value derived using K_{oc} values from ORNL (2014)</u>: 1,3-Dichlorobenzene, 2-Nitrophenol, 3-Nitroaniline, 4-Bromophenylphenyl ether, 4-Chlorophenylphenyl ether, 4-Nitrophenol, Acenaphthylene, Benzo(ghi)perylene, Delta-BHC, Dichloroprop, Dimethyl phthalate, Endosulfan sulfate, Endrin aldehyde, Endrin ketone, Phenanthrene. ○ <u>K_d value derived from consideration of total petroleum hydrocarbon ranges (ECF- 100NR2-12-0053)</u>: Total petroleum hydrocarbons - diesel range, Total petroleum hydrocarbons - motor oil (high boiling)	

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WAC	Requirement				Response
			Justification: • Refer to responses by entry, below. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety) • ECF-100NR2-12-0053, Rev. 2, *Saturated Zone Flow and Transport Modeling in Support of 100-N RI/FS Document*, Section 4.6.2.3 "K_d for TPH"; note this document is part of the 100-N RI/FS, and hence is not included the 100-D/H RI/FS.		
8(b)(i)	(4c)	(i)	The K_{oc} (soil organic carbon-water partition coefficient) parameter specified in Equation 747-2 shall be derived as follows:		
8(b)(i)	(4c)	(i)	(A)	(A) **Nonionic organics.** Are there individual nonionic hydrophobic organic hazardous substances (e.g., benzene and naphthalene)?	**Yes**
				Explanation: • The COPC list includes nonionic organics, including naphthalene. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(A)	• If so, were K_{oc} values from Table 747-1 used? OR	**Yes**

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WAC				Requirement	Response
				Explanation: • Yes, K_{oc} values from Table 747-1 were used. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(A)	• For hazardous substances not listed in Table 747-1, were K_d values used from (5) (variable three-phase partitioning model)?	**N/A**
				Explanation: • No COPCs analyzed met this condition. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(B)	(B) **Ionizing organics.** For ionizing organic hazardous substances (e.g., pentachlorophenol and benzoic acid), were K_{oc} values used from Table 747-2? (required)	**Yes**
				Explanation:	

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WAC				Requirement	Response
				• The following ionizing organic hazardous substances are COPCs: 2,4,5-Trichlorophenol, 2,4,6-Trichlorophenol, 2,4-Dichlorophenol, 2,4-Dimethylphenol, 2,4-Dinitrophenol, 2-Chlorophenol, Pentachlorophenol. K_d values for these were derived under Method (4)(c)(i), using Equation 747-2 from WAC 173-340-747 for the following organics using analyte-specific soil organic carbon-water partitioning coefficient (K_{oc}) values from CLARC tables (Ecology 2009). Justification: • Compliant; no further justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(B)	Was the soil pH measured? (required) and the K_{oc} value for the corresponding soil pH used?	**Yes**
				Explanation: • Soil pH was measured and the K_{oc} value for the corresponding soil pH was used. Justification: • Compliant; no further justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(B)	If the soil pH fell between the pH values provided, were the values correctly interpolated?	**N/A**
				Explanation:	

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WAC	Requirement				Response
				• None detected, and hence not applicable. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(ii)	**(ii) Metals.**		
8(b)(i)	(4c)	(ii)	Were the K_d values from Table 747-3 used?		**Yes** **Except Cr(VI)**
			Explanation: • Yes: K_d values from Table 747-3 were used for the following metals: Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Silver, Thallium, Vanadium, Zinc. • No: K_d values were not available from Table 747-4 and were obtained from EPA (2012) for the following metals: Aluminum, Boron, Calcium, cobalt, Fluoride, Iron, Lithium, Magnesium, Manganese, Molybdenum, Potassium, Sodium, Strontium, Tin • No: a site-specific K_d value based on leach test results was used for Hexavalent Chromium. Justification: • No justification is required for the use of K_d values from Table 747-3. • Justification for using a site-specific K_d value derived from leach test results is provided below, in the response to 5(b)(iii). Documented:		

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WAC	Requirement			Response
			• Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(ii)	If metals were not listed in Table 747-3, was the subsection (5) (variable three-phase partitioning model) used?	**No**
			Explanation: • The variable three-phase partitioning model was not used. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	5(b)		**5(b) Methods for deriving a distribution coefficient (K_d).** To derive a site-specific distribution coefficient, which one of the following methods was used? Go to (i), (ii), (iii), or (iv).	**(iii) and (iv)**
			Explanation: • A site-specific K_d value for hexavalent chromium for the 100 Area was derived from batch leach test results under Method (iii). • Scientific literature was used to derive site-specific values for K_d for several constituents under Method (iv). Justification: • Justification is provided with explanation in responses to Methods (iii) and (iv), below. Documented:	

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WAC	Requirement				Response
		• Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)			
8(b)(i)	5(b)	(i)	**(i) Deriving K_d from soil fraction of organic carbon (foc) measurements.**		
			• Was Equation 747-2 used to derive distribution coefficients for nonionic hydrophobic organics for site-specific measurements of soil organic carbon?		**Yes**
			Explanation: • The COPC list includes nonionic organics, including naphthalene, and Equation 747-2 was used to derive distribution coefficients. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)		
8(b)(i)	5(b)	(i)	• Were soil organic carbon measurements based on uncontaminated soil below the root zone (i.e., soil greater than one meter in depth) that is representative of site conditions or in areas through which contaminants are likely to migrate?		**N/A**
8(b)(i)	5(b)	(i)	• Were laboratory protocols in the Puget Sound Estuary Program (March, 1986) used?		**N/A**
8(b)(i)	5(b)	(i)	• Were other methods used and approved by the department?		**N/A**

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WAC	Requirement			Response
8(b)(i)	5(b)	(i)	• Were all laboratory measurements of soil organic carbon based on methods that do not include inorganic carbon in the measurements?	**N/A**
8(b)(i)	5(b)	(ii)	**(ii) Deriving K_d from site data.**	
8(b)(i)	5(b)	(ii)	• Were site-specific measurements of hazardous concentrations in soil and soil pore water or ground water used to derive a K_d and was department approval obtained?	**No**
			Explanation: • This method was not used to derive a K_d value for any COPC evaluated. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	5(b)	(ii)	• Were K_ds derived from site data based on measurements of soil and ground water hazardous substance concentrations from the same depth and location?	**N/A**
8(b)(i)	5(b)	(ii)	• Were soil and ground water samples containing hazardous substances present as a nonaqueous phase liquid (NAPL) used to derive a K_d? (not allowed) and were measures taken to minimize biodegradation and volatilization during sampling, transport and analysis?	**N/A**
8(b)(i)	5(b)	(iii)	(iii) **Deriving K_d from batch tests.**	

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WAC	Requirement			Response
8(b)(i)	5(b)	(iii)	• Was a site-specific K_d derived by using batch equilibrium tests to measure hazardous substance adsorption and desorption and was department approval obtained?	**Yes**
			Explanation: • A site-specific value (specific to the 100 Area of the Hanford Site) of K_d for hexavalent chromium was derived using batch equilibrium tests. Justification: • Ecology approved the batch leach testing with the approval of the D/H SAP DOE/RL-2009-40 Rev 0. Page 2-127 describes the procedure. It was also modified by TPA-CN-368 signed by Ecology on 8/26/2010 to allow for removing the requirement for pH adjustment of demineralized water. Documented: • **Chapter 5, Section 5.5.2 "Development of a Hexavalent Chromium Distribution Coefficient for Vadose Zone Simulations from Batch Leach Testing Results"** • Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area* (in its entirety)	
8(b)(i)	5(b)	(iii)	• Were samples with hazardous substances present as a nonaqueous phase liquid (NAPL) used to derive a distribution coefficient (not allowed) and were measures shall be taken to minimize biodegradation and volatilization during testing?	**No**
			Explanation: • No samples with NAPLs present were used in the determination of K_d values. Justification: • No justification is required for this response.	

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WAC	Requirement			Response
			Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	5(b)	(iv)	(iv) **Deriving K_d from the scientific literature.** Was scientific literature used to derive a site-specific distribution coefficient (K_d)? If so, were the requirements in WAC 173-340-702 (14), (15) and (16) met? (*see end of list under 8(c)*)	**Yes**
			Explanation: • Scientific literature values were applied to select COPCs as follows: General K_d values were derived from scientific literature for these COPCs: ○ Silver-108m – from ANL (1993) Hanford site-specific K_d values were derived from scientific literature for these COPCs: ○ Thorium-228, Thorium-230, Thorium-232 - Ames and Rai (1978) ○ Americium-241, Cesium-137, Cobalt-60, Europium-152, Europium-154, Europium-155, Nickel-63, Strontium-90 - Ames and Serne (1991) ○ Carbon-14 – from BHI (2002a) ○ Curium-243, Curium-244, Iodine-129, Neptunium-237, Niobium-94, Potassium-40, Sodium-22 – from Kincaid et al. (1998) ○ Plutonium-238, Plutonium-239/240, Plutonium-239, Plutonium-240, Plutonium-241, Radium-226, Radium-228, Technetium-99, Tritium (H-3), Uranium-233/234, Uranium-235, Uranium-238 – from Serne and Wood (1990), except all uranium values are replaced with "NVR" (no value required) for 100-D/H modeling purposes because uranium does not require modeling. No K_d values were available for these COPCs:	

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WAC	Requirement	Response
	○ No value available: 3+4 Methylphenol (cresol, m+p), Bismuth, Bromide, Calcium, Co-elution of Aroclor 1242 and Aroclor 1016, Phosphate, Silicon. Justification: • Best-available scientific information applied in absence of higher-precedence values (CLARC 2014, EPA 2012, or ORNL 2014). Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area,* Table 3-5 "Final Nonradiological Analyte Distribution Coefficient (K_d) Selection" and Table 3-6 "Radiological Analyte Distribution Coefficients (K_d)" • DOE/RL-96-17, 2009, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 6 (in its entirety). Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0095436	
8(b)(ii)	**Vapor phase partitioning.** If Henry's law constant is used to establish vapor phase partitioning, then the constant shall be derived in accordance with subsection (4)(d) of this section.	**N/A**
	Explanation: • Volatilization was conservatively neglected in the calculation of SSL and PRG values. Justification: • This assumption is conservative, with respect to SSL and PRG values only, because modeling volatilization would reduce the mass transport to the groundwater pathway, with result of lower peak groundwater concentrations and hence higher SSL and PRG values. • This calculation is not the basis for direct exposure evaluations (presented in Chapter 6 of the RI/FS). Hence, this assumption does not apply to the inhalation pathway for direct exposure. Documented: • Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 6.1 "Modeling Conservatisms" notes that volatile organic compounds were assumed to have negligible volatilization so that the resulting peak concentrations are larger than if volatilization had been included. • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary*	

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WAC	Requirement			Response
	Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units, Section 3.4 "Contaminant Transport Parameters" documents neglecting volatilization.			
8(b)(ii)	(4)(d)	**(4)(d) Henry's law constant.**		
8(b)(ii)	(4)(d)		For petroleum fractions, were the values for Henry's law constant in Table 747-4 used in Equation 747-1? (required)	**N/A**
8(b)(ii)	(4)(d)		For individual organic hazardous substances, was the value based on values in the scientific literature? (required)	**N/A**
8(b)(ii)	(4)(d)		For all metals present as inorganic compounds except mercury, was zero used? (required) For mercury, was either 0.47 or a value derived from the scientific literature used? (required)	**N/A**
8(b)(ii)	(4)(d)		Did the derivation of Henry's law constant from the scientific literature comply with WAC 173-340-702 (14), (15) and (16)? (required) (*see end of list under 8(c)*)	**N/A**
8(b)(iii)	**Natural biodegradation.** Were the rates of natural biodegradation derived from site-specific measurements? (required)			**No**
	Explanation: • Biodegradation is not incorporated into the calculation. Justification: • All COPCs are assumed not to be subject to natural biodegradation for purposes of calculating SSLs and PRG values. This is generally a conservative assumption (because of overstating COPC persistence by neglecting biodegradation). • This assumption may be non-conservative in some circumstances, e.g., COPCs such as chloroform can degrade to methylene chloride and chloromethane, which have higher cancer slope factors. Dichloroethylene can eventually degrade to vinyl chloride, which has a higher cancer slope factor than dichloroethylene. Groundwater protection levels are calculated based on meeting all applicable standards immediately under the waste site; including meeting ambient water quality standards with no credit for attenuation of organics as they			

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WAC	Requirement	Response
	travel from the waste site and interface with oxic water conditions. This additional conservatism covers the potential for biodegradation products to be generated while keeping the calculations as simple and transparent as possible. This is further supported by groundwater data collected from the OU which indicate that biodegradation products, such as 1,1-DCE and vinyl chloride, have not been detected in groundwater. Documented: • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.4 "Contaminant Transport Parameters" documents that biodegradation is not incorporated into the calculation.	
8(b)(iv)	**Dispersion.** Were estimates of dispersion derived from either site-specific measurements or literature values? (required)	**N/A**
	Explanation: • Dispersion was conservatively minimized in the calculation by setting coefficients for hydrodynamic dispersion to zero. Additional considerations of the 1-D model construct follow: • The 1-D model construct does not address lateral transport, effectively assuming that contaminants in the vadose zone are continuously moving in one direction (downward) with no accounting for potential lateral migration. While lateral migration is highly likely under field conditions, this effect reduces and delays the peak groundwater concentration resulting from a given waste site. Hence, this 1-D modeling construct is conservative because it overstates the potential for groundwater impacts compared to a higher-dimensionality model construct that accounts for lateral migration. • The PRZ is not explicitly modeled (rise and fall of the water table is not assumed) to provide a bounding calculation. A fluctuating water table will provide additional attenuation distance between the source area and groundwater for six months every year. • Conditions from summer months (the period of highest river stage and groundwater heads in this locale) are used in the 1D STOMP models. This parameterization provides the simplest and most conservative evaluation of conditions under a waste site by providing the shortest travel distance from the contaminated source to groundwater, and by assuming that this short travel distance persists indefinitely. This, in turn, maximizes the predicted impact on groundwater by yielding a higher peak concentration is calculated than if water table is simulated as fluctuating. The effects of the PRZ are handled internally within STOMP. A three-dimensional treatment cannot result in greater impact on groundwater than the one-dimensional assumption because the one-dimensional treatment allows no lateral diffusion of contaminants; the only possible direction for contaminant movement is downward. Justification:	

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WAC	Requirement	Response
	• Simulating with no hydrodynamic dispersion is conservative, with respect to SSL and PRG values, because inclusion of greater hydrodynamic dispersion would result in lower peak groundwater concentrations, and therefore higher SSL and PRG values. Documented: • Chapter 5, Table 5-5, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-D and 100-H Operable Units" • Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.5.1 "Parameters and Ranges" notes that dispersion was conservatively assumed negligible, so dispersivity values were all set to zero. • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.4 "Contaminant Transport Parameters" documents that hydrodynamic dispersion is set to zero in the calculation.	
8(b)(v)	**Decaying source.** Were fate and transport algorithms used that account for decay over time? Regulation states that Fate and Transport algorithms may be used that account for decay over time.	**Yes**
	Explanation: • Radioactive decay is accounted for in the STOMP code for radionuclides only. The STOMP simulator solves the Arrhenius-type kinetic reaction (PNNL-12030) according to the equation $$\frac{\partial c}{\partial t} = -\lambda^C c$$ where c is concentration of the COPC C in solute, t is time, and λ^C is the decay rate constant for COPC C. The decay rate is related to the radionuclide half-life according to the equation $$\lambda^C = \frac{\ln(2)}{t_{\frac{1}{2}}^C}$$ where $t_{1/2}^C$ is the half-life of COPC C. STOMP is capable of solving for chain decay, but this feature was not required or used for the SSL and PRG calculations. The only input parameter required is the half-lives $t_{1/2}^C$ for each radionuclide. All half-lives for this RI/FS were obtained from the Radiochemistry website in September 2011 (Radiochemistry Society, 2011). Justification:	

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WAC	Requirement	Response
	• Radioactive decay is an established physical process for radionuclides evaluated in this RI/FS and follow well established rate laws that are solved using analytical equations in the STOMP code. DOE/RL-96-17 Rev. 6 notes, with regard to radioactive daughter products, "The development of cleanup standards for the 100 Area will not be affected because the principal radionuclides of concern in the 100 Area (e.g., cobalt-60, cesium-137, europium-152, and europium-154) do not decay to daughter products that are more radioactive." • No radionuclide is simulated that has significant daughter products (no significant daughter/decay products associated with the alpha, beta, and gamma emitters that are present at 100-D/H. The gamma emitters do not have decay products). • It is true that some volatiles are simulated with no biodegradation, which can have more toxic daughter products. While this could generate lower PRGs and SSLs for these volatiles, other conservatisms allow the calculated values to remain protective. The most notable conservatism for these volatiles is that their cleanup levels are based on the lowest applicable water quality standard. The groundwater protection levels are calculated based on meeting all applicable standards immediately under the waste site; including meeting ambient water quality standards with no credit for attenuation of organics as they travel from the waste site and interface with oxic water conditions. This additional conservatism covers the potential for biodegradation products to be generated while keeping the calculations as simple and transparent as possible. This is further supported by groundwater data collected from the OU which indicate that biodegradation products, such as 1,1-DCE and vinyl chloride, have not been detected in groundwater. Documented: • Chapter 5, Section 5.3.2, "Persistence of Radiological Constituents" describes the applicable radioactive decay processes. • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.4 "Contaminant Transport Parameters" documents that STOMP is used to account for first-order decay in the solute mass conservation equation. The half-lives used for input to STOMP by radionuclide COPC are listed in Attachment B, Table B-3 and in Attachment C, Table C-3 list. Section 3.4 "Contaminant Transport Parameters" references PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide*, which describes the calculation of radioactive decay in the STOMP code. Section 3.4 "Contaminant Transport Parameters" also notes chain decay is not accounted for in this calculation. • DOE/RL-96-17 Rev. 6, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Section 2.1.2.2 "Remedial Action Goals for Radionuclide Contaminants in Soil" dismisses the need to consider chain decay based on lack of daughter products for principal radionuclides of concern in the 100 Area. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0095436.	
8(b)(vi)	**Dilution.** Was dilution based on site-specific measurements or estimated using a model incorporating site-specific characteristics? (required)	**Estimated using a model incorporating site-specific**

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WAC	Requirement	Response
		characteristics
	Explanation: • Dilution is directly simulated in the STOMP model for SSL and PRG calculation through inclusion of the upper portion of the aquifer in the model, and using the mean hydraulic gradient for the OU to simulate for dilution directly. The dilution factor can be derived from the equation $$Df = \frac{Q_{VZ} + Q_A}{Q_{VZ}}$$ where D_f is the dimensionless dilution factor, Q_{VZ} is the volumetric flux from the vadose zone into the aquifer, and Q_A is the volumetric flux through the upper 5 m of the aquifer. The value of Q_A is dependent upon the hydraulic gradient and hydraulic conductivity of the aquifer portion of the model. These input parameter values are input to the STOMP model constructed for SSL and PRG development. The dilution factor is noted to vary significantly depending on whether the aquifer is composed of the Ringold Formation or the Hanford formation (e.g., for 100-D the Ringold dilution factor was two times less than the Hanford dilution factor). The recharge rate varies over time in the calculation according to the recharge scenario simulated; hence, the effective dilution factor also varies in time because the Q_{VZ} term in the dilution factor calculation represents the flux attributable to the recharge rate. The effective dilution factors were calculated and presented for all combinations of recharge scenarios, recharge phases, and hydraulic gradients used in the alternative fate and transport modeling. These dilution rates ranged from a low of 76 for the irrigation recharge rate at 100-D waste sites that have the saturated zone in the Ringold Formation, to a high of 15,600 for the mature shrub-steppe recharge rate at 100-H waste sites that have the saturated zone in the Hanford formation. For context, if the default fixed parameter three-phase partition model (WAC 173-340-747(3)(a)) were used to establish soil concentrations for groundwater protection, the default groundwater dilution factor is 20 for unsaturated zone soil. • Using the upper 5 m of the aquifer, although allowed by the regulations, does not match site-specific conditions for some waste site locations where the aquifer thickness is less than 5 m. In these locations, the thinner aquifer would result in a higher concentration in the model prediction if all other factors in this calculation were unchanged. However, use of the median area hydraulic gradient in the model for each area, rather than site-specific hydraulic gradient, would also affect the dilution if considered (this gradient would typically be higher at locations with a thinner aquifer to maintain the same aquifer flow rate). Justification: • Where using an alternative fate and transport model (WAC 173-340-747(8)), it is required that dilution "be based on site-specific measurements or estimated using a model incorporating site-specific characteristics." The hydraulic gradient incorporates site-specific characteristics of the aquifer. The depth of the aquifer used for the dilution calculation follows WAC 173-340-747. Documented:	

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WAC	Requirement	Response
	• Chapter 5, Section 5.6 "Vadose Zone Modeling Methods and Results" describes the methodology for inclusion of the aquifer in the model domain and direct simulation of dilution as a function of aquifer depth, hydraulic gradient, domain size, and vadose zone leaching. • Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 5.4 "Calculating Dilution Factors" presents and discusses dilution factor calculation in the STOMP modeling. • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 5.1.3 "Dilution Factor"	
8(b)(vi)	If detectable concentrations of hazardous substances are present in upgradient ground water, then the dilution factor may need to be adjusted downward in proportion to the background (upgradient) concentration. Was an adjustment made?	**No**
	Explanation: • Adjustments were not made based on upgradient groundwater concentrations of hazardous substances. Justification: • In 100-D/H, there are no upgradient contamination issues for groundwater COCs other than Cr(VI). For Cr(VI), the current plume is not background contamination (all sources are anthropogenic in origin), and the existing Cr(VI) is being addressed through the pump-and-treat remedy that will effectively eliminate the upgradient contamination in a relatively short period of time. This remedy will address any leaching of Cr(VI) during the remedy application period. • Ecology has determined that no dilution factor adjustments are needed in the alternative fate and transport modeling for the following reasons: o WAC language allows for dilution factor adjustment, but does not require it. o The soil PRGs for protection of groundwater/surface water for hexavalent chromium is not based on the results of alternative fate and transport modeling, but on the values from the interim cleanup actions (originally based on the "100 times rule"). o The fate and transport modeling results show no migration of vadose zone contaminants to groundwater within 1000 years. With no migration to groundwater, the value of the dilution factor is irrelevant. Note that the "100 times rule" used as the basis for the interim cleanup actions produced a more conservative limit for hexavalent chromium than did the alternative fate and transport modeling. Documented: • Appendix F, ECF-HANFORD-11-0063 Rev 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary*	

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WAC	Requirement	Response
	Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units, Section 5.1.3 "Dilution Factor"	
8(b)(vii)	**Infiltration.** Was infiltration derived in accordance with subsection (5)(f)(ii)(A) or (B) of this section? (required)	**Yes; (B)**

	Explanation:
	• (5)(f)(ii)(B); Infiltration was derived from site-specific measurements.
	Justification:
	• Use of site-specific values is permitted under (5)(f)(ii)(B).
	Documented:
	• Chapter 5, Section 5.4.1 "Surface Cover, Infiltration, and Recharge"
	• Chapter 5, Table 5-5, "Summary of Selected Fate and Transport Simulation Input Parameters Used with 1 D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-D and 100-H Operable Units"
	• Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
	  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
	• Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" identifies the use of 100-Area-specific recharge rates for disturbed soils in the model (Tables 3 and 4 and Figures 3 and 4) obtained from
	  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.	

8(b)(vii) (5)(f)(ii)	**(5)(f)(ii) Calculating or estimating infiltration.** Was equation 747-5 used to calculate the volume of water infiltrating (Q_p)?	**No**
	Explanation: • Equation 747-5 was not used. Site-specific measurements of infiltration were applied.	

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WAC	Requirement			Response

		Justification:
		• Use of site-specific values is permitted under (5)(f)(ii)(B).
		Documented:
		• Chapter 5, Section 5.4.1 "Surface Cover, Infiltration, and Recharge"
		• Chapter 5, Table 5-5, "Summary of Selected Fate and Transport Simulation Input Parameters Used with 1 D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-D and 100-H Operable Units"
		• Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
		  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
		• Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils from
		  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.		

8(b)(vii)	(5)(f)(ii)	(A)	(A) If a default annual infiltration value (Inf) was used, the value shall meet the following: (required) • For sites west of the Cascade Mountains, was the default annual infiltration value = 70% of the average annual precipitation amount used? • For sites east of the Cascade Mountains, was the default annual infiltration value = 25% of the average annual precipitation amount used?	N/A
			Explanation: • Default infiltration values under (5)(f)(ii)(A) were not used. Justification: • Use of site-specific values is permitted under (5)(f)(ii)(B).	

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WAC	Requirement			Response

			Documented:
			• Chapter 5, Section 5.4.1 "Surface Cover, Infiltration, and Recharge"
			• Chapter 5, Table 5-5 "Summary of Selected Fate and Transport Simulation Input Parameters Used with 1 D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-D and 100-H Operable Units"
			• Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
			  o PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
			• Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils in the model (reference Tables 3 and 4 and Figures 3 and 4 in that section) from
			  o PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.	

8(b)(vii)	(5)(f)(ii)	(B)	(B) If a site-specific measurement or estimate of infiltration (Inf) was made, was it based on	
8(b)(vii)	(5)(f)(ii)	(B)	• Site conditions without surface caps (e.g., pavement) or other structures that would control or impede infiltration?	**Yes**
			Explanation: • Site-specific measurements of infiltration for site surface conditions without surface caps that would impede infiltration were used in the STOMP modeling to derive SSL and PRG values. Justification: • Reductions in infiltration due to surface caps are not considered; hence, no justification is necessary for this response.	

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-D/H Remedial Investigation / Feasibility Study

WAC			Requirement	Response

			Documented:
			• Chapter 5, Section 5.4.1 "Surface Cover, Infiltration, and Recharge"
			• Chapter 5, Table 5-5 "Summary of Selected Fate and Transport Simulation Input Parameters Used with 1 D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-D and 100-H Operable Units"
			• Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
			  o PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
			• Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils in the model (Tables 3 and 4 and Figures 3 and 4) from
			  o PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf	

8(b)(vii)	(5)(f)(ii)	(B)	• The presence of a cover or cap may be considered when evaluating the protectiveness of a remedy under WAC 173-340-350 through 173-340-360.	**Not Considered**
			Explanation: • Site-specific measurements of infiltration for site surface conditions without surface caps that would impede infiltration were used in the STOMP modeling to derive SSL and PRG values. Justification: • Reductions in infiltration due to surface caps are not considered; no justification is necessary for this response. Documented: • Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates	

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WAC	Requirement			Response
			from o PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf. • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils (Figures 3 and 4) from o PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.	
8(b)(vii)	(5)(f)(ii)	(B)	• If a site-specific measurement or estimate of infiltration is made, did it comply with WAC 173-340-702 (14), (15) and (16)? required) (*requirements of 173-340-702 subsections follow*)	**Yes**
			Explanation: • Infiltration values used were temporally variable, reflecting changing surface conditions under two recharge scenarios. These were the native vegetation recharge scenario, representing the expected future land use (conservation with native shrub steppe vegetation developing over time following closure and revegetation) and the irrigation recharge scenario (representing an irrigated agriculture land use beginning very soon following closure). Justification: • Site-specific measurements of infiltration applicable to three different surface soil types present in the 100 Areas (Ephrata sandy loam and Ephrata stony loam; Burbank sandy loam; and Rupert sand) are used to represent the variability of surface soil types on infiltration rates. Infiltration rates for these surface soil types under mature shrub steppe conditions that prevailed before Hanford operations commenced (that is, prior to 1944), and that would be prevalent again in the future following site closure with revegetation and a transition period to develop mature shrub steppe, are taken from values reported in PNNL-14702 Rev 1, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*. Successful revegetation programs in the 100 Areas are well documented (WCH-288 Rev. 0; WCH-362 Rev. 0; WCH-428 Rev. 0; WCH-512 Rev. 0; WCH-554 Rev. 0), supporting the recharge scenarios that postulate plant succession for the native vegetation recharge scenario. The recharge rate estimates for natural recharge from PNNL-14702 Rev. 1 do not account for overland flow from roadways or roofs, waterline leaks, or any other anthropogenic recharge sources. The estimates were developed for natural		

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WAC			Requirement	Response

			and disturbed soils, and these are composited into the temporally variable recharge scenarios used to develop SSLs (irrigation scenario) and PRGs (native vegetation recharge scenario).DOE-RL/2011-50 Rev. 1 references PNNL-14702 Rev. 1 as a basis for recharge rates appropriate as initial parameter values for modeling of Central Plateau sites. The surface soil types and vegetation patterns present on the Central Plateau are prevalent in the River Corridor, so Hanford Site-specific recharge rates use the same documented basis that are listed above. The prevalence of the same surface soil types, precipitation patterns, and vegetation patterns that control recharge rates are the justification for use of recharge rate estimates derived from measurements collected at multiple sites across the Hanford Site. A range of surface soil types and temporally varying recharge reflecting changing surface conditions are used in the model to capture a range of expected response, with the most conservative result applied for determination of SSLs and PRGs.
			
			<u>Documented:</u>
			
			• Recharge scenarios and rates are discussed in:
			  ○ Chapter 5, Section 5.4.1 "Surface Cover, Infiltration, and Recharge"
			  ○ Chapter 5, Table 5-5, "Summary of Selected Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-D and 100-H Operable Units"
			  ○ Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from PNNL-14702 Rev. 1. See Tables 4-1 and 4-2 in that report.
			  ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils from PNNL-14702 Rev. 1 in the model. Reference Tables 3 and 4 and Figures 3 and 4 in that section.
			
			• Limitations and uncertainty associated with recharge scenarios and rates are discussed in:
			  ○ Chapter 5, Section 5.9.4 "Uncertainties, Assumptions, and Limitations Specific to Vadose Zone Modeling"
			  ○ Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 6 "Model Sensitivity and Uncertainty" presents discussion of the modeling conservatism and the results of sensitivity and uncertainty analyses conducted to gain understanding of the important parameters that can affect soil screening level and preliminary remediation goal calculations, including	

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WAC	Requirement			Response
			recharge rate considerations. ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.6 "Uncertainties, Assumptions, and Conservatism" • Revegetation is discussed in: ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1.1 "Native Vegetation Recharge Scenario" discusses revegetation of waste sites in accordance with the DOE/RL-96-32, *Hanford Biological Resources Management Plan*. Documentation of successful revegetation conducted in the 100 Areas is provided in: ▪ WCH-288 Rev. 0, *2008 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-352 Rev. 0, 2009 *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-428 Rev. 0, *2010 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-512 Rev. 0, *2011 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-554 Rev. 0, *2012 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*.	
340-702	**Evaluation criteria.** Proposed fate and transport models, input parameters, and assumptions shall comply with WAC 173-340-702 (14), (15) and (16).			**Yes**
	See responses to (14), (15), and (16) below.			
340-702	14	**WAC 173-340-702 (14) Burden of proof.** Any person responsible for undertaking a cleanup action under this chapter who proposes to:		
340-702	14	(a)	(a) Use a reasonable maximum exposure scenario other than the default provided for each medium;	**No**

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WAC			Requirement	Response
			Explanation: • The default reasonable maximum exposure scenario (WAC 173-340-720-4) was used. Justification: • No justification is necessary for using the default maximum exposure scenario. Documented: • Section 6.3.2.2 "Identification of Action Levels"	
340-702	14	(b)	(b) Use assumptions other than the default values provided for in this chapter;	Yes

			Explanation:
			• The following parameter values used in modeling were not default values:
			  ○ Infiltration Rate: Assigned site-specific values for recharge rates (net infiltration).
			  ○ Dilution Factor: The default dilution factor for the three-phase equation (WAC 173-340-747(3)(a)) was not used. Instead, of site-specific hydraulic properties and median site-specific hydraulic gradient were applied in the saturated portion of the model to effectively account for groundwater dilution in the calculation.
			Justification:
			• Infiltration Rate: Use of site-specific values is permitted under (5)(f)(ii)(B).
			• Dilution Factor: If using an alternative fate and transport model (WAC 173-340-747(8)), it is required that dilution "be based on site-specific measurements or estimated using a model incorporating site-specific characteristics."
			Documented:
			• Infiltration Rate
			  ○ Chapter 5, Section 5.4.1 "Surface Cover, Infiltration, and Recharge"
			  ○ Chapter 5, Table 5-5, "Summary of Selected Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-D and 100-H Operable Units"
			  ○ Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*,	

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WAC	Requirement			Response
			Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from PNNL-14702 Rev. 1. See Tables 4-1 and 4-2 in that report. o Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils from PNNL-14702 Rev. 1 in the model. Reference Tables 3 and 4 and Figures 3 and 4 in that section. • Dilution Factor o Chapter 5, Section 5.6 "Vadose Zone Modeling Methods and Results" describes the methodology for inclusion of the aquifer in the model domain and direct simulation of dilution as a function of aquifer depth, hydraulic gradient, domain size, and vadose zone leaching. o Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 5.4 "Calculating Dilution Factors" presents and discusses dilution factor calculation in the STOMP modeling. o Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 5.1.3 "Dilution Factor".	
340-702	14	(c)	(c) Establish a cleanup level under Method C; or	**No**
			Explanation: • A cleanup level was not established under Method C; the cleanup level used was beneficial use (drinking water). Justification: • For groundwater, The NCP at 40 C.F.R. § 300.430(a)(1)(iii)(F) states that EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. The State of Washington defines groundwater as potable in WAC 173 340 720(2), unless the exclusion criteria in WAC 173 340 720(2)(a) through (c) can be demonstrated (insufficient yield, natural constituents that make it unsuitable as a drinking water source). The groundwater beneath the 100 Area does not meet the exclusion criteria; therefore, it is classified by the State as potable. The State of Washington has further determined that the highest beneficial use for potable groundwater, including the potable groundwater at	

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WAC			Requirement	Response
			the Hanford Site, is as a potential source of domestic drinking water (WAC 173 340 720(1)(a)). For surface water, the point of compliance is defined in the MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(7)(a)) as the point or points at which hazardous substances are released to surface waters of the state. MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(7)(b)) indicates that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup levels. Documented: • Chapter 6, Section 6.3.2.2 "Identify Action Levels" • Appendix G, ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.	
340-702	14	(d)	d) Use a conditional point of compliance,	**No**
			Explanation: • The point of compliance is all soil per WAC-173-340-740(6)(b). Note here that the point of calculation referenced in the RI/FS and supporting documentation is the point where groundwater impacts of soil contamination is calculated to derive SSLs and PRGs; it is not the point of compliance itself. Justification: • No justification is necessary for using the prescribed point of compliance. Documented: • Chapter 5, Section 5.7.1 "Identification of Peak Groundwater Concentrations" • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 2.4 "Point of Calculation, Point of Compliance, and Protectiveness Criteria" identifies the point of compliance for SSL and PRG calculation as the WAC required point of compliance: all vadose zone soil.	
340-702	14		shall have the burden of demonstrating to the department that requirements in this chapter have been met to ensure protection of human health and the environment. The department shall only approve of such proposals when it determines that this burden of proof is met.	

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WAC		Requirement		Response
340-702	15	**WAC 173-340-702 (15) New scientific information.** Did the proposal to use new scientific information meet the quality of information requirements in (16)? (required) Any proposal to use new scientific information should be introduced as early in the cleanup process as possible. Proposals to use new scientific information may be considered up to the time of issuance of the final cleanup action plan governing the cleanup action for a site unless triggered as part of a periodic review under WAC 173-340-420 or through a reopener under RCW 70.105D.040 (4)(c).		**Yes**
		Explanation: • New scientific information was introduced in the derivation of a site-specific value (specific to the 100 Area of the Hanford Site) of K_d for hexavalent chromium using batch equilibrium tests. Justification: • Ecology approved the batch leach testing with the approval of the D/H SAP DOE/RL-2009-40 Rev 0. Page 2-127 describes the procedure. It was also modified by TPA-CN-368 signed by Ecology on 8/26/2010 to allow for removing the requirement for pH adjustment of demineralized water. Documented: • **Chapter 5, Section 5.5.2 "Development of a Hexavalent Chromium Distribution Coefficient for Vadose Zone Simulations from Batch Leach Testing Results"** • Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area.*		
340-702	16	**WAC 173-340-702 (16) Criteria for quality of information.**		
340-702	16	(a)	(a) The intent of this subsection is to establish minimum criteria to be considered when evaluating information used by or submitted to the department proposing to modify the default methods or assumptions specified in this chapter or proposing methods or assumptions not specified in this chapter for calculating cleanup levels and remediation levels. This subsection does not establish a burden of	

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WAC	Requirement				Response
			proof or alter the burden of proof provided for elsewhere in this chapter.		
340-702	16	(b)	(b) When evaluating the quality of the information the department shall consider the following factors, as appropriate for the type of information submitted:		
340-702	16	(b)	(i)	(i) Is the information based on a theory or technique that has widespread acceptance within the relevant scientific community?	**Yes**
				Explanation: • The general modeling approach for using the STOMP code to calculate SSLs and PRGs under was proposed and accepted in DOE/RL-2011-50 Rev. 1. **This document was noted to "provide justification for the uses of the STOMP code itself, but specific models implemented using the STOMP code require justification in application specific documents". Such information is provided in key supporting** documents included in Appendix F of this RI/FS report. Justification: • Use of STOMP as a computational code to implement a numerical model for calculation of SSLs and PRGs under a general approach is justified in DOE/RL-2011-50 Rev. 1. (This justification is limited to STOMP as a computational tool, and does not cover the specific models implemented in STOMP, which must be documented and justified for specific applications.) • As noted by Ecology in their acceptance of DOE/RL-2011-50 Rev. 1, specific applications of this approach and use of STOMP require presentation and justification of model implementation (construction and parameterization) in application-specific documents. This RI/FS constitutes such an application-specific document. The specific conceptual model and parameterization to be implemented in STOMP are presented and justified in the RI/FS, specifically in the model package report SGW-50776 Rev. 2 and in the application of the model to calculate SSLs and PRGs in ECF-HANFORD-11-0063 Rev. 6. Documented: • **Chapter 5, Section 5.7 "Groundwater/Surface Water Protection Screening Level and Preliminary Remediation Goal Development" presents an overview of the SSL and PRG modeling approach.** • DOE/RL-2011-50 Rev. 1, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection*, justifies use of STOMP as a computational code for implementation of	

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WAC	Requirement				Response
				numerical models to calculate SSLs and PRGs. • PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide,* comprehensively documents the available governing and constitutive equations available in the STOMP code. • Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor* (in its entirety) presents the basis for the modeling and parameterization of vadose zone models implemented in STOMP for the purpose of calculation of SSL and PRG values. This includes identification of the specific operational mode of STOMP used to implement the model, as well as identification of which STOMP equations are used in this model (in Section 4.1 "Governing Equations"). • Appendix F, ECF-Hanford-11-0063 (in its entirety) presents details on the application of STOMP to calculate SSL and PRG values.	
340-702	16	(b)	(ii)	(ii) Is the information derived using standard testing methods or other widely accepted scientific methods?	**Yes**
				Explanation: • Batch leach test data used to derive a 100 Area specific K_d value for hexavalent chromium. Site-specific recharge rates were taken from scientific literature. Justification: • Batch leach test data were collected and submitted for leaching using ASTM D3987-06, *Standard Test Method for Shake Extraction of Solid Waste with Water.* Documented: • Soil Leaching Data: o Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area.* • Recharge Rates: o Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 3.2.2 "Recharge and Evapotranspiration", Section 4.4.1 "Flow and Transport Boundary Conditions", and Section 6.2.2 "Sensitivity to Long Term Recharge"	

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WAC				Requirement	Response
				○ Appendix F, ECF-HANFORD-11-0063, *STOMP 1-D Modeling for Determination of Preliminary Remediation Goals for 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" which references these sources of site-specific recharge rates: ▪ PNNL-14702 Rev. 1, *Vadose Zone Hydrogeology Data Package for Hanford Assessments* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf) cites scientific data noted above in response to WAC requirement 8(b)(vii). ▪ PNNL-17841, *Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17841.pdf) provides additional scientific basis for recharge rate measurements.	
340-702	16	(b)	(iii)	(iii) Has a review of relevant available information, both in support of and not in support of the proposed modification, been provided along with the rationale explaining the reasons for the proposed modification?	**Yes**
				Explanation: • A conservative basis was selected for deriving a K_d value for hexavalent chromium through use of a 90 percent likelihood that actual values for residual hexavalent chromium contamination would exhibit a greater sorptive value. Justification: • This basis represents a conservative value for sorption of residual hexavalent chromium in the vadose zone. This assumption is not applicable to the mobile fraction of hexavalent chromium that has already migrated to groundwater. Documented: • Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area* (in its entirety)	
				Explanation:	

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WAC				Requirement	Response
				• Batch leach test data used to derive a 100 Area specific K_d value for hexavalent chromium. Site-specific recharge rates were taken from scientific literature. Justification: • Batch leach test data were collected and submitted for leaching using ASTM D3987-06, *Standard Test Method for Shake Extraction of Solid Waste with Water.* Documented: • Soil Leaching Data: ○ Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area.* • Recharge Rates: ○ Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 3.2.2 "Recharge and Evapotranspiration", Section 4.4.1 "Flow and Transport Boundary Conditions", and Section 6.2.2 "Sensitivity to Long Term Recharge" ○ Appendix F, ECF-HANFORD-11-0063, *STOMP 1-D Modeling for Determination of Preliminary Remediation Goals for 100-D and 100-H Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" which references these sources of site-specific recharge rates: ▪ PNNL-14702 Rev. 1, *Vadose Zone Hydrogeology Data Package for Hanford Assessments* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf) cites scientific data noted above in response to WAC requirement 8(b)(vii). ▪ PNNL-17841, *Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17841.pdf) provides additional scientific basis for recharge rate measurements.	
340-702	16	(b)	(iv)	(iv) Are the assumptions used in applying the information to the facility valid and would they ensure the proposed modification would err on behalf of human health and the environment?	**Yes**

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WAC	Requirement				Response
				Explanation: • The modeling approach applied conservative assumptions, with respect to SSLs and PRGs, to structure and parameterization of the model, where uncertainty existed, to achieve this standard. Conservative assumptions include (not are not limited to): o The point of calculation is assumed to at the waste site boundary on the downstream side of the waste site, o Contaminant source is assumed to span a large portion of the vadose zone (100% of the vadose zone for mobile and somewhat immobile contaminants; upper 70% for less mobile contaminants), and o No credit is taken for natural degradation, air-phase partitioning, or hydrodynamic dispersion. Discussion of the limitations and uncertainty in the model and parameterization are provided. Other examples of conservatism include: o Application of irrigation for the irrigation recharge scenario starting less than five years after remedial action (when presumably institutional controls would delay this by decades; resulting in conservatism because higher recharge mobilizes and transports contaminants sooner and faster with higher peak groundwater concentrations and hence lower PRG values); o Derivation of stratigraphic profiles for the model at maximum water table (conservative because this minimizes transport distance in the vadose zone, resulting in earlier and higher peak concentrations); and o Assumption of uniform contamination in the vadose zone at the peak level (100:0 and 70:30 rules, depending on contaminant mobility) which is conservative because it brackets, and likely overestimates, the amount of contaminant mass present. These examples are not an exhaustive list of the conservatisms present in the alternative fate and transport model used for SSL and PRG development; full discussion is provided in model uncertainty and limitations discussions in Chapter 5 and the supporting environmental calculation file. Conservatism in the initial concentration distribution was validated to determine whether site-specific modeling was required. A more conservative approach was applied to simulate strontium-90 with a 100:0 distribution, despite its lower mobility under present day transport conditions, in recognition of its current distribution in the deep subsurface environment as a result of past discharge conditions for that constituent. • Dilution factors were treated with representative, site-specific parameter values rather than conservative	

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WAC	Requirement	Response
	assumptions. For context, if the default fixed parameter three-phase partition model [WAC 173-340-747(3)(a)] were used to establish soil concentrations for groundwater protection, the default groundwater dilution factor is 20 for unsaturated zone soil. However, this default is not applicable to this calculation, because it uses alternative fate and transport models [WAC 173-340-747(8)] and not the default parameter three-phase partition model [WAC 173-340-747(3)]. Where alternative fate and transport models are used, the WAC requires that dilution "be based on site-specific measurements or estimated using a model incorporating site-specific characteristics". This requirement is met in this calculation by using STOMP to model the aquifer with the appropriate aquifer thickness and a median hydraulic gradient based on site-specific measurements. • Using the upper 5 m of the aquifer, although allowed by the regulations, does not match site-specific conditions for some waste site locations where the aquifer thickness is less than 5 m. In these locations, the thinner aquifer would result in a higher concentration in the model prediction if all other factors in this calculation were unchanged. However, use of the median area hydraulic gradient in the model for each area, rather than site-specific hydraulic gradient, would also affect the dilution if considered (this gradient would typically be higher at locations with a thinner aquifer to maintain the same aquifer flow rate). Justification: • Uncertainty is consistently addressed through use of conservative assumptions and parameterization. Documented: • Point of Calculation: o Chapter 5, Section 5.9.4 "Uncertainties, Assumptions, and Limitations Specific to Vadose Modeling" o Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 2.4 "Point of Calculation, Point of Compliance, and Protectiveness Criteria" • Contaminant Initial Source Representation: o Chapter 5, Section 5.6.1 "Initial Contaminant Distribution" o Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and*	

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WAC				Requirement	Response
				100-H Source Operable Units, Section 3.2.4 "Initial Conditions" • No credit taken for natural degradation, air-phase partitioning, or dispersion: ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.4 "Contaminant Transport Parameters" • Model Uncertainties: ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.6 "Uncertainties, Assumptions, and Conservatism" • Validation of conservatism in initial distribution conditions for SSL and PRG development and treatment of strontium-90 initial condition: ○ Chapter 5, Section 5.7.2 "Site-Specific Modeling" ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 5.2.1 "Validation of Conservative Basis for 70:30 Source Distribution for High K_d Contaminants" • Dilution Factor: ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 5.3 "Dilution Factor" • Aquifer Thickness Representation: ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.2.3 "Lateral Boundary Conditions"	
340-702	16	(b)	(v)	(v) Does the information adequately address populations that are more highly exposed than the population as a whole and are reasonably likely to be present at the site? And	**No**

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				Explanation: • No cleanup levels are developed for sensitive subpopulations. However, Native American risk assessments are prepared and presented. Justification: • Reasonable maximum exposure assumptions are based on exposure scenarios used to derive regulatory standards, and therefore assumed protective of all populations and adequate to restore the resource to beneficial use. Documented: • Chapter 6, Sections 6.1.4 "Other Residential Land Use Scenarios in RCBRA" • Chapter 6, Section 6.3.8.4.1 "Uncertainties Associated with the Native American Risk Assessments" • Appendix G, ECF-100HR3-10-0477 Rev. 1, *Native American Risk Assessment for the 100-HR-3 Groundwater Operable Unit* (in its entirety)	
340-702	16	(b)	(vi)	(vi) • Has adequate quality assurance and quality control procedures been used? • Are any significant anomalies adequately explained? • Are the limitations of the information identified? and Is the known or potential rate of error is acceptable?	**Yes**
				Explanation: • Quality assurance for use of modeling to develop SSL and PRG values was performed following EPA guidance (EPA/240/R-02/007, EPA QA/G-5M, *Guidance for Quality Assurance Project Plans for Modeling*). Requirements addressed modeler training, software and model documentation and configuration control, model application checking, and controlled software use in the preparation of calculations using STOMP to derive SSL and PRG values. No significant anomalies were found during implementation of the STOMP model. The limitations of the alternative fate and transport modeling used to derive SSL and PRG values are identified. The STOMP code solves the numerical equations to a defined level of precision; hence, effectively any error would be associated with model uncertainties,	

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	scenario uncertainties, and parameter uncertainties. Judicious use of conservatism is made in the development of the model, scenarios, and parameterization to ensure that errors are biased in a conservative direction relative to protection of surface water and groundwater. That is, conservatism with regard to these areas where uncertainty in the model exists is used to cause calculated SSL and PRG values to be lower than would be calculated with reduced uncertainty and/or with less conservative bias in model development. Quality assurance for use of software used to implement the model was performed in accordance with the requirements of DOE Order 414.1, *Quality Assurance*, which imposes NQA-1 standards on software use. The STOMP software was tested and qualified before use for modeling under procedures that implement the requirements of DOE Order 414.1 and guidance of NQA-1.
	
	Justification:
	
	• Approved quality assurance plans and procedures written to meet the requirements of DOE and the guidance of the EPA were adhered to throughout the modeling process. All aspects required under this WAC requirement were included in the RI/FS documentation. Limitations of the model are discussed in the primary categories of (1) model uncertainties, (2) scenario uncertainties, and (3) parameter uncertainties.
	
	Documented:
	
	• Demonstration of quality assurance and quality control procedure use:
	  ○ Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units* (in its entirety) provides demonstration of documentation of model application in compliance with a plan that followed the guidance provided in
	  ○ EPA/240/R-02/007, EPA QA/G-5M, *Guidance for Quality Assurance Project Plans for Modeling*
	
	• Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 4 " Software Applications" demonstrates controlled software use under an approved quality assurance process in compliance with implementing procedures compliant with
	  ○ DOE O 414.1D, *Quality Assurance*
	
	• Signatures of the checker and senior reviewer on cover sheet of Appendix F, Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and*	

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				Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units,, validate completion of independent review and checking of model application as required under an approved quality assurance procedure governing preparation of environmental calculations. Limitations of the information identified, and known or potential error rate: • Chapter 5, Section 5.9 "Uncertainties that Apply to Groundwater and Vadose Zone Modeling" • Appendix F, SGW-50776 Rev. 2, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 6.1 "Modeling Conservatisms", Section 6.2 "Sensitivity Analyses", and Section 6.3 "Uncertainty Analyses" • Appendix F, ECF-HANFORD-11-0063 Rev. 6, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*, Section 3.6 "Uncertainties, Assumptions, and Conservatism"	

Attachment B

Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water for the 100-D and 100-H Source Operable Units

Note

Tabulated soil screening level (SSL) values are presented in Tables B-1, B-2, and B-3 in ascending K_d order. This sorting order reveals the correlation between analyte K_d values and resulting SSL values. The threshold at which breakthrough does not occurs is denoted by a bold red borderline for each area (100-D, 100-H) within these tables. Below this threshold, "NR" (nonrepresentative result) values are reported (though shorter-lived radionuclides may result in "NR" values above the indicated threshold due to radiological decay). The "NR" code reflects that the model simulations did not predict breakthrough within 1000 years, defined here as a peak groundwater concentration exceeding 0.0001 μg/L for non-radionuclide analytes, or 0.0001 pCi/m^3 for radionuclide analytes), a value set as the lower limit of numerical significance for model groundwater concentration results.

The same SSL values are presented again in Tables B-4, B-5, and B-6, but in ascending analyte name order to enable lookup by the reader by analyte name.

Table B-1. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	1.26E+04	1.39E+05
14797-55-8	Nitrate	Nitrate	0	45,000	2.50E+00	2.27E+03	2.51E+04
14797-65-0	Nitrite	Nitrite	0	3,300	2.50E+00	1.66E+02	1.84E+03
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	10,000	7.50E-01	5.04E+02	5.57E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1,000	7.50E-01	5.04E+01	5.57E+02
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	10,000	---	5.04E+02	5.57E+03
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	1.26E+04	1.39E+05
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	0,032	8.25E-01	1.61E+00	1.78E+01
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	3.66E+02	4.04E+03
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	800	---	4.20E+01	4.63E+02
75-99-0	Dalapon	Dalapon	0.0032	200	---	1.06E+01	1.16E+02
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	4800.0	1.00E-02	2.58E+02	2.85E+03
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	6.41E-01	7.05E+00
75-09-2	Methylene chloride	methylene chloride	0.0100	5.00	5.00E-03	2.90E-01	3.19E+00
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	3.85E+01	4.23E+02
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	2.93E+00	3.21E+01
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	0,040	2.00E-02	2.47E+00	2.71E+01
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	6.36E-03	4.32E-02
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	0.01	3.30E-01	4.20E-01	5.40E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.0270	0	5.00E-03	3.10E-02	3.39E-01
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.0270	0	5.00E-03	3.10E-02	3.39E-01
1918-00-9	Dicamba	Dicamba	0.0288	480	---	3.47E+01	3.80E+02
108-95-2	Phenol	Phenol	0.0288	2,400	3.30E-01	1.74E+02	1.90E+03
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.0355	16.0	5.00E-03	1.24E+00	1.36E+01
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	0.5	5.00E-03	3.80E-02	4.16E-01
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.0380	100.0	5.00E-03	7.91E+00	8.66E+01
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	3.98E+01	4.36E+02
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene, 1,2- (mixed isomers)	0.0396	72.00	5.00E-03	5.78E+00	6.33E+01
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	2.00E+02	2.19E+03
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	6.79E+01	7.43E+02
78-59-1	Isophorone	isophorone	0.0468	46.05	3.30E-01	3.95E+00	4.32E+01
78-87-5	1,2-Dichloropropane	dichloropropane; 1,2-	0.0470	1	5.00E-03	1.04E-01	1.14E+00
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	16.000	2.10E+00	2.67E+00	1.52E+01

Table B-1. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)	
						100-D	100-H
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	7.68	1.00E-02	6.94E-01	7.58E+00
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	1.28E-01	1.39E+00
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	6.49E-02	7.09E-01
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	7.73E-02	8.44E-01
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	5.11E-02	5.58E-01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	7.00	1.00E-02	6.96E-01	7.60E+00
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	4.20E-01	5.40E-01
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	16.0	3.30E-01	1.64E+00	1.79E+01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	1	5.00E-03	8.22E-02	8.96E-01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	4.20E-01	5.40E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	0.2	5.00E-03	2.41E-02	2.63E-01
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	1.44E+03	1.57E+04
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	4.20E-01	7.70E-01
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	400	3.30E-01	4.77E+01	5.20E+02
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	1.15E-01	1.26E+00
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	0,000	3.30E-01	4.20E-01	5.40E-01
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy) butanoic acid)	Dichlorophenoxy) butyric Acid, 4-(2,4-	0.0984	128.0	1.30E-02	1.60E+01	1.74E+02
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	4	3.30E-01	5.53E-01	6.02E+00
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	5.81E-01	6.33E+00
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	0,160	3.30E-01	2.15E+01	2.34E+02
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	16.0	3.30E-01	2.25E+00	2.44E+01
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	8.07E-01	8.78E+00
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	200	5.00E-03	3.05E+01	3.32E+02
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	1.00E+02	1.09E+03
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	24	3.30E-01	3.88E+00	4.22E+01
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	1.03E-01	1.12E+00
108-38-3	m-Xylene	Xylene, m-	0.1960	1600	---	3.19E+02	3.45E+03
100-41-4	Ethylbenzene	ethylbenzene	0.2040	0,004	5.00E-03	8.19E-01	8.84E+00
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	160.00	3.30E-01	3.36E+01	3.62E+02
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	2.21E+01	2.39E+02
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	3.65E+02	3.94E+03
95-47-6	o-Xylene	xylene,o-	0.2410	1600.0	---	3.75E+02	4.04E+03
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	1.27E+00	1.36E+01
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	2.25E+02	2.41E+03
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA

Table B-1. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)	
						100-D	100-H
95-50-1	1,2-Dichlorobenzene	dichlorobenzene; 1,2- (ortho-Dichlorobenzene)	0.38	0,600	3.30E-01	2.05E+02	2.20E+03
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2, 4,6-	0.38	4	3.30E-01	1.36E+00	1.46E+01
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	40.0	3.30E-01	1.39E+01	1.50E+02
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	6.85E+02	7.37E+03
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	0.2	3.30E-01	4.20E-01	1.19E+00
106-46-7	1,4-Dichlorobenzene	dichlorobenzene; 1,4- (para-Dichlorobenzene)	0.62	8	5.00E-03	4.26E+00	4.59E+01
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine ;3,3'-	0.72	0.194	3.30E-01	4.20E-01	1.28E+00
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	8.15E-01	8.80E+00
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	48	---	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	100	5.00E-03	7.73E+01	8.36E+02
91-20-3	Naphthalene	naphthalene	1.19	160	1.00E-01	1.58E+02	1.74E+03
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	0,018	3.30E-01	1.91E+01	2.09E+02
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.079545455	1.65E-03	8.87E-02	9.73E-01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	2.06E+03	2.26E+04
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	800	3.30E-01	1.05E+03	1.15E+04
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene; 1,2,4-	1.66	1.5	3.30E-01	2.05E+00	2.25E+01
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	1.99E-02	2.19E-01
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.09375	3.30E-01	1.59E+00	1.74E+01
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	1.60E+02	1.77E+03
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	1.60E+02	1.77E+03
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	0.048611111	1.65E-03	8.51E-02	9.39E-01
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	1.86E+01	2.06E+02
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	640	3.30E-01	1.29E+03	1.43E+04
91-57-6	2-Methylnaphthalene	methylnapthalene ;2-	2.48	32	3.30E-01	6.46E+01	7.13E+02
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	7.78E+03	8.59E+04
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	1.20E+01	1.32E+02
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA

Table B-1. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	1.61E+03	1.78E+04
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	1.61E+03	1.78E+04
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	2.42E+01	2.67E+02
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	1.89E+03	2.09E+04
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	2.01E+02	2.22E+03
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	2.69E+01	2.96E+02
86-73-7	Fluorene	fluorene	7.7	320.000	3.00E-02	2.02E+03	2.18E+04
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	5.57E+02	5.86E+03
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	1.55E-01	1.62E+00
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	1.55E-01	1.62E+00
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	6.56E+01	6.52E+02
76-44-8	Heptachlor	heptachlor	9.5	0.02	1.65E-03	1.72E-01	1.66E+00
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
57-12-5	Cyanide	cyanide	9.9	4.80	---	4.61E+01	4.30E+02
72-20-8	Endrin	endrin	10.8	2.00	3.30E-03	2.38E+01	2.02E+02
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	1.30E+03	5.98E+03
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
7439-98-7	Molybdenum	molybdenum	20.0	0,080	2.00E+00	1.82E+04	1.51E+04
7440-50-8	Copper	copper	22.0	640	1.00E+00	2.86E+05	1.36E+05
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	3.89E+05	3.89E+05
7439-89-6	Iron	Iron	25.0	11200	5.00E+00	3.89E+05	3.89E+05
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	7.98E+00	1.47E+00
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	2.46E+02	1.95E+01
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	3.89E+05	3.89E+05
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	3.89E+05	3.89E+05
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR	5.59E+03
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR	4.47E+03
72-54-8	4,4'-DDD (Dichlorodiphenyl dichloroethane)	ddd	45.8	0.36	3.30E-03	NR	3.57E+02
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR	3.00E+00
206-44-0	Fluoranthene	fluoranthene	49	640	5.00E-02	NR	3.89E+05
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR	3.34E+02
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR	3.34E+02

Table B-1. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
7439-97-6	Mercury	mercury (using mercruric chloride)	52	2.000	---	NR	2.83E+03
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	1	3.30E-01	NR	8.75E+02
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR	3.89E+05
7439-96-5	Manganese	manganese	65	0,384	5.00E+00	NR	3.89E+05
7440-02-0	Nickel	nickel soluble salts	65	100	4.00E+00	NR	2.89E+05
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR	3.89E+05
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR	6.27E+02
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR	2.24E+02
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR	2.41E+02
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	0.1	3.30E-01	NR	3.30E+02
72-43-5	Methoxychlor	methoxychlor	80	40.000	1.65E-02	NR	2.41E+05
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.005	1.65E-03	NR	3.35E+01
72-55-9	4,4'-DDE (Dichlorodiphenyl dichloroethylene)	dde	86	0	3.30E-03	NR	2.07E+03
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR	9.51E+02
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR	9.27E+03
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR	1.30E+05
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR	1.85E+03
16984-48-8	Fluoride	fluoride (using fluorine)	150	960	5.00E+00	NR	3.89E+05
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	48.00	3.30E-01	NR	NR
7440-31-5	Tin	tin	250	9600	1.00E+01	NR	NR
7439-93-2	Lithium	Lithium	300	32	2.50E+00	NR	NR
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR	NR
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyl trichloroethane)	ddt	678	0.257352941	3.30E-03	NR	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR	NR
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR	NR
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA

Table B-1. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	0.119863014	3.00E-02	NR	NR
7439-92-1	Lead	lead	10000	15	5.00E-01	NR	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR	NR
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington. K_d values reported here were used in calculations and may differ in precision (rounding) from values reported in ECF-HANFORD-12-0023, but were derived from the same electronic data set.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to soil screening levels:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.
- Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

e. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table B-2. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	1.16E+04	1.28E+05
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA	NA
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA	NA
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA	NA
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA	NA
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	--	5.00E-03	NA	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	--	5.00E-03	NA	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	--	5.00E-03	NA	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA	NA
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	--	5.00E-03	NA	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	--	5.00E-03	NA	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA	NA
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA	NA
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	--	5.00E-03	NA	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA	NA
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA	NA

Table B-2. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA	NA
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA	NA
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA	NA
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA	NA
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA	NA
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA	NA
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	--	3.30E-01	NA	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA	NA

Table B-2. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	6.58E+00	7.09E+01
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	--	3.30E-01	NA	NA
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	8.92E-02	9.79E-01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	--	3.30E-01	NA	NA
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	9.36E-02	1.03E+00
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	9.36E-02	1.03E+00
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	--	1.65E-03	NA	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA	NA
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	--	3.30E-01	NA	NA
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA

Table B-2. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	2.01E+01	2.22E+02
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	1.34E+00	1.48E+01
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	1.82E+01	1.91E+02
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	9.92E-02	1.04E+00
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	9.92E-02	1.04E+00
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA	NA
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	3.36E-02	3.25E-01
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
57-12-5	Cyanide	cyanide	9.9	5.2	---	4.99E+01	4.66E+02
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	2.74E-02	2.32E-01
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA	NA
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	4.03E+03	1.92E+03
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	3.89E+05	2.58E+05
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	2.77E+00	5.09E-01
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	3.89E+05	5.02E+04
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA	NA
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA	NA
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	--	3.30E-03	NA	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR	2.21E+00
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR	5.74E+00
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR	5.74E+00
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR	1.70E+01
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR	2.25E+05
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR	1.50E+05
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA	NA
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR	7.18E+01
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR	7.73E+01
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA	NA
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR	1.81E+02

Table B-2. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR	2.65E+01
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	--	3.30E-03	NA	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR	2.39E+00
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR	2.60E+02
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA	NA
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR	5.91E+02
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA	NA
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA	NA
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.0010	3.30E-03	NR	NR
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA	NA
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR	NR
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA	NA
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	--	1.50E-02	NA	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	--	1.50E-02	NA	NA
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA

Table B-2. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington. K_d values reported here were used in calculations and may differ in precision (rounding) from values reported in ECF-HANFORD-12-0023, but were derived from the same electronic data set.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to soil screening levels:

   a. "NA" was assigned where no applicable water quality standard was available.

   b. "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).

   c. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

   d. Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

e. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table B-3. Soil Screening Levels for Radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

Radionuclide	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Maximum Contaminant Level [a] (pCi/L)	Half-life [b] (yr)	Estimated Quantitation Limit [c] (mg/kg)	Dimensional Soil Screening Level Protective of Groundwater [d,e] (pCi/g·m)	
					100-D	100-H
Carbon-14 [f]	0	2000	5.7300E+03	---	1.01E+02	1.11E+03
Cesium-137	50	200	3.0000E+01	1.00E-01	NR	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR	NR
Iodine-129	1	1	1.5700E+07	---	8.42E-01	9.21E+00
Neptunium-237	15	15	2.1400E+06	---	6.25E+02	2.11E+03
Nickel-63	30	50	9.6000E+01	---	NR	1.70E+06
Strontium-90 [g]	25	8	2.9120E+01	---	2.94E+04	1.57E+05
Technetium-99	0	900	2.1300E+05	---	4.54E+01	5.01E+02
Tritium	0	20000	1.2350E+01	---	2.06E+03	1.80E+04
Americium-241	200	15	4.32E+02	1.00E+00	NR	NR
Carbon-14 [h]	200	2,000	5.73E+03	---	NR	NR
Curium-243	200	15	2.85E+01	---	NR	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR	NR
Niobium-94	200	--	2.03E+04	---	NA	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR	NR
Plutonium-241	200	300	1.40E+01	---	NR	NR
Radium-226	200	5	1.60E+03	---	NR	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR	NR
Thorium-228	200	15	1.91E+00	---	NR	NR
Thorium-230	200	15	7.70E+04	---	NR	NR
Thorium-232	200	15	1.41E+10	---	NR	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington. K_d values reported here wre used in calculations and may differ in precision (rounding) from values reported in ECF-HANFORD-12-0023, but were derived from the same electronic data set.

b. Radiochemistry Society website, Available at: http://www.radiochemistry.org/.

c. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

d. The following restrictions were applied to soil screening levels:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 pCi/m^3 (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

f. Carbon-14 in liquid form (typically associated with reactor gas condensate).

g. The soil screening level for strontium-90 is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these OUs.

h. Carbon-14 in solid form (typically associated with graphite).

Table B-4. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	200	5.00E-03	3.05E+01	3.32E+02
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	0.2	5.00E-03	2.41E-02	2.63E-01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	1	5.00E-03	8.22E-02	8.96E-01
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	7.68	1.00E-02	6.94E-01	7.58E+00
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	7.00	1.00E-02	6.96E-01	7.60E+00
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	1.5	3.30E-01	2.05E+00	2.25E+01
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	0,600	3.30E-01	2.05E+02	2.20E+03
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	0.5	5.00E-03	3.80E-02	4.16E-01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	72.00	5.00E-03	5.78E+00	6.33E+01
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	1	5.00E-03	1.04E-01	1.14E+00
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	8	5.00E-03	4.26E+00	4.59E+01
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	16.000	2.10E+00	2.67E+00	1.52E+01
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	800	3.30E-01	1.05E+03	1.15E+04
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	4	3.30E-01	1.36E+00	1.46E+01
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy) butanoic acid)	Dichlorophenoxy) butyric Acid, 4-(2,4-	0.0984	128.0	1.30E-02	1.60E+01	1.74E+02
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	24	3.30E-01	3.88E+00	4.22E+01
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	160.00	3.30E-01	3.36E+01	3.62E+02
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	0,032	8.25E-01	1.61E+00	1.78E+01
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	0,000	3.30E-01	4.20E-01	5.40E-01
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	16.0	3.30E-01	1.64E+00	1.79E+01
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	4800.0	1.00E-02	2.58E+02	2.85E+03
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	800	---	4.20E+01	4.63E+02
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	640	3.30E-01	1.29E+03	1.43E+04
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	40.0	3.30E-01	1.39E+01	1.50E+02
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	0,040	2.00E-02	2.47E+00	2.71E+01
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	32	3.30E-01	6.46E+01	7.13E+02
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	400	3.30E-01	4.77E+01	5.20E+02
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	0,160	3.30E-01	2.15E+01	2.34E+02
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA

Table B-4. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)	
						100-D	100-H
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine ;3,3'-	0.72	0.194	3.30E-01	4.20E-01	1.28E+00
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	4	3.30E-01	5.53E-01	6.02E+00
72-54-8	4,4'-DDD (Dichlorodiphenyl dichloroethane)	ddd	45.8	0.36	3.30E-03	NR	3.57E+02
72-55-9	4,4'-DDE (Dichlorodiphenyl dichloroethylene)	dde	86	0	3.30E-03	NR	2.07E+03
50-29-3	4,4'-DDT (Dichlorodiphenyl trichloroethane)	ddt	678	0.257352941	3.30E-03	NR	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	8.15E-01	8.80E+00
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	3.98E+01	4.36E+02
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	6.85E+02	7.37E+03
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	4.20E-01	5.40E-01
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	3.85E+01	4.23E+02
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	2.25E+02	2.41E+03
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	5.81E-01	6.33E+00
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	1.89E+03	2.09E+04
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	3.66E+02	4.04E+03
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR	3.00E+00
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	1.99E-02	2.19E-01
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR	3.34E+02
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR	NR
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	3.89E+05	3.89E+05
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR	5.59E+03
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR	9.27E+03
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	1.55E-01	1.62E+00
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	1.55E-01	1.62E+00
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR	2.41E+02
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR	2.24E+02
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR	1.85E+03
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR	NR

Table B-4. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)	
						100-D	100-H
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	2.46E+02	1.95E+01
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	3.89E+05	3.89E+05
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	7.73E-02	8.44E-01
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR	NR
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	0.048611111	1.65E-03	8.51E-02	9.39E-01
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	4.20E-01	7.70E-01
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	2.93E+00	3.21E+01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	4.20E-01	5.40E-01
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR	1.30E+05
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	7.78E+03	8.59E+04
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	6.49E-02	7.09E-01
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	8.07E-01	8.78E+00
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	6.41E-01	7.05E+00
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	1.30E+03	5.98E+03
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	2.69E+01	2.96E+02
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	1.20E+01	1.32E+02
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	6.79E+01	7.43E+02
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	1.03E-01	1.12E+00
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR	3.34E+02
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	1.26E+04	1.39E+05
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	2.21E+01	2.39E+02
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	1.28E-01	1.39E+00
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR	NR
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.0355	16.0	5.00E-03	1.24E+00	1.36E+01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.0270	0	5.00E-03	3.10E-02	3.39E-01
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR	4.47E+03
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
7440-50-8	Copper	copper	22.0	640	1.00E+00	2.86E+05	1.36E+05

Table B-4. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
57-12-5	Cyanide	cyanide	9.9	4.80	---	4.61E+01	4.30E+02
75-99-0	Dalapon	Dalapon	0.0032	200	---	1.06E+01	1.16E+02
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR	NR
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	6.56E+01	6.52E+02
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	5.11E-02	5.58E-01
1918-00-9	Dicamba	Dicamba	0.0288	480	---	3.47E+01	3.80E+02
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	7.98E+00	1.47E+00
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	1.44E+03	1.57E+04
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	2.06E+03	2.26E+04
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR	NR
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	2.42E+01	2.67E+02
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	1.60E+02	1.77E+03
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	1.60E+02	1.77E+03
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
72-20-8	Endrin	endrin	10.8	2.00	3.30E-03	2.38E+01	2.02E+02
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	0,004	5.00E-03	8.19E-01	8.84E+00
206-44-0	Fluoranthene	fluoranthene	49	640	5.00E-02	NR	3.89E+05
86-73-7	Fluorene	fluorene	7.7	320.000	3.00E-02	2.02E+03	2.18E+04
16984-48-8	Fluoride	fluoride (using fluorine)	150	960	5.00E+00	NR	3.89E+05
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.079545455	1.65E-03	8.87E-02	9.73E-01
76-44-8	Heptachlor	heptachlor	9.5	0.02	1.65E-03	1.72E-01	1.66E+00
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.005	1.65E-03	NR	3.35E+01
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	0.1	3.30E-01	NR	3.30E+02
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	1	3.30E-01	NR	8.75E+02
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	48.00	3.30E-01	NR	NR
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.09375	3.30E-01	1.59E+00	1.74E+01
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	48	---	6 [e]	6 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	0.119863014	3.00E-02	NR	NR
7439-89-6	Iron	Iron	25.0	11200	5.00E+00	3.89E+05	3.89E+05
78-59-1	Isophorone	isophorone	0.0468	46.05	3.30E-01	3.95E+00	4.32E+01
7439-92-1	Lead	lead	10000	15	5.00E-01	NR	NR
7439-93-2	Lithium	Lithium	300	32	2.50E+00	NR	NR
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA

Table B-4. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
7439-96-5	Manganese	manganese	65	0,384	5.00E+00	NR	3.89E+05
7439-97-6	Mercury	mercury (using mercruric chloride)	52	2.000	---	NR	2.83E+03
72-43-5	Methoxychlor	methoxychlor	80	40.000	1.65E-02	NR	2.41E+05
75-09-2	Methylene chloride	methylene chloride	0.0100	5.00	5.00E-03	2.90E-01	3.19E+00
7439-98-7	Molybdenum	molybdenum	20.0	0,080	2.00E+00	1.82E+04	1.51E+04
108-38-3	m-Xylene	Xylene, m-	0.1960	1600	---	3.19E+02	3.45E+03
91-20-3	Naphthalene	naphthalene	1.19	160	1.00E-01	1.58E+02	1.74E+03
7440-02-0	Nickel	nickel soluble salts	65	100	4.00E+00	NR	2.89E+05
14797-55-8	Nitrate	Nitrate	0	45,000	2.50E+00	2.27E+03	2.51E+04
14797-65-0	Nitrite	Nitrite	0	3,300	2.50E+00	1.66E+02	1.84E+03
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	16.0	3.30E-01	2.25E+00	2.44E+01
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	10,000	7.50E-01	5.04E+02	5.57E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1,000	7.50E-01	5.04E+01	5.57E+02
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	10,000	---	5.04E+02	5.57E+03
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	0.01	3.30E-01	4.20E-01	5.40E-01
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	0,018	3.30E-01	1.91E+01	2.09E+02
95-47-6	o-Xylene	xylene,o-	0.2410	1600.0	---	3.75E+02	4.04E+03
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	0.2	3.30E-01	4.20E-01	1.19E+00
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
108-95-2	Phenol	Phenol	0.0288	2,400	3.30E-01	1.74E+02	1.90E+03
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR	3.89E+05
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	2.01E+02	2.22E+03
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	5.57E+02	5.86E+03
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	3.89E+05	3.89E+05
100-42-5	Styrene	styrene	0.91	100	5.00E-03	7.73E+01	8.36E+02
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	1.26E+04	1.39E+05
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	1.27E+00	1.36E+01
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR	6.27E+02
7440-31-5	Tin	tin	250	9600	1.00E+01	NR	NR
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	1.00E+02	1.09E+03
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	1.61E+03	1.78E+04
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	1.61E+03	1.78E+04
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR	9.51E+02
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.0380	100.0	5.00E-03	7.91E+00	8.66E+01

Table B-4. Soil Screening Levels for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.0270	0	5.00E-03	3.10E-02	3.39E-01
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	1.86E+01	2.06E+02
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	1.15E-01	1.26E+00
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	2.00E+02	2.19E+03
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]	NVR [f]
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR	NR
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	6.36E-03	4.32E-02
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	3.65E+02	3.94E+03
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR	3.89E+05

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington. K_d values reported here were used in calculations and may differ in precision (rounding) from values reported in ECF-HANFORD-12-0023, but were derived from the same electronic data set.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to soil screening levels:

   a. "NA" was assigned where no applicable water quality standard was available.

   b. "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).

   c. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

   d. Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

e. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table B-5. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA	NA
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	--	3.30E-01	NA	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	--	5.00E-03	NA	NA
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	--	5.00E-03	NA	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	--	3.30E-01	NA	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA	NA
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA	NA
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	--	3.30E-01	NA	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	--	3.30E-01	NA	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA	NA
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	--	3.30E-03	NA	NA

Table B-5. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	--	3.30E-03	NA	NA
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.0010	3.30E-03	NR	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA	NA
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR	2.21E+00
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR	5.74E+00
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR	NR
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR	2.60E+02
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	9.92E-02	1.04E+00
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	9.92E-02	1.04E+00
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR	7.73E+01
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR	7.18E+01
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR	5.91E+02
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	3.89E+05	5.02E+04
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA	NA
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA	NA
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA	NA
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	--	1.50E-02	NA	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	--	1.50E-02	NA	NA

Table B-5. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA	NA
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	--	1.65E-03	NA	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA	NA
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA	NA
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA	NA
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA	NA
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	1.34E+00	1.48E+01
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA	NA
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR	5.74E+00
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	1.16E+04	1.28E+05
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR	NR
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	--	5.00E-03	NA	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	--	5.00E-03	NA	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	4.03E+03	1.92E+03
57-12-5	Cyanide	cyanide	9.9	5.2	---	4.99E+01	4.66E+02
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA	NA
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA	NA
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA	NA
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA	NA
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	2.77E+00	5.09E-01

Table B-5. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA	NA
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	9.36E-02	1.03E+00
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	9.36E-02	1.03E+00
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	2.74E-02	2.32E-01
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA	NA
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA	NA
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA	NA
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	8.92E-02	9.79E-01
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	3.36E-02	3.25E-01
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR	2.65E+01
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA	NA
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	6 [e]	6 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	3.89E+05	2.58E+05
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR	NR
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA	NA
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR	1.70E+01
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR	1.81E+02
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR	1.50E+05
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA	NA

Table B-5. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA	NA
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	6.58E+00	7.09E+01
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	2.01E+01	2.22E+02
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	1.82E+01	1.91E+02
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA	NA
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR	2.39E+00
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	--	5.00E-03	NA	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	--	5.00E-03	NA	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA	NA
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]	NVR [f]
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR	2.25E+05

Table B-5. Soil Screening Levels for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington. K_d values reported here were used in calculations and may differ in precision (rounding) from values reported in ECF-HANFORD-12-0023, but were derived from the same electronic data set.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to soil screening levels:

   a. "NA" was assigned where no applicable water quality standard was available.

   b. "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).

   c. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

   d. Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

e. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table B-6. Soil Screening Levels for Radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

Radionuclide	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Maximum Contaminant Level [a] (pCi/L)	Half-life [b] (yr)	Estimated Quantitation Limit [c] (mg/kg)	Dimensional Soil Screening Level Protective of Groundwater [d,e] (pCi/g·m)	
					100-D	100-H
Americium-241	200	15	4.32E+02	1.00E+00	NR	NR
Carbon-14 [f]	0	2000	5.7300E+03	---	1.01E+02	1.11E+03
Carbon-14 [g]	200	2,000	5.73E+03	---	NR	NR
Cesium-137	50	200	3.0000E+01	1.00E-01	NR	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR	NR
Curium-243	200	15	2.85E+01	---	NR	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR	NR
Iodine-129	1	1	1.5700E+07	---	8.42E-01	9.21E+00
Neptunium-237	15	15	2.1400E+06	---	6.25E+02	2.11E+03
Nickel-63	30	50	9.6000E+01	---	NR	1.70E+06
Niobium-94	200	--	2.03E+04	---	NA	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR	NR
Plutonium-241	200	300	1.40E+01	---	NR	NR
Radium-226	200	5	1.60E+03	---	NR	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR	NR
Strontium-90 [h]	25	8	2.9120E+01	---	2.94E+04	1.57E+05
Technetium-99	0	900	2.1300E+05	---	4.54E+01	5.01E+02
Thorium-228	200	15	1.91E+00	---	NR	NR
Thorium-230	200	15	7.70E+04	---	NR	NR
Thorium-232	200	15	1.41E+10	---	NR	NR
Tritium	0	20000	1.2350E+01	---	2.06E+03	1.80E+04

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington. K_d values reported here wre used in calculations and may differ in precision (rounding) from values reported in ECF-HANFORD-12-0023, but were derived from the same electronic data set.

b. Radiochemistry Society website, Available at: http://www.radiochemistry.org/.

c. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

d. The following restrictions were applied to soil screening levels:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 pCi/m^3 (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

f. Carbon-14 in liquid form (typically associated with reactor gas condensate).

g. Carbon-14 in solid form (typically associated with graphite).

h. The soil screening level for strontium-90 is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these OUs.

Attachment C

Preliminary Remediation Goals Protective of Groundwater and Preliminary Remediation Goals Protective of Surface Water for the 100-D and 100-H Source Operable Units

Note

Tabulated preliminary remediation goal (PRG) values are presented in Tables C-1, C-2, and C-3 in ascending K_d order. This sorting order reveals the correlation between analyte K_d values and resulting PRG values. The threshold at which breakthrough does not occurs is denoted by a bold red borderline for each area (100-D, 100-H) within these tables. Below this threshold, "NR" (nonrepresentative result) values are reported (though shorter-lived radionuclides may result in "NR" values above the indicated threshold due to radiological decay). The "NR" code reflects that the model simulations did not predict breakthrough within 1000 years, defined here as a peak groundwater concentration exceeding 0.0001 µg/L for non-radionuclide analytes, or 0.0001 pCi/m3 for radionuclide analytes), a value set as the lower limit of numerical significance for model groundwater concentration results.

The same PRG values are presented again in Tables C-4, C-5, and C-6, but in ascending analyte name order to enable lookup by the reader by analyte name.

Table C-1. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [c, d] (mg/kg·m) 100-D	100-H
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	1.88E+04	1.80E+05
14797-55-8	Nitrate	Nitrate	0	45,000	2.50E+00	3.38E+03	3.24E+04
14797-65-0	Nitrite	Nitrite	0	3,300	2.50E+00	2.48E+02	2.37E+03
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	10,000	7.50E-01	7.52E+02	7.19E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1,000	7.50E-01	7.52E+01	7.19E+02
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	10,000	---	7.52E+02	7.19E+03
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	1.88E+04	1.80E+05
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	0,032	8.25E-01	2.41E+00	2.30E+01
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	5.46E+02	5.23E+03
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	800	---	6.26E+01	6.02E+02
75-99-0	Dalapon	Dalapon	0.0032	200	---	1.57E+01	1.51E+02
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	4800.0	1.00E-02	3.84E+02	3.71E+03
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	9.51E-01	9.25E+00
75-09-2	Methylene chloride	methylene chloride	0.0100	5.00	5.00E-03	4.30E-01	4.19E+00
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	5.71E+01	5.59E+02
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	4.34E+00	4.25E+01
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	0,040	2.00E-02	3.66E+00	3.59E+01
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	6.36E-03	5.75E-02
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	0.01	3.30E-01	4.20E-01	5.40E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.0270	0	5.00E-03	4.58E-02	4.57E-01
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.0270	0	5.00E-03	4.58E-02	4.57E-01
1918-00-9	Dicamba	Dicamba	0.0288	480	---	5.13E+01	5.13E+02
108-95-2	Phenol	Phenol	0.0288	2,400	3.30E-01	2.56E+02	2.57E+03
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.0355	16.0	5.00E-03	1.83E+00	1.85E+01
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	0.5	5.00E-03	5.61E-02	5.69E-01
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.0380	100.0	5.00E-03	1.17E+01	1.18E+02
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	5.88E+01	5.96E+02
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene, 1,2- (mixed isomers)	0.0396	72.00	5.00E-03	8.53E+00	8.67E+01
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	2.96E+02	3.02E+03
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	1.00E+02	1.03E+03
78-59-1	Isophorone	isophorone	0.0468	46.05	3.30E-01	5.83E+00	5.97E+01
78-87-5	1,2-Dichloropropane	dichloropropane; 1,2-	0.0470	1	5.00E-03	1.54E-01	1.58E+00
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	16.000	2.10E+00	2.67E+00	2.11E+01

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75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	7.68	1.00E-02	1.02E+00	1.06E+01
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	1.88E-01	1.95E+00
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	9.58E-02	9.92E-01
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	1.14E-01	1.19E+00
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	7.55E-02	7.90E-01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	7.00	1.00E-02	1.03E+00	1.08E+01
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	4.20E-01	5.40E-01
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	16.0	3.30E-01	2.43E+00	2.56E+01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	1	5.00E-03	1.22E-01	1.29E+00
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	4.20E-01	5.40E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	0.2	5.00E-03	3.57E-02	3.81E-01
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	2.14E+03	2.29E+04
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	4.20E-01	1.13E+00
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	400	3.30E-01	7.11E+01	7.70E+02
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	1.72E-01	1.87E+00
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	0,000	3.30E-01	4.20E-01	5.62E-01
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy) butanoic acid)	Dichlorophenoxy) butyric Acid, 4-(2,4-	0.0984	128.0	1.30E-02	2.39E+01	2.61E+02
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	4	3.30E-01	8.32E-01	9.20E+00
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	8.74E-01	9.67E+00
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	0,160	3.30E-01	3.24E+01	3.59E+02
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	16.0	3.30E-01	3.40E+00	3.80E+01
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	1.23E+00	1.38E+01
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	200	5.00E-03	4.66E+01	5.31E+02
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	1.53E+02	1.76E+03
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	24	3.30E-01	5.98E+00	6.91E+01
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	1.60E-01	1.86E+00
108-38-3	m-Xylene	Xylene, m-	0.1960	1600	---	5.13E+02	6.26E+03
100-41-4	Ethylbenzene	ethylbenzene	0.2040	0,004	5.00E-03	1.32E+00	1.63E+01
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	160.00	3.30E-01	5.45E+01	6.75E+02
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	3.65E+01	4.59E+02
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	6.09E+02	7.71E+03
95-47-6	o-Xylene	xylene,o-	0.2410	1600.0	---	6.31E+02	8.06E+03
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	2.19E+00	2.86E+01
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	4.05E+02	5.45E+03
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA

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95-50-1	1,2-Dichlorobenzene	dichlorobenzene; 1,2- (ortho-Dichlorobenzene)	0.38	0,600	3.30E-01	4.10E+02	5.86E+03
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2, 4,6-	0.38	4	3.30E-01	2.73E+00	3.92E+01
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	40.0	3.30E-01	2.82E+01	4.06E+02
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	1.60E+03	2.45E+04
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	0.2	3.30E-01	4.20E-01	4.76E+00
106-46-7	1,4-Dichlorobenzene	dichlorobenzene; 1,4- (para-Dichlorobenzene)	0.62	8	5.00E-03	1.17E+01	1.90E+02
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine ;3,3'-	0.72	0.194	3.30E-01	4.20E-01	6.35E+00
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	2.64E+00	4.56E+01
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	48	---	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	100	5.00E-03	2.96E+02	5.39E+03
91-20-3	Naphthalene	naphthalene	1.19	160	1.00E-01	8.13E+02	1.56E+04
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	0,018	3.30E-01	1.08E+02	2.09E+03
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.079545455	1.65E-03	5.31E-01	1.03E+01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	1.50E+04	2.96E+05
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2 ,4,5-	1.60	800	3.30E-01	7.84E+03	1.55E+05
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene; 1,2,4-	1.66	1.5	3.30E-01	1.61E+01	3.19E+02
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	1.70E-01	3.38E+00
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.09375	3.30E-01	1.38E+01	2.74E+02
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	3.89E+05	4.79E+04
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	3.89E+05	4.79E+04
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	0.048611111	1.65E-03	4.89E+02	2.68E+01
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	2.21E+05	6.60E+03
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	640	3.30E-01	3.89E+05	3.89E+05
91-57-6	2-Methylnaphthalene	methylnapthalene ;2-	2.48	32	3.30E-01	3.89E+05	2.46E+04
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	NR	3.89E+05
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	NR	7.80E+03
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA

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						100-D	100-H
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	NR	3.89E+05
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	NR	3.89E+05
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	NR	2.62E+04
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	NR	3.89E+05
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	NR	3.16E+05
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	NR	9.33E+04
86-73-7	Fluorene	fluorene	7.7	320.000	3.00E-02	NR	3.89E+05
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	NR	3.89E+05
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	NR	1.00E+03
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	NR	1.00E+03
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	NR	3.89E+05
76-44-8	Heptachlor	heptachlor	9.5	0.02	1.65E-03	NR	1.50E+03
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
57-12-5	Cyanide	cyanide	9.9	4.80	---	NR	3.89E+05
72-20-8	Endrin	endrin	10.8	2.00	3.30E-03	NR	2.63E+05
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	NR	NR
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
7439-98-7	Molybdenum	molybdenum	20.0	0,080	2.00E+00	NR	NR
7440-50-8	Copper	copper	22.0	640	1.00E+00	NR	NR
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	NR	NR
7439-89-6	Iron	Iron	25.0	11200	5.00E+00	NR	NR
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	NR	NR
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	NR	NR
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	NR	NR
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR	NR
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR	NR
72-54-8	4,4'-DDD (Dichlorodiphenyl dichloroethane)	ddd	45.8	0.36	3.30E-03	NR	NR
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR	NR
206-44-0	Fluoranthene	fluoranthene	49	640	5.00E-02	NR	NR
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR	NR
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR	NR

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7439-97-6	Mercury	mercury (using mercruric chloride)	52	2.000	---	NR	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	1	3.30E-01	NR	NR
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR	NR
7439-96-5	Manganese	manganese	65	0,384	5.00E+00	NR	NR
7440-02-0	Nickel	nickel soluble salts	65	100	4.00E+00	NR	NR
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR	NR
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	0.1	3.30E-01	NR	NR
72-43-5	Methoxychlor	methoxychlor	80	40.000	1.65E-02	NR	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.005	1.65E-03	NR	NR
72-55-9	4,4'-DDE (Dichlorodiphenyl dichloroethylene)	dde	86	0	3.30E-03	NR	NR
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR	NR
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR	NR
16984-48-8	Fluoride	fluoride (using fluorine)	150	960	5.00E+00	NR	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	48.00	3.30E-01	NR	NR
7440-31-5	Tin	tin	250	9600	1.00E+01	NR	NR
7439-93-2	Lithium	Lithium	300	32	2.50E+00	NR	NR
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR	NR
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyl trichloroethane)	ddt	678	0.257352941	3.30E-03	NR	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR	NR
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR	NR
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA

Table C-1. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [c, d] (mg/kg·m) 100-D	100-H
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	0.119863014	3.00E-02	NR	NR
7439-92-1	Lead	lead	10000	15	5.00E-01	NR	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR	NR
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to preliminary remediation goals:

   a. "NA" was assigned where no applicable water quality standard was available.

   b. "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).

   c. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

   d. Value was limited to a physical upper bound of 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table C-2. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	1.73E+04	1.65E+05
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA	NA
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA	NA
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA	NA
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA	NA
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.0270	--	5.00E-03	NA	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.0270	--	5.00E-03	NA	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.0355	--	5.00E-03	NA	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA	NA
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.0380	--	5.00E-03	NA	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene, 1,2- (mixed isomers)	0.0396	--	5.00E-03	NA	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA	NA
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA	NA
78-87-5	1,2-Dichloropropane	dichloropropane; 1,2-	0.0470	--	5.00E-03	NA	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA	NA

Table C-2. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA	NA
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA	NA
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA	NA
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA	NA
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy) butanoic acid)	Dichlorophenoxy) butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA	NA
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA	NA
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA

Table C-2. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
95-50-1	1,2-Dichlorobenzene	dichlorobenzene; 1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2, 4,6-	0.38	--	3.30E-01	NA	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA	NA
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	1.75E+01	2.83E+02
106-46-7	1,4-Dichlorobenzene	dichlorobenzene; 1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine ;3,3'-	0.72	--	3.30E-01	NA	NA
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	5.34E-01	1.04E+01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene; 1,2,4-	1.66	--	3.30E-01	NA	NA
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	3.77E+02	2.79E+01
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	3.77E+02	2.79E+01
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	--	1.65E-03	NA	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA	NA
91-57-6	2-Methylnaphthalene	methylnapthalene ;2-	2.48	--	3.30E-01	NA	NA
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA

Table C-2. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

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TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	NR	3.16E+04
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	NR	4.67E+03
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	NR	1.14E+05
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	NR	6.42E+02
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	NR	6.42E+02
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA	NA
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	NR	2.94E+02
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
57-12-5	Cyanide	cyanide	9.9	5.2	---	NR	3.89E+05
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	NR	3.02E+02
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA	NA
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	NR	NR
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	NR	NR
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	NR	NR
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA	NA
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA	NA
72-54-8	4,4'-DDD (Dichlorodiphenyl dichloroethane)	ddd	45.8	--	3.30E-03	NA	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR	NR
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR	NR
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR	NR
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR	NR

Table C-2. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR	NR
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR	NR
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA	NA
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA	NA
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR	NR
72-55-9	4,4'-DDE (Dichlorodiphenyl dichloroethylene)	dde	86	--	3.30E-03	NA	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR	NR
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA	NA
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR	NR
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA	NA
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA	NA
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyl trichloroethane)	ddt	678	0.0010	3.30E-03	NR	NR
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA	NA
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR	NR
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA	NA
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	--	1.50E-02	NA	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	--	1.50E-02	NA	NA
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR	NR

Table C-2. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (K_d order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to preliminary remediation goals:
   a. "NA" was assigned where no applicable water quality standard was available.
   b. "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).
   c. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.
   d. Value was limited to a physical upper bound of 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table C.3. Preliminary Remediation Goal for Radionuclides Protective of Groundwater for 100-D and 100-H Source Operable Units (K_d order)

Radionuclide	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Maximum Contaminant Level [a] (pCi/L)	Half-life [b] (yr)	Estimated Quantitation Limit [c] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [d,e] (pCi/g·m)	
					100-D	100-H
Carbon-14 [f]	0	2000	5.7300E+03	---	1.51E+02	1.44E+03
Cesium-137	50	200	3.0000E+01	1.00E-01	NR	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR	NR
Iodine-129	1	1	1.5700E+07	---	3.55E+00	6.63E+01
Neptunium-237	15	15	2.1400E+06	---	NR	NR
Nickel-63	30	50	9.6000E+01	---	NR	NR
Strontium-90 [g]	25	8	2.9120E+01	---	7.74E+05	NR
Technetium-99	0	900	2.1300E+05	---	6.77E+01	6.47E+02
Tritium	0	20000	1.2350E+01	---	2.32E+03	1.97E+04
Americium-241	200	15	4.32E+02	1.00E+00	NR	NR
Carbon-14 [h]	200	2,000	5.73E+03	---	NR	NR
Curium-243	200	15	2.85E+01	---	NR	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR	NR
Niobium-94	200	--	2.03E+04	---	NA	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR	NR
Plutonium-241	200	300	1.40E+01	---	NR	NR
Radium-226	200	5	1.60E+03	---	NR	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR	NR
Thorium-228	200	15	1.91E+00	---	NR	NR
Thorium-230	200	15	7.70E+04	---	NR	NR
Thorum-232	200	15	1.41E+10	---	NR	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. Radiochemistry Society website, Available at: http://www.radiochemistry.org/.

c. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

d. The following restrictions were applied to preliminary remediation goals:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 pCi/m^3 (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

f. Carbon-14 in liquid form (typically associated with reactor gas condensate).

g. The preliminary remediation goal for strontium-90 is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these OUs.

h. Carbon-14 in solid form (typically associated with graphite).

Table C-4. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	200	5.00E-03	4.66E+01	5.31E+02
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	0.2	5.00E-03	3.57E-02	3.81E-01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	1	5.00E-03	1.22E-01	1.29E+00
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	7.68	1.00E-02	1.02E+00	1.06E+01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	7.00	1.00E-02	1.03E+00	1.08E+01
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	1.5	3.30E-01	1.61E+01	3.19E+02
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	0,600	3.30E-01	4.10E+02	5.86E+03
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	0.5	5.00E-03	5.61E-02	5.69E-01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	72.00	5.00E-03	8.53E+00	8.67E+01
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	1	5.00E-03	1.54E-01	1.58E+00
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	8	5.00E-03	1.17E+01	1.90E+02
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	16.000	2.10E+00	2.67E+00	2.11E+01
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	800	3.30E-01	7.84E+03	1.55E+05
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	4	3.30E-01	2.73E+00	3.92E+01
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy) butanoic acid)	Dichlorophenoxy) butyric Acid, 4-(2,4-	0.0984	128.0	1.30E-02	2.39E+01	2.61E+02
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	24	3.30E-01	5.98E+00	6.91E+01
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	160.00	3.30E-01	5.45E+01	6.75E+02
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	0,032	8.25E-01	2.41E+00	2.30E+01
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	0,000	3.30E-01	4.20E-01	5.62E-01
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	16.0	3.30E-01	2.43E+00	2.56E+01
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	4800.0	1.00E-02	3.84E+02	3.71E+03
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	800	---	6.26E+01	6.02E+02
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	640	3.30E-01	3.89E+05	3.89E+05
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	40.0	3.30E-01	2.82E+01	4.06E+02
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	0,040	2.00E-02	3.66E+00	3.59E+01
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	32	3.30E-01	3.89E+05	2.46E+04
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	400	3.30E-01	7.11E+01	7.70E+02
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	0,160	3.30E-01	3.24E+01	3.59E+02
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	0.194	3.30E-01	4.20E-01	6.35E+00

Table C-4. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)	
						100-D	100-H
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	4	3.30E-01	8.32E-01	9.20E+00
72-54-8	4,4'-DDD (Dichlorodiphenyl dichloroethane)	ddd	45.8	0.36	3.30E-03	NR	NR
72-55-9	4,4'-DDE (Dichlorodiphenyl dichloroethylene)	dde	86	0	3.30E-03	NR	NR
50-29-3	4,4'-DDT (Dichlorodiphenyl trichloroethane)	ddt	678	0.257352941	3.30E-03	NR	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	2.64E+00	4.56E+01
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	5.88E+01	5.96E+02
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	1.60E+03	2.45E+04
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	4.20E-01	5.40E-01
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	5.71E+01	5.59E+02
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	4.05E+02	5.45E+03
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	8.74E-01	9.67E+00
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	NR	3.89E+05
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	5.46E+02	5.23E+03
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR	NR
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	1.70E-01	3.38E+00
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR	NR
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	NR	NR
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR	NR
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	NR	1.00E+03
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	NR	1.00E+03
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	NR	NR
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	NR	NR

Table C-4. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)	
						100-D	100-H
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	1.14E-01	1.19E+00
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	0.119863014	1.50E-02	NR	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR	NR
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	0.048611111	1.65E-03	4.89E+02	2.68E+01
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	4.20E-01	1.13E+00
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	4.34E+00	4.25E+01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	4.20E-01	5.40E-01
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR	NR
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	NR	3.89E+05
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	9.58E-02	9.92E-01
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	1.23E+00	1.38E+01
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	9.51E-01	9.25E+00
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	NR	NR
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	NR	9.33E+04
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	NR	7.80E+03
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	1.00E+02	1.03E+03
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	1.60E-01	1.86E+00
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR	NR
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	1.88E+04	1.80E+05
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	3.65E+01	4.59E+02
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	1.88E-01	1.95E+00
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR	NR
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.0355	16.0	5.00E-03	1.83E+00	1.85E+01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.0270	0	5.00E-03	4.58E-02	4.57E-01
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR	NR
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
7440-50-8	Copper	copper	22.0	640	1.00E+00	NR	NR
57-12-5	Cyanide	cyanide	9.9	4.80	---	NR	3.89E+05
75-99-0	Dalapon	Dalapon	0.0032	200	---	1.57E+01	1.51E+02

Table C-4. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)	
						100-D	100-H
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR	NR
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	NR	3.89E+05
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	7.55E-02	7.90E-01
1918-00-9	Dicamba	Dicamba	0.0288	480	---	5.13E+01	5.13E+02
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	NR	NR
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	2.14E+03	2.29E+04
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	1.50E+04	2.96E+05
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR	NR
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	NR	2.62E+04
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	3.89E+05	4.79E+04
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	3.89E+05	4.79E+04
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
72-20-8	Endrin	endrin	10.8	2.00	3.30E-03	NR	2.63E+05
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	0,004	5.00E-03	1.32E+00	1.63E+01
206-44-0	Fluoranthene	fluoranthene	49	640	5.00E-02	NR	NR
86-73-7	Fluorene	fluorene	7.7	320.000	3.00E-02	NR	3.89E+05
16984-48-8	Fluoride	fluoride (using fluorine)	150	960	5.00E+00	NR	NR
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.079545455	1.65E-03	5.31E-01	1.03E+01
76-44-8	Heptachlor	heptachlor	9.5	0.02	1.65E-03	NR	1.50E+03
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.005	1.65E-03	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	0.1	3.30E-01	NR	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	1	3.30E-01	NR	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	48.00	3.30E-01	NR	NR
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.09375	3.30E-01	1.38E+01	2.74E+02
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	48	---	6 [e]	6 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	0.119863014	3.00E-02	NR	NR
7439-89-6	Iron	Iron	25.0	11200	5.00E+00	NR	NR
78-59-1	Isophorone	isophorone	0.0468	46.05	3.30E-01	5.83E+00	5.97E+01
7439-92-1	Lead	lead	10000	15	5.00E-01	NR	NR
7439-93-2	Lithium	Lithium	300	32	2.50E+00	NR	NR
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA
7439-96-5	Manganese	manganese	65	0,384	5.00E+00	NR	NR
7439-97-6	Mercury	mercury (using mercruric chloride)	52	2.000	---	NR	NR

Table C-4. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m) 100-D	100-H
72-43-5	Methoxychlor	methoxychlor	80	40.000	1.65E-02	NR	NR
75-09-2	Methylene chloride	methylene chloride	0.0100	5.00	5.00E-03	4.30E-01	4.19E+00
7439-98-7	Molybdenum	molybdenum	20.0	0,080	2.00E+00	NR	NR
108-38-3	m-Xylene	Xylene, m-	0.1960	1600	---	5.13E+02	6.26E+03
91-20-3	Naphthalene	naphthalene	1.19	160	1.00E-01	8.13E+02	1.56E+04
7440-02-0	Nickel	nickel soluble salts	65	100	4.00E+00	NR	NR
14797-55-8	Nitrate	Nitrate	0	45,000	2.50E+00	3.38E+03	3.24E+04
14797-65-0	Nitrite	Nitrite	0	3,300	2.50E+00	2.48E+02	2.37E+03
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	16.0	3.30E-01	3.40E+00	3.80E+01
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	10,000	7.50E-01	7.52E+02	7.19E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1,000	7.50E-01	7.52E+01	7.19E+02
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	10,000	---	7.52E+02	7.19E+03
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	0.01	3.30E-01	4.20E-01	5.40E-01
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	0,018	3.30E-01	1.08E+02	2.09E+03
95-47-6	o-Xylene	xylene,o-	0.2410	1600.0	---	6.31E+02	8.06E+03
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	0.2	3.30E-01	4.20E-01	4.76E+00
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
108-95-2	Phenol	Phenol	0.0288	2,400	3.30E-01	2.56E+02	2.57E+03
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR	NR
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	NR	3.16E+05
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	NR	3.89E+05
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	NR	NR
100-42-5	Styrene	styrene	0.91	100	5.00E-03	2.96E+02	5.39E+03
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	1.88E+04	1.80E+05
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	2.19E+00	2.86E+01
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR	NR
7440-31-5	Tin	tin	250	9600	1.00E+01	NR	NR
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	1.53E+02	1.76E+03
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	NR	3.89E+05
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	NR	3.89E+05
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR	NR
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.0380	100.0	5.00E-03	1.17E+01	1.18E+02
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.0270	0	5.00E-03	4.58E-02	4.57E-01
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	2.21E+05	6.60E+03

Table C-4. Preliminary Remediation Goals for Non-radionuclides Protective of Groundwater in 100-D and 100-H Source Operable Units (analyte order)

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						100-D	100-H
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	1.72E-01	1.87E+00
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	2.96E+02	3.02E+03
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]	NVR [f]
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR	NR
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	6.36E-03	5.75E-02
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	6.09E+02	7.71E+03
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to preliminary remediation goals:

   a. "NA" was assigned where no applicable water quality standard was available.

   b. "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).

   c. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

   d. Value was limited to a physical upper bound of 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table C-5. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA	NA
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	--	3.30E-01	NA	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	--	5.00E-03	NA	NA
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	--	5.00E-03	NA	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA	NA
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	--	3.30E-01	NA	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy) butanoic acid)	Dichlorophenoxy) butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA	NA
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA	NA
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	--	3.30E-01	NA	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	--	3.30E-01	NA	NA

Table C-5. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

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65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA	NA
72-54-8	4,4'-DDD (Dichlorodiphenyl dichloroethane)	ddd	45.8	--	3.30E-03	NA	NA
72-55-9	4,4'-DDE (Dichlorodiphenyl dichloroethylene)	dde	86	--	3.30E-03	NA	NA
50-29-3	4,4'-DDT (Dichlorodiphenyl trichloroethane)	ddt	678	0.0010	3.30E-03	NR	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA	NA
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA	NA
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR	NR
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR	NR
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	NR	6.42E+02
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	NR	6.42E+02
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	NR	NR
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA	NA

Table C-5. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA	NA
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA	NA
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	--	1.50E-02	NA	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	--	1.50E-02	NA	NA
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA	NA
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	--	1.65E-03	NA	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA	NA
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA	NA
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA	NA
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA	NA
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	NR	4.67E+03
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA	NA
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR	NR
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	1.73E+04	1.65E+05
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR	NR
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.0355	--	5.00E-03	NA	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.0270	--	5.00E-03	NA	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	NR	NR
57-12-5	Cyanide	cyanide	9.9	5.2	---	NR	3.89E+05
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA	NA

Table C-5. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)	
						100-D	100-H
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA	NA
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA	NA
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA	NA
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	NR	NR
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA	NA
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	3.77E+02	2.79E+01
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	3.77E+02	2.79E+01
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA	NA
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	NR	3.02E+02
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA	NA
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA	NA
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA	NA
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA	NA
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	5.34E-01	1.04E+01
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	NR	2.94E+02
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA	NA
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	6 [e]	6 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	NR	NR
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR	NR
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA	NA
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA	NA
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR	NR

Table C-5. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR	NR
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR	NR
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA	NA
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	1.75E+01	2.83E+02
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA	NA
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	NR	3.16E+04
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	NR	1.14E+05
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA	NA
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA	NA
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR	NR
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.0380	--	5.00E-03	NA	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.0270	--	5.00E-03	NA	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA	NA

Table C-5. Preliminary Remediation Goals for Non-radionuclides Protective of Surface Water in 100-D and 100-H Source Operable Units (analyte order)

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m) 100-D	100-H
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]	NVR [f]
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

c. The following restrictions were applied to preliminary remediation goals:

   a. "NA" was assigned where no applicable water quality standard was available.

   b. "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).

   c. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

   d. Value was limited to a physical upper bound of 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

Table C.6. Preliminary Remediation Goal for Radionuclides Protective of Groundwater for 100-D and 100-H Source Operable Units (analyte order)

Radionuclide	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Maximum Contaminant Level [a] (pCi/L)	Half-life [b] (yr)	Estimated Quantitation Limit [c] (mg/kg)	Preliminary Remediation Goal Protective of Groundwater [d,e] (pCi/g·m)	
					100-D	100-H
Americium-241	200	15	4.32E+02	1.00E+00	NR	NR
Carbon-14 [f]	0	2000	5.7300E+03	---	1.51E+02	1.44E+03
Carbon-14 [g]	200	2,000	5.73E+03	---	NR	NR
Cesium-137	50	200	3.0000E+01	1.00E-01	NR	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR	NR
Curium-243	200	15	2.85E+01	---	NR	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR	NR
Iodine-129	1	1	1.5700E+07	---	3.55E+00	6.63E+01
Neptunium-237	15	15	2.1400E+06	---	NR	NR
Nickel-63	30	50	9.6000E+01	---	NR	NR
Niobium-94	200	--	2.03E+04	---	NA	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR	NR
Plutonium-241	200	300	1.40E+01	---	NR	NR
Radium-226	200	5	1.60E+03	---	NR	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR	NR
Strontium-90 [h]	25	8	2.9120E+01	---	7.74E+05	NR
Technetium-99	0	900	2.1300E+05	---	6.77E+01	6.47E+02
Thorium-228	200	15	1.91E+00	---	NR	NR
Thorium-230	200	15	7.70E+04	---	NR	NR
Thorum-232	200	15	1.41E+10	---	NR	NR
Tritium	0	20000	1.2350E+01	---	2.32E+03	1.97E+04

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. Radiochemistry Society website, Available at: http://www.radiochemistry.org/.

c. DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100DR-2, 100-HR-1, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington (Appendix A).

d. The following restrictions were applied to preliminary remediation goals:

   a. "NA" was assigned where no applicable water quality standard was available.

   - "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 pCi/m^3 (a value set as the lower limit of numerical significance).
   - Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

f. Carbon-14 in liquid form (typically associated with reactor gas condensate).

g. Carbon-14 in solid form (typically associated with graphite).

h. The preliminary remediation goal for strontium-90 is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these OUs.

Attachment D

Software Installation and Checkout Form for STOMP

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 4

EXECUTABLE INFORMATION:

2. Executable Name (include path):

All executable files installed in directory /srv/samba/saved_data/bin

MD5 File Signature	Executable File Name
6536b8e12d8c5b83dca76f2c947b6153	stomp-wae-bcg-chprc04i.x
e0cdf04bc1a2f6c55c5a1b499939f663	stomp-wae-bcg-chprc04l.x
6e72340bb39f6056e232fe5ff241c4d4	stomp-wae-bd-chprc04i.x
3f837a0fb8d9f47dbcada686f542d7fc	stomp-wae-bd-chprc04l.x
7e5b4cc36a8991b3d5a8ea2ed155ce47	stomp-wae-cgsq-chprc04i.x
00a898c0c3ec06817485781ad1c9ec46	stomp-wae-cgsq-chprc04l.x
f18ff5ab5667065d8ab12657344fb6a0	stomp-wae-cgst-chprc04i.x
061af86cf21ad8435b046d0efabe971b	stomp-wae-cgst-chprc04l.x
3c8111a9855dc0e430bf3c8a7abcf37e	stomp-w-bcg-chprc04i.x
20436d615a94955a2ce8eecdb8cba546	stomp-w-bcg-chprc04l.x
8b3df29df21d040189c3e2a50ef823bb	stomp-w-bd-chprc04i.x
066a289a75aedb933eb2536da5d7d1ff	stomp-w-bd-chprc04l.x
c8e62ad7a0d9b6fca39d8a8952ef5d8e	stomp-w-cgsq-chprc04i.x
28ad16806e1307aca51fd7bf89793e75	stomp-w-cgsq-chprc04l.x
6c25051016db2fe1f883a7caaaab1e97	stomp-w-cgst-chprc04i.x
ff9ff6f29b3469419ffaece87d7e772b	stomp-w-cgst-chprc04l.x
0c3e3fba40f5b93e71bcf9586432fd27	stomp-w-r-bcg-chprc04i.x
78492aee80a8c2d0a4e82aabf4a9c213	stomp-w-r-bcg-chprc04l.x
84b129786aba9c4be884e15e45a67389	stomp-w-r-bd-chprc04i.x
e990f1566c8099a8d54508de3da9cd88	stomp-w-r-bd-chprc04l.x
18a589a2b55aab2db290efea19b39351	stomp-w-r-cgsq-chprc04i.x
6569959476772a137df35ce874821889	stomp-w-r-cgsq-chprc04l.x

3. Executable Size (bytes): MD5 signatures above uniquely identify each executable file

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

Tellus Subsurface Modeling Platform

5. Operating System (include version number):

Linux tellusmgmt.rl.gov 2.6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86 64 x86 64 GNU/Linux

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

Green Linux Cluster

7. Operating System (include version number):

Linux green 3.2.0-35-generic #55-Ubuntu SMP Wed Dec 5 17:42:16 UTC 2012 x86_64 x86_64 x86 64 GNU/Linux

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 4

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

/srv/samba/saved data/test/stomp/build-04/itc

10. Procedure(s):

CHPRC-00211 Rev 1, STOMP Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

Input files for ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-2
(Baseline for comparison are results files from ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-3 prepared on Tellus during acceptance testing)

13. Output Files:

plot.* files produced by STOMP in testing

14. Test Cases:

ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-3

15. Test Case Results:

Pass for all executable files listed above.

16. Test Performed By: WE Nichols

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Accepted; Installation noted in HISI for users TJ Budge, N Hasan, A Mayenna, WJ McMahon, WE Nichols, S Mehta, H Rashid.

Prepared By:

19.	Software Owner (Signature)	WE Nichols Print	25 APRIL 2013 Date

20. Test Personnel:

Sign	WE Nichols Print	25 APRIL 2013 Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	Software SME (Signature)	N/R (per CHPRC-00211 Rev 1) Print	Date

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Attachment E

Identification of Waste Sites and Contaminants of Potential Concern Requiring Evaluation of the Conservatism of the 70:30 Initial Contaminant Distribution for Soil Screening Level and Preliminary Remedial Goal Development

Tabulated Reduction of RI Borehole Samples for Conservatism Testing

Table E-1. Preliminary Identification of Waste Sites and COPCs that Appear Non-Conservative with Respect to the 70:30 Initial Concentration Distribution based on Review of RI Borehole Data 176

Table E-2. Waste Sites and COPCs to Test for Conservatism of 70:30 Initial Concentration Distribution (After Exclusion Criteria[a] Applied to List in Table D-1) 192

Table E-1 contains the full list of waste sites and COPCs with apparent deep contamination that may indicate non-conservative representation by the 70:30 initial concentration distribution assumption used in modeling of the vadose zone for purposes of calculating SSL and PRG values.

Table E-2 contains the filtered list after the following exclusions are applied:

- boreholes that did not sample the lower 30 percent of the vadose zone
- COPCs that had no background values
- COPCs with reported concentrations in the lower 30 percent of the vadose zone that were within the range of background
- COPCs had $K_d > 25$ (will not yield numerical SSL or PRG values under 100:0)
- Strontium-90 (already using 100:0 model per other considerations)

Table E-1. Preliminary Identification of Waste Sites and COPCs that Appear Non-Conservative with Respect to the 70:30 Initial Concentration Distribution based on Review of RI Borehole Data

Vadose Zone re-evaluation for groundwater protection at 100-DH.

Identifying vadose zone conditions for constituents with higher Kd, but exhibiting full-thickness contamination (i.e., non-70:30 conditions).

Inspection of data performed by: CW Miller/PRC

Inspection Date: 10-Oct-12

Approach to Data Inspection: Reviewed vertical distribution profiles from Chap 4 of RI/FS Report. Identified by inspection COPCs that were not constrained to 70:30 distribution.

Data conditions that preclude using 70:30 distribution model:

1. The constituent typically exhibits a reference K_d of 2 ml/g or greater.
2. An anthropogenic (non-background) contaminant is present throughout the vadose, including within the lower 30% of the vadose thickness.
3. An anthropogenic contaminant with an established background level exceeds the 90th percentile background at some depth interval(s) and reported MDCs for the remaining measurements are greater than the 90th percentile background.
4. An anthropogenic contaminant is present in the deepest sample of a vadose profile, if sampling did not examine the entire vadose.
5. An anthropogenic contaminant was not detected, however, all non-detects exhibit MDCs greater than the 90th percentile background concentration.
6. An anthropogenic contaminant exhibits increasing concentration with depth in the lower 30% of the vadose.

Uncertainties to Consider:

a. Not all naturally-occurring metals have established background concentration statistics (e.g., Sr, Sn)

This precludes assessing whether or not the observed concentrations exceed background.

b. Some investigative wells and borings did not fully penetrate the vadose zone. This results in obvious uncertainty in the distribution of contaminants within the deeper vadose, particularly where the contaminant(s) are consistently detected in the upper vadose portion and are detected in the deepest vadose samples analyzed. This does not provide a basis for concluding the absence of the contaminant in deeper vadose.-

c. Unacceptably-high minimum detectable concentrations (e.g., MDCs greater than the 90th percentile background concentration, or MDCs greater than quantified detections) do not provide a basis for concluding the absence of a contaminant in vadose zone samples.

d. Some constituents may exhibit site-specific, or historical waste stream-specific Kd that results in historic migration differing substantially from predicted future migration.

e. Established soil background statistics may not be representative of actual naturally-occurring concentrations at various depths within the vadose zone.

Note: COPCs highlighted in BLUE are selected for alternative SSL/PRG calculation. COPCs highlighted in ORANGE are not selected because background statistics have not been developed.
Note: Applicable uncertainties are dominated by partial vadose characterization at locations with apparent residual vadose contamination and high analyte MDCs that do not support exclusion from vadose transport analysis.

Note: Sr-90 (highlighted in GREEN) has already been simulated under 100:0 distribution scenario; it is included in this table for completeness.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-D-1A	199-D5-21	Am-241	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Co-60	Detected throughout vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Cr	Detected throughout vadose exceeding 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Cs-137	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Eu-152	Detected throughout vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Eu-154	Detected throughout vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Hg	Detected throughout vadose exceeding 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Pb	Detected throughout vadose exceeding 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Pu-239	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1A	199-D5-21	Sr-90	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-4	199-D5-24	Ag	Detected in deepest vadose sample, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Ag	MDCs exceed 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Am-241	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Cd	MDCs exceed 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Co-60	Detections near deepest zone sampled.	Boring did not penetrate entire vadose zone; partial characterization.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-D-1B	199-D5-29	Cs-137	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Eu-152	Detections near deepest zone sampled.	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Eu-154	Detections near deepest zone sampled.	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Hg	MDCs exceed 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Pu-239	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-1B	199-D5-29	Sr-90	Detected in every vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-7	199-D8-60	Ag	Detected in vadose at, or above, 90% background, high MDCs	Boring did not penetrate entire vadose zone; partial characterization.
116-D-7	199-D8-60	Cr	Detected in vadose at, or above, 90% background, high MDCs	Boring did not penetrate entire vadose zone; partial characterization.
116-D-7	199-D8-60	Cs-137	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-D-7	199-D8-60	Sr-90	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Ag	Detected in vadose, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Am-241	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Cs-137	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Eu-152	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Eu-154	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Hg	Detected in vadose, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Pu-239	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-61	Sr-90	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-62	Ag	Present in all vadose samples above 90% background	Boring did not penetrate entire vadose zone; partial characterization.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-DR-1&2	199-D8-62	Co-60	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-62	Cs-137	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-62	Eu-152	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-62	Hg	Present in vadose, high MDCs	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-62	Pu-239	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-1&2	199-D8-62	Sr-90	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-64	Aroclor-1260	Detected in deep vadose, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-64	Cd	Hi MDCs	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-64	Hg	Detected in deep vadose, high MDCs	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-64	Sr-90	Present in vadose, no background	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-65	Ag	Detected throughout vadose in excess of 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-65	Cd	Detected in deep vadose sample, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-65	Cs-137	Detected in deep vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-65	Eu-152	Detected in deepest sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-65	Hg	Detected in deep sample, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-65	Pu-239	Detected in deepest sample, increasing with depth	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-65	Sr-90	Detected throughout vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-66	Ag	Present in vadose, high MDCs	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-66	Cd	Detected in deepest sample, increasing with depth	Boring did not penetrate entire vadose zone; partial characterization.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-DR-9	199-D8-66	Co-60	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-66	Cs-137	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-66	Eu-152	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-66	Eu-154	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
116-DR-9	199-D8-66	Sr-90	Detected throughout vadose	Boring did not penetrate entire vadose zone; partial characterization.
Non-specific	199-D3-5	Mo	Detected in deep vadose at, or above 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-D3-5	Sn		Detected throughout vadose, no background established
116-H-6	199-H4-50	Ag	Detected in vadose, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-50	Cs-137	Detected in vadose samples	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-50	Hg	Detected in vadose, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-50	Sb	Detected in vadose samples, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-50	U-234	Detected in all vadose samples above 90% b ackground	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-50	U-235	Detected in all vadose samples above 90% b ackground	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-50	U-238	Detected in all vadose samples above 90% b ackground	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-51	Cd	Detected at, or above, 90% background, increasing with depth	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-52	Ag	Detected in deepest vadose sample, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-52	Cd	Detected exceeding 90% background in deepest sample, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-52	Hg	Detected in deepest vadose sample, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-52	Sb	Detected in deepest vadose sample, high MDC	Boring did not penetrate entire vadose zone; partial characterization.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-H-6	199-H4-53	Hg	Detected in vadose zone, MDC exceeds 90% bckground by 10x	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-53	Sb	Detected over vadose zone exceeding 90% background, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-55	Cd	Detected at, or above, 90% background, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-55	Hg	Detected at, or above, 90% background, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-55	Sb	Detected throughout vadose above 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-55	Se	Detected above 90% background, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-56	Pb	Detected throughout vadose at, or above 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-56	Sb	Detected throughout vadose above 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-H-6	199-H4-57	Sb	Detected throughout vadose above 90% background, High MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-1	199-H4-58	Eu-152	Present in deepest sample	Boring did not penetrate entire vadose zone; partial characterization.
116-H-1	199-H4-58	Eu-154	Present in deepest sample	Boring did not penetrate entire vadose zone; partial characterization.
116-H-1	199-H4-58	Pu-239/240	Present in deepest sample	Boring did not penetrate entire vadose zone; partial characterization.
116-H-1	199-H4-58	Se	Present in vadose, high MDCs	Boring did not penetrate entire vadose zone; partial characterization.
116-H-2	199-H4-59	Cr	Present in all vadose samples, increasing with depth	Boring did not penetrate entire vadose zone; partial characterization.
116-H-2	199-H4-59	Ni	Present in all vadose samples, increasing with depth	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Co-60	Detected in deep vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Cr	Detected in deep vadose above 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Cs-137	Detected in deep vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Eu-152	Detected in all vadose samples	Boring did not penetrate entire vadose zone; partial characterization.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-H-7	199-H4-61	Eu-154	Detected in all vadose samples	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Hg	Detected throughout vadose, high MDC	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Pu-239/240	Detected in deep vadose	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Se	MDC exceeds 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-H-7	199-H4-61	Sr-90	Detected in deep vadose	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Acenaphthene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Acenaphthylene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Antrhacene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Benzo(a)pyrene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Benzo(b)fluoranthene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Benzo(k)Anthracene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Bezo(a)anthracene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Chrysene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Fluoranthene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Fluorene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Pb	Detected in deepest vadose sample above 90% background	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Phenanthrene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
1607-H4	Test Pit	Pyrene	Detected in deepest vadose sample	Boring did not penetrate entire vadose zone; partial characterization.
100-D-56	199-D5-143	Sr-90	Detected in deep vadose zone	Duplicate sample was non-detect.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
Non-specific	199-D3-5	Sr		Detected throughout vadose, no background established
Non-specific	199-D5-133	Mo	Detected in deep vadose at, or above 90% background	
100-D-12	199-D5-144	Tl	MDCs exceed 90% background	High MDCs do not support exclusion from GW protection analysis.
100-D-56	199-D5-143	Cr	Detected throughout vadose, increasing with depth	
116-D-1A	199-D5-132	Hg	MDCs exceed 90% background	High MDCs do not support exclusion from GW protection analysis.
116-D-1A	199-D5-132	Sb	MDCs exceed 90% background	High MDCs do not support exclusion from GW protection analysis.
116-D-1A	199-D5-132	Np-237	Present over vadose thickness	
116-D-7	C7851	Cs-137	Detected in deep vadose	
116-D-7	C7851	Mo	Detected in deep vadose at, or above 90% background	
116-D-7	C7851	Cr	Detected in vadose at, or above, 90% background	
116-D-7	199-D8-60	Hg	Detected in vadose at, or above, 90% background, high MDCs	High MDCs do not support exclusion from GW protection analysis.
116-D-7	C7851	Hg	Detected in vadose at, or above, 90% background, high MDCs	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-D5-133	Pb	Detected in deep vadose at, or above 90% background	
Non-specific	199-D5-133	Sn		Detected throughout vadose, no background established
116-D-7	C7851	Sb	Detected in vadose at, or above, 90% background, high MDCs	
116-DR-1&2	C7852	Hg	Detected in deep profile, high MDC	High MDCs do not support exclusion from GW protection analysis.
116-DR-1&2	199-D8-62	Tl	Detected in vadose soil, high MDCs	High MDCs do not support exclusion from GW protection analysis.
116-DR-1&2	B8786	Hg	Present in vadose, high MDCs	High MDCs do not support exclusion from GW protection analysis.
116-DR-9	C7850	Acenaphthene	Detected in deep vadose, high MDCs	High MDCs do not support exclusion from GW protection analysis.
116-DR-9	C7850	Aroclor-1260	Detected in deep vadose, high MDCs	High MDCs do not support exclusion from GW protection analysis.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-H-1	C7864	Chrysene	Detected in deep vadose	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-D5-133	Sr		Detected throughout vadose, no background established
116-H-1	C7864	Fluoranthene	Detected in deep vadose	
Non-specific	199-D5-134	Sb	Detected in all vadose samples above 90% b ackground	May reflect variability in background concentrations with depth.
116-H-1	C7864	Phenanthrene	Detected in deep vadose	High MDCs do not support exclusion from GW protection analysis.
116-H-1	C7864	Pyrene	Detected in deep vadose	
116-H-1	C7864	Cs-137	Present in deep vadose	
116-H-1	C3048	Eu-152	Present in deep vadose	
116-H-1	C7864	Eu-152	Present in deep vadose	
100-D-12	199-D5-144	Sr-90	Detected throughout vadose, increasing with depth	Kd may differ from reference value.
Non-specific	199-D5-134	Sn		Detected throughout vadose, no background established
116-D-1A	199-D5-132	Cr	Detected throughout vadose	May reflect variability in background concentrations with depth.
116-D-1A	199-D5-132	Mo	Exceeds background over vadose	May reflect variability in background concentrations with depth.
116-D-1A	199-D5-132	Ni	Detected throughout vadose	May reflect variability in background concentrations with depth.
Non-specific	199-D5-134	Sr		Detected throughout vadose, no background established
Non-specific	199-D5-140	Hg	MDCs exceed 90% background	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-D5-140	Cr	Detected throughout vadose at, or above, 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-D5-140	Mo	Presented throughout vadose exceeding 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-D5-140	Ni	Detected throughout vadose, increasing with depth	May reflect variability in background concentrations with depth.
100-D-56	199-D5-143	Li	Detected throughout vadose, increasing with depth	May reflect variability in background concentrations with depth.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
100-D-56	199-D5-143	Mo	Detected throughout vadose exceeding 90% background	May reflect variability in background concentrations with depth.
116-D-1A	199-D5-21	Cd	Detected throughout vadose exceeding 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-D5-140	Sn		Detected throughout vadose, no background established
Non-specific	199-D5-140	Sr		Detected throughout vadose, no background established
Non-specific	199-D5-141	Mo	Detected throughout vaadose at, or above, 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-D5-141	Sb	Detected throughout vadose above 90% background, High MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-D5-141	Sn		Detected throughout vadose, no background established
Non-specific	199-D5-141	Sr		Detected throughout vadose, no background established
Non-specific	199-D6-3	Cr	Detected in deep vadose at, or above 90% background	
Non-specific	199-D6-3	Cs-137	Detected in deep vadose	
116-H-1	C3048	Hg	Present in deep vadose	May reflect variability in background concentrations with depth.
116-DR-9	C7850	Mo	Present throughout vadose at, or above, 90% background	May reflect variability in background concentrations with depth.
116-D-7	C7851	Ni	Detected in deep vadose at, or above 90% background	May reflect variability in background concentrations with depth.
116-DR-1&2	C7852	Mo	Present throughout vadose at, or above, 90% background	May reflect variability in background concentrations with depth.
116-D-1B	C7855	Hg	Detections exceed background throughout vadose	May reflect variability in background concentrations with depth.
116-D-1B	C7855	Mo	Detections exceed background throughout vadose	May reflect variability in background concentrations with depth.
116-D-1B	C7855	Sb	Detections exceed background throughout vadose	May reflect variability in background concentrations with depth.
116-H-1	C7864	Cu	Present over vadose at, or greater than, 90% background	May reflect variability in background concentrations with depth.
116-H-1	C7864	Hg	Present at, or greater than, 90% background, elevated MDCs	May reflect variability in background concentrations with depth.

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-H-1	C7864	Mo	Present over vadose at, or greater than, 90% background	May reflect variability in background concentrations with depth.
116-H-1	C7864	Pb	Present over vadose at, or greater than, 90% background	May reflect variability in background concentrations with depth.
116-H-1	C7864	Sb	Present in deep vadose	May reflect variability in background concentrations with depth.
100-D-12	199-D5-144	Mo	Detected throughout vadose exceeding 90% background	Range of background conditions may differ in deep vadose.
116-H-1	C7864	Cr	Present over vadose at, or greater than, 90% background	
116-D-1A	199-D5-132	Sr-90	Present over vadose thickness	
116-H-4	C7862	Sb	Present in deep vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-D6-3	Sn		Detected throughout vadose, no background established
Non-specific	199-D6-3	Sr		Detected throughout vadose, no background established
116-D-4	199-D5-24	Sr-90	Detected in deepest vadose sample	
Non-specific	199-H1-7	Cr	Detected in deep vadose, increasing concentration	Boring did not penetrate entire vadose zone; partial characterization.
Non-specific	199-H1-7	Mo	Detected throughout vadose at, or above, 90% background	Boring did not penetrate entire vadose zone; partial characterization.
116-H-4	C7862	Cr	Present in vadose samples at, or above, 90% background	
Non-specific	199-H3-6	Sr-90	Detectedin deep vadose	
Non-specific	199-H3-9	Sr-90	Detected in deep vadose	
116-H-4	C7862	Mo	Present in vadose samples at, or above, 90% background, increasing with depth	
116-DR-1&2	B8786	Sr-90	Present throughout vadose	
116-H-6	199-H4-54	Cd	Detected at, or above 90% background over vadose; MDC exceeds background level	High MDCs do not support exclusion from GW protection analysis.
116-H-1	C3048	Sr-90	Present throughout vadose	
116-DR-9	C7850	Sr-90	Present in deep vadose	

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-H-6	C7863	Np-237	Detected in deep vadose	
116-H-6	199-H4-54	Sb	Detected in the vadose and MDC exceeds 90% background	High MDCs do not support exclusion from GW protection analysis.
116-H-6	C7860	Sb	Detected over vadose above 90% background, high MDC	High MDCs do not support exclusion from GW protection analysis.
116-H-6	C7863	Mo	Detected throughout vadose at, or above, 90% background	
116-D-1B	C7855	Sr-90	Detected throughout entire vadose zone	
116-H-6	C7860	Hg	Detected throughout vadose zone at, or above 90% background	
Non-specific	199-H1-7	Tl	Detected throughout vadose at, or above, 90% background, High MDC	High MDCs do not support exclusion from GW protection analysis.
118-D-6	C7857	Sr-90	Present throught vadose	
116-H-6	C7860	Mo	Detected throughout vadose zone at, or above 90% background	
116-H-6	C7863	Hg	MDC exceeds 90% background	High MDCs do not support exclusion from GW protection analysis.
116-H-6	C7860	Sr-90	Detected in deep vadose	
116-H-7	C7861	Sb	Detected in deep vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H1-7	Sn		Detected throughout vadose, no background established
116-H-7	C7861	Mo	Detected throughout vadose above 90% background	
116-H-7	C7861	Hg	Detected throughout vadose at, or above 90% background	
116-H-7	C7861	Sr-90	Detected throughout vadose zone, increasing with depth	
116-H-7	C7861	Cr	Detected throughout vadose at, or above, 90% background	
116-H-7	C7861	Cs-137	Detected throughout vadose zone	
118-D-6	C7857	Hg	Detected in vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H1-7	Sr		Detected throughout vadose, no background established
116-H-6	C7863	Sr-90	Detected in deep vadose	
Non-specific	199-H2-1	Mo	Detected throughout vadose at, or above, 90% background	May reflect variability in background concentrations with depth.
118-D-6	C7857	Cr	present in vadose at greater than 90% background	

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
118-D-6	C7857	Mo	Present over vadose thickness at greater than90% background	
Non-specific	199-H2-1	Sn		Detected throughout vadose, no background established
Non-specific	199-H2-1	Sr		Detected throughout vadose, no background established
116-H-1	C7864	Sr-90	Present throughout vadose	
Non-specific	199-H3-10	Mo	Detected throughout vadose at, or above, 90% background	
Non-specific	199-H3-10	Sn		Detected throughout vadose, no background established
116-D-1A	199-D5-132	Sn		Detected throughout vadose, no background established
116-D-1A	199-D5-132	Sr		Detected throughout vadose, no background established
Non-specific	199-H3-10	Sr		Detected throughout vadose, no background established
Non-specific	199-H3-6	Sn		Detected throughout vadose, no background established
Non-specific	199-H3-6	Sr		Detected throughout vadose, no background established
Non-specific	199-H3-7	2-Hexanone	Detected in lower vadose zone, High MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H3-7	Mo	Detected throughout vadose at, or above, 90% background	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H3-7	Styrene	Detected in deep vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H3-7	Tl	Detected throughout vadose exceeding 90% background	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H3-7	Sn		Detected throughout vadose, no background established
100-D-56	199-D5-143	Sn		Detected throughout vadose, no background established
100-D-56	199-D5-143	Sr		Detected throughout vadose, no background established
100-D-12	199-D5-144	Sn		Detected throughout vadose, no background established

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
100-D-12	199-D5-144	Sr		Detected throughout vadose, no background established
Non-specific	199-H3-7	Sr		Detected throughout vadose, no background established
Non-specific	199-H3-9	Cr	Detected throughout vadose, at, or above 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-H3-9	Cu	Detected in deep vadose at, or above 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-H3-9	Mo	Detected throughout vadose at, or above, 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-H3-9	Ni	Detected in deep vadose above 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-H3-9	Sb	Detected throughout vadose, at, or above 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-H3-9	Sn		Detected throughout vadose, no background established
Non-specific	199-H3-9	Sr		Detected throughout vadose, no background established
Non-specific	199-H6-3	Hg	MDCs exceed 90% background	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H6-3	Mo	Detected throughout vadose at, or above, 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-H6-3	Ni	Detected throughout vadose at, or above, 90% background	May reflect variability in background concentrations with depth.
Non-specific	199-H6-3	Sn		Detected throughout vadose, no background established
Non-specific	199-H6-3	Sr		Detected throughout vadose, no background established
Non-specific	199-H6-4	2-Hexanone	Detected in deep vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H6-4	Mo	Detected throughout vadose at, or above, 90% background	
Non-specific	199-H6-4	Styrene	Detected in deep vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
Non-specific	199-H6-4	Sn		Detected throughout vadose, no background established
Non-specific	199-H6-4	Sr		Detected throughout vadose, no background established

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-DR-9	C7850	Sn		Detected throughout vadose, no background established
116-DR-9	C7850	Sr		Detected throughout vadose, no background established
116-D-7	C7851	Sn		Detected throughout vadose, no background established
116-D-7	C7851	Sr		Detected throughout vadose, no background established
116-DR-1&2	C7852	Sn		Detected throughout vadose, no background established
116-DR-1&2	C7852	Sr		Detected throughout vadose, no background established
118-D-6	C7857	Sn		Detected throughout vadose, no background established
118-D-6	C7857	Sr		Detected throughout vadose, no background established
116-H-6	C7860	Sn		Detected throughout vadose, no background established
116-H-6	C7860	Sr		Detected throughout vadose, no background established
116-H-7	C7861	Sn		Detected throughout vadose, no background established
116-H-7	C7861	Sr		Detected throughout vadose, no background established
116-H-4	C7862	Sn		Detected throughout vadose, no background established
116-H-4	C7862	Sr		Detected throughout vadose, no background established
116-H-6	C7863	Sn		Detected throughout vadose, no background established
116-H-6	C7863	Sr		Detected throughout vadose, no background established
116-H-1	C7864	Sn		Detected throughout vadose, no background established
116-H-1	C7864	Sr		Detected throughout vadose, no background established
100-D-4	Test Pit	Sn		Detected throughout vadose, no background established

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
100-D-4	Test Pit	Sr		Detected throughout vadose, no background established
116-D-4	Test Pit	Sn		Detected throughout vadose, no background established
116-D-4	Test Pit	Sr		Detected throughout vadose, no background established
116-H-2	Test Pit	Sn		Detected throughout vadose, no background established
116-H-2	Test Pit	Sr		Detected throughout vadose, no background established
1607-H4	Test Pit	Sn		Detected throughout vadose, no background established
1607-H4	Test Pit	Sr		Detected throughout vadose, no background established

Table E-2. Waste Sites and COPCs to Test for Conservatism of 70:30 Initial Concentration Distribution (After Exclusion Criteria[a] Applied to List in Table D-1)

Waste Site	Sample Location	COPC	Rationale for non-70:30 Distribution	Applicable Uncertainty
116-D-1A	199-D5-132	Np-237	Present over vadose thickness	
116-D-7	C7851	Sb	Detected in vadose at, or above, 90% background, high MDCs	
116-DR-9	C7850	Acenaphthene	Detected in deep vadose, high MDCs	High MDCs do not support exclusion from GW protection analysis.
116-H-1	C7864	Phenanthrene	Detected in deep vadose	High MDCs do not support exclusion from GW protection analysis.
116-H-1	C7864	Sb	Present in deep vadose	May reflect variability in background concentrations with depth; added back
116-H-4	C7862	Sb	Present in deep vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
116-H-6	C7860	Sb	Detected over vadose above 90% background, high MDC	High MDCs do not support exclusion from GW protection analysis.
116-H-7	C7861	Sb	Detected in deep vadose, high MDC	High MDCs do not support exclusion from GW protection analysis.
116-H-7	C7861	Mo	Detected throughout vadose above 90% background	
118-H-6	C7863	Np-237	Detected in deep vadose	

a. Excluded:

- Boreholes not associated with a waste site (SSLs and PRGs calculated only for waste site evaluation)
- Boreholes that did not sample the lower 30 percent of the vadose zone
- COPCs that had no background values
- COPCs with reported concentrations in the lower 30 percent of the vadose zone that were within the range of background
- COPCs had Kd > 25 (will not yield numerical SSL or PRG values under 100:0)
- Strontium-90 (already using 100:0 model per other considerations)