WAC 173-340-747 Deriving soil concentrations for groundwater protection. (1) **Purpose.** The purpose of this section is to establish soil concentrations that will not cause contamination of groundwater at levels that exceed the groundwater cleanup levels established under WAC 173-340-720. Soil concentrations established under this section are used to establish either Method B soil cleanup levels (see WAC 173-340-740 (3)(b)(iii)(A)) or Method C soil cleanup levels (see WAC 173-340-745 (5)(b)(iii)(A)).

For the purposes of this section, "soil concentration" means the concentration in the soil that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720.

(2) **General requirements.** The soil concentration established under this section for each hazardous substance shall meet the following two criteria:

(a) The soil concentration shall not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720. To determine if this criterion is met, one of the methodologies specified in subsections (4) through (9) of this section shall be used; and

(b) To ensure that the criterion in (a) of this subsection is met, the soil concentration shall not result in the accumulation of nonaqueous phase liquid on or in groundwater. To determine if this criterion is met, one of the methodologies specified in subsection (10) of this section shall be used.

(3) **Overview of methods.** This subsection provides an overview of the methods specified in subsections (4) through (10) of this section for deriving soil concentrations that meet the criteria specified in subsection (2) of this section. Certain methods are tailored for particular types of hazardous substances or sites. Certain methods are more complex than others and certain methods require the use of site-specific data. The specific requirements for deriving a soil concentration under a particular method may also depend on the hazardous substance.

(a) **Fixed parameter three-phase partitioning model.** The three-phase partitioning model with fixed input parameters may be used to establish a soil concentration for any hazardous substance. Site-specific data are not required for use of this model. See subsection (4) of this section.

(b) **Variable parameter three-phase partitioning model.** The three-phase partitioning model with variable input parameters may be used to establish a soil concentration for any hazardous substance. Site-specific data are required for use of this model. See subsection (5) of this section.

(c) **Four-phase partitioning model.** The four-phase partitioning model may be used to derive soil concentrations for any site where hazardous substances are present in the soil as a nonaqueous phase liquid (NAPL). The department expects that this model will be used at sites contaminated with petroleum hydrocarbons. Site-specific data are required for use of this model. See subsection (6) of this section.

(d) **Leaching tests.** Leaching tests may be used to establish soil concentrations for certain metals. Leaching tests may also be used to establish soil concentrations for other hazardous substances, including petroleum hydrocarbons, provided sufficient information is available to demonstrate that the leaching test can accurately predict groundwater impacts. Testing of soil samples from the site is required for use of this method. See subsection (7) of this section.

(e) **Alternative fate and transport models.** Fate and transport models other than those specified in subsections (4) through (6) of

this section may be used to establish a soil concentration for any hazardous substance. Site-specific data are required for use of such models. See subsection (8) of this section.

(f) **Empirical demonstration.** An empirical demonstration may be used to show that measured soil concentrations will not cause an exceedance of the applicable groundwater cleanup levels established under WAC 173-340-720. This empirical demonstration may be used for any hazardous substance. Site-specific data (e.g., groundwater samples and soil samples) are required under this method. If the required demonstrations cannot be made, then a protective soil concentration shall be established under one of the methods specified in subsections (4) through (8) of this section. See subsection (9) of this section.

(g) **Residual saturation.** To ensure that the soil concentration established under one of the methods specified in subsections (4) through (9) of this section will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720, the soil concentration must not result in the accumulation of nonaqueous phase liquid (NAPL) on or in groundwater. The methodologies and procedures specified in subsection (10) of this section shall be used to determine if this criterion is met.

(4) **Fixed parameter three-phase partitioning model.**

(a) **Overview.** This subsection specifies the procedures and requirements for establishing soil concentrations through the use of the fixed parameter three-phase partitioning model. The model may be used to establish soil concentrations for any hazardous substance. The model may be used to calculate both unsaturated and saturated zone soil concentrations.

This method provides default or fixed input parameters for the three-phase partitioning model that are intended to be protective under most circumstances and conditions; site-specific measurements are not required. In some cases it may be appropriate to use site-specific measurements for the input parameters. Subsection (5) of this section specifies the procedures and requirements to establish site-specific input parameters for use in the three-phase partitioning model.

(b) **Description of the model.** The three-phase partitioning model is described by the following equation:

[Equation 747-1]

$$C_s = C_w (UCF) DF \left[K_d + \frac{(\theta_w + \theta_a H_{cc})}{\rho_b} \right]$$

Where:

C_s	=	Soil concentration (mg/kg)
C_w	=	Groundwater cleanup level established under WAC 173-340-720 (ug/l)
UCF	=	Unit conversion factor (1mg/1,000 ug)
DF	=	Dilution factor (dimensionless: 20 for unsaturated zone soil; see (e) of this subsection for saturated zone soil)
K_d	=	Distribution coefficient (L/kg; see (c) of this subsection)
θ_w	=	Water-filled soil porosity (ml water/ml soil: 0.3 for unsaturated zone soil; see (e) of this subsection for saturated zone soil)

$$\theta_a \quad = \quad \text{Air-filled soil porosity (ml air/ml soil: 0.13 for unsaturated zone soil; see (e) of this subsection for saturated zone soil)}$$

$$H_{cc} \quad = \quad \text{Henry's law constant (dimensionless; see (d) of this subsection)}$$

$$\rho_b \quad = \quad \text{Dry soil bulk density (1.5 kg/L)}$$

(c) **Distribution coefficient (K_d).** The default K_d values for organics and metals used in Equation 747-1 are as follows:

(i) **Organics.** For organic hazardous substances, the K_d value shall be derived using Equation 747-2. The K_{oc} (soil organic carbon-water partition coefficient) parameter specified in Equation 747-2 shall be derived as follows:

(A) **Nonionic organics.** For individual nonionic hydrophobic organic hazardous substances (e.g., benzene and naphthalene), the K_{oc} values in Table 747-1 shall be used. For hazardous substances not listed in Table 747-1, K_d values may be developed as provided in subsection (5) of this section (variable three-phase partitioning model).

(B) **Ionizing organics.** For ionizing organic hazardous substances (e.g., pentachlorophenol and benzoic acid), the K_{oc} values in Table 747-2 shall be used. Table 747-2 provides K_{oc} values for three different pHs. To select the appropriate K_{oc} value, the soil pH must be measured. The K_{oc} value for the corresponding soil pH shall be used. If the soil pH falls between the pH values provided, an appropriate K_{oc} value shall be selected by interpolation between the listed K_{oc} values.

[Equation 747-2]

$$K_d \quad = \quad K_{oc} \times f_{oc}$$

Where:

$$K_d \quad = \quad \text{Distribution coefficient (L/kg)}$$

$$K_{oc} \quad = \quad \text{Soil organic carbon-water partitioning coefficient (L/kg). See (c)(i) of this subsection.}$$

$$f_{oc} \quad = \quad \text{Soil fraction of organic carbon (0.1\% or 0.001 g/g)}$$

(ii) **Metals.** For metals, the K_d values in Table 747-3 shall be used. For metals not listed in Table 747-3, K_d values may be developed as provided in subsection (5) of this section (variable three-phase partitioning model).

(d) **Henry's law constant.** For petroleum fractions, the values for Henry's law constant in Table 747-4 shall be used in Equation 747-1. For individual organic hazardous substances, the value shall be based on values in the scientific literature. For all metals present as inorganic compounds except mercury, zero shall be used. For mercury, either 0.47 or a value derived from the scientific literature shall be used. Derivation of Henry's law constant from the scientific literature shall comply with WAC 173-340-702 (14), (15) and (16).

(e) **Saturated zone soil concentrations.** Equation 747-1 may also be used to derive concentrations for soil that is located at or below the groundwater table (the saturated zone). The following input parameters shall be changed if Equation 747-1 is used to derive saturated zone soil concentrations:

(i) The dilution factor shall be changed from 20 to 1;

(ii) The water-filled soil porosity value shall be changed from 0.3 ml water/ml soil to 0.43 ml water/ml soil; and

(iii) The air-filled soil porosity value shall be changed from 0.13 ml air/ml soil to zero.

(5) **Variable parameter three-phase partitioning model.**

(a) **Overview.** This section specifies the procedures and requirements to derive site-specific input parameters for use in the three-phase partitioning model. This method may be used to establish soil concentrations for any hazardous substance. This method may be used to calculate both unsaturated and saturated zone soil concentrations.

This method allows for the substitution of site-specific values for the default values in Equation 747-1 for one or more of the following five input parameters: Distribution coefficient, soil bulk density, soil volumetric water content, soil air content, and dilution factor. The methods that may be used and the requirements that shall be met to derive site-specific values for each of the five input parameters are specified in (b) through (f) of this subsection.

(b) **Methods for deriving a distribution coefficient (K_d).** To derive a site-specific distribution coefficient, one of the following methods shall be used:

(i) **Deriving K_d from soil fraction of organic carbon (foc) measurements.** Site-specific measurements of soil organic carbon may be used to derive distribution coefficients for nonionic hydrophobic organics using Equation 747-2. Soil organic carbon measurements shall be 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.

The laboratory protocols for measuring soil organic carbon in the Puget Sound Estuary Program (March, 1986) may be used. Other methods may also be used if approved by the department. All laboratory measurements of soil organic carbon shall be based on methods that do not include inorganic carbon in the measurements.

(ii) **Deriving K_d from site data.** Site-specific measurements of the hazardous substance concentrations in the soil and the soil pore water or groundwater may be used, subject to department approval, to derive a distribution coefficient. Distribution coefficients that have been derived from site data shall be based on measurements of soil and groundwater hazardous substance concentrations from the same depth and location. Soil and groundwater samples that have hazardous substances present as a nonaqueous phase liquid (NAPL) shall not be used to derive a distribution coefficient and measures shall be taken to minimize biodegradation and volatilization during sampling, transport and analysis of these samples.

(iii) **Deriving K_d from batch tests.** A site-specific distribution coefficient may be derived by using batch equilibrium tests, subject to department approval, to measure hazardous substance adsorption and desorption. The results from the batch test may be used to derive K_d from the sorption/desorption relationship between hazardous substance concentrations in the soil and water. Samples that have hazardous substances present as a nonaqueous phase liquid (NAPL) shall not be used to derive a distribution coefficient and measures shall be taken to minimize biodegradation and volatilization during testing.

(iv) **Deriving K_d from the scientific literature.** The scientific literature may be used to derive a site-specific distribution coefficient (K_d) for any hazardous substance, provided the requirements in WAC 173-340-702 (14), (15) and (16) are met.

(c) **Deriving soil bulk density.** ASTM Method 2049 or other methods approved by the department may be used to derive soil bulk density values.

(d) **Deriving soil volumetric water content using laboratory methods.** ASTM Method 2216 or other methods approved by the department may be used to derive soil volumetric water content values.

(e) **Estimating soil air content.** An estimate of soil air content may be determined by calculating soil porosity and subtracting the volumetric water content.

(f) **Deriving a dilution factor from site-specific estimates of infiltration and groundwater flow volume.** Site-specific estimates of infiltration and groundwater flow volume may be used in the following equation to derive a site-specific dilution factor:

[Equation 747-3]

$$DF = (Q_p + Q_a)/Q_p$$

Where:

DF = Dilution factor (dimensionless)

Q_p = Volume of water infiltrating (m^3/yr)

Q_a = Groundwater flow (m^3/yr)

(i) **Calculating groundwater flow volume.** The following equation shall be used under this method to calculate the volume of groundwater flow (Q_a):

[Equation 747-4]

$$Q_a = K \times A \times I$$

Where:

Q_a = Groundwater flow volume (m^3/year)

K = Hydraulic conductivity (m/year). Site-specific measurements shall be used to derive this parameter.

A = Aquifer mixing zone (m^2). The aquifer mixing zone thickness shall not exceed 5 meters in depth and be equal to a unit width of 1 meter, unless it can be demonstrated empirically that the mixing zone thickness exceeds 5 meters.

I = Gradient (m/m). Site-specific measurements shall be used to derive this parameter.

(A) Equation 747-4 assumes the groundwater concentrations of hazardous substances of concern upgradient of the site are not detectable. If this assumption is not true, the dilution factor may need to be adjusted downward in proportion to the upgradient concentration.

(B) Direct measurement of the flow velocity of groundwater using methods approved by the department may be used as a substitute for measuring the groundwater hydraulic conductivity and gradient.

(ii) **Calculating or estimating infiltration.** The following equation shall be used under this method to calculate the volume of water infiltrating (Q_p):

[Equation 747-5]

$$Q_p = L \times W \times Inf$$

Where:

Q_p = Volume of water infiltrating (m^3/year)

L = Estimated length of contaminant source area parallel to groundwater flow (m)

W = Unit width of contaminant source area (1 meter)

Inf = Infiltration (m/year)

(A) If a default annual infiltration value (Inf) is used, the value shall meet the following requirements. For sites west of the Cascade Mountains, the default annual infiltration value shall be 70 percent of the average annual precipitation amount. For sites east of the Cascade Mountains, the default annual infiltration value shall be 25 percent of the average annual precipitation amount.

(B) If a site-specific measurement or estimate of infiltration (Inf) is made, it shall be based on site conditions without surface caps (e.g., pavement) or other structures that would control or impede infiltration. 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. If a site-specific measurement or estimate of in-filtration is made, then it must comply with WAC 173-340-702 (14), (15) and (16).

(6) **Four-phase partitioning model.**

(a) **Overview.** This subsection specifies the procedures and re-quirements for establishing soil concentrations through the use of the four-phase partitioning model. This model may be used to derive soil concentrations for any site where hazardous substances are present in the soil as a nonaqueous phase liquid (NAPL). The model is described in (c) of this subsection. Instructions on how to use the model to es-tablish protective soil concentrations are provided in (d) of this subsection.

(b) **Restrictions on use of the model for alcohol enhanced fuels.** The four-phase partitioning model may be used on a case-by-case basis for soil containing fuels (e.g., gasoline) that have been enhanced with alcohol. If the model is used for alcohol enhanced fuels, then it shall be demonstrated that the effects of cosolvency have been ade-quately considered and, where necessary, taken into account when ap-plying the model. Use of the model for alcohol enhanced fuels without considering the effects of cosolvency and increased groundwater con-tamination is prohibited.

(c) **Description of the model.** The four-phase partitioning model is based on the following three equations:

(i) **Conservation of volume equation.**

[Equation 747-6]

$$n = \theta_w + \theta_a + \theta_{NAPL}$$

Where:

n = Total soil porosity (ml total pore space/ml total soil volume). Use a default value of 0.43 ml/ml or use a value determined from site-specific measurements.

θ_w = Volumetric water content (ml water/ml soil). For unsaturated soil use a default value of 0.3 or a value determined from site-specific measurements. For saturated soil this value is unknown and must be solved for. Volumetric water content equals the total soil porosity minus volume occupied by the NAPL.

θ_a = Volumetric air content (ml air volume/ml total soil volume). For unsaturated soil this value is unknown and must be solved for. Volumetric air content equals the total soil porosity minus the volume occupied by the water and NAPL. For saturated soil this value is zero.

θ_{NAPL} = Volumetric NAPL content (ml NAPL volume/ml total soil volume). For both unsaturated and saturated soil this value is unknown and must be solved for.

(ii) **Four-phase partitioning equation.**

[Equation 747-7]

$$\frac{M_T^i}{m_{soil}} = \frac{x_i S_i}{\rho_b}\left[\theta_w + K_{oc}^i f_{oc}\rho_b + H_{cc}^i\theta_a + \frac{GFW_i}{S_i}\rho_{NAPL}\theta_{NAPL}\right]$$

Where:

M_T^i = Total mass of each component in the system (mg). This value is derived from site-specific measurements.

m_{soil} = Total soil mass (kg).

x_i = Mole fraction (at equilibrium) of each component (dimensionless). This value is unknown and must be solved for.

S_i = Solubility of each component (mg/l). See Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.

P_b = Dry soil bulk density (1.5 kg/l).

K_{oc}^i = Soil organic carbon-water partitioning coefficient for each component (l/kg). See Table 747-4 for petroleum hydrocarbons; see subsection (4)(b) of this section for other hazardous substances.

f_{oc} = Mass fraction of soil natural organic carbon (0.001 g soil organic/g soil).

H_{cc}^i = Henry's law constant for each component (dimensionless). See Table 747-4 for petroleum hydrocarbons; see subsection (4)(c) of this section for other hazardous substances.

GFW_i = Gram formula weight, or molecular weight of each component (mg/mol). See Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.

$\rho NAPL$ = Molar density of the mixture (mol/l). See Equation 747-8.

$Component$ = For petroleum mixtures, this means the petroleum fractions, and organic hazardous substances with a reference dose; for other hazardous substances, this means each organic hazardous substance that is found in the NAPL.

(iii) **Molar density equation.**

[Equation 747-8]

$$\rho_{NAPL} = \frac{\left[\sum x_i GFW_i \Big/ \left(\sum x_i GFW_i/\rho_i\right)\right]}{\sum x_i GFW_i}$$

$$= \frac{1}{\sum (x_i GFW_i/\rho_i)}$$

Where:

GFW_i = Gram formula weight, or molecular weight of each component (mg/mol). See Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.

x_i = Mole fraction (at equilibrium) of each component (dimensionless). This value is unknown and must be solved for.

ρ_i = Density of each component (mg/l). See Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.

$Component$ = For petroleum mixtures, this means the petroleum fractions plus organic hazardous substances with a reference dose; for other hazardous substances, this means each organic hazardous substance that is found in the NAPL.

(d) **Instructions for using the model.** This subsection provides instructions for using the four-phase partitioning model to predict groundwater concentrations and to establish protective soil concentrations. The model uses an iterative process to simultaneously solve multiple equations for several unknowns (see step 4 for the number of equations). To predict a groundwater concentration, the mole fraction of each component (at equilibrium) must be known. The predicted groundwater concentration is obtained by multiplying the water solubility of each component by the equilibrated mole fraction (Equation 747-7).

(i) **Step 1: Measure hazardous substance soil concentrations.** Collect and analyze soil samples and, if appropriate, samples of the product released, for each component. For petroleum hydrocarbons, see Table 830-1 for a description of what to analyze for.

(ii) **Step 2: Derive physical/chemical data.** For each of the components, determine the Henry's law constant, water solubility, soil organic carbon-water partitioning coefficient, density and molecular weight values. For petroleum hydrocarbons, see Table 747-4.

(iii) **Step 3: Derive soil parameters.** Derive a value for each of the following soil parameters as follows:

(A) **Soil organic carbon content.** Use the default value (0.001 g soil organic/g soil) or a site-specific value derived under subsection (5)(b)(i) of this section.

(B) **Soil volumetric water content.** Use the default value (0.43 minus the volume of NAPL and air) or a site-specific value derived under subsection (5)(d) of this section.

(C) **Soil volumetric air content.** Use the default value (0.13 ml/ml for unsaturated zone soil; zero for saturated zone soil) or a site-specific value derived under subsection (5)(e) of this section.

(D) **Soil bulk density and porosity.** Use the default values of 1.5 kg/l for soil bulk density and 0.43 for soil porosity or use site-specific values. If a site-specific value for bulk density is used, the method specified in subsection (5)(c) of this subsection shall be used. If a site-specific bulk density value is used, a site-specific porosity value shall also be used. The site-specific soil porosity value may be calculated using a default soil specific gravity of 2.65 g/ml or measuring the soil specific gravity using ASTM Method D 854.

(iv) **Step 4: Predict a soil pore water concentration.** Equation 747-7 shall be used to predict the soil pore water concentration for each component. To do this, multiple versions of Equation 747-7 shall be constructed, one for each of the components using the associated parameter inputs for K_{oc}, H_{cc}, GFW, and S. These equations shall then be combined with Equations 747-6 and 747-8 and the condition that $\Sigma x_i = 1$ and solved simultaneously for the unknowns in the equations (mole fraction of each component (X_i), volumetric NAPL content (θ_{NAPL}), and either the volumetric water content (θ_w) or the volumetric air content (θ_a).

(v) **Step 5: Derive a dilution factor.** Derive a dilution factor using one of the following two methods:

(A) Use the default value of 20 for unsaturated soils and one for saturated soils); or

(B) Derive a site-specific value using site-specific estimates of infiltration and groundwater flow volume under subsection (5)(f) of this section.

(vi) **Step 6: Calculate a predicted groundwater concentration.** Calculate a predicted groundwater concentration for each component by dividing the predicted soil pore water concentration for each component by a dilution factor to account for the dilution that occurs once the component enters groundwater.

(vii) **Step 7: Establishing protective soil concentrations.**

(A) **Petroleum mixtures.** For petroleum mixtures, compare the predicted groundwater concentration for each component and for the total petroleum hydrocarbon mixture (sum of the petroleum components in the NAPL) with the applicable groundwater cleanup level established under WAC 173-340-720.

(I) If the predicted groundwater concentration for each of the components and for the total petroleum hydrocarbon mixture is less than or equal to the applicable groundwater cleanup level, then the soil concentrations measured at the site are protective.

(II) If the condition in (d)(vii)(A)(I) of this subsection is not met, then the soil concentrations measured at the site are not protective. In this situation, the four-phase partitioning model can be used in an iterative process to calculate protective soil concentrations.

(B) **Other mixtures.** For mixtures that do not include petroleum hydrocarbons, compare the predicted groundwater concentration for each hazardous substance in the mixture with the applicable groundwater cleanup level established under WAC 173-340-720.

(I) If the predicted groundwater concentration for each of the hazardous substances in the mixture is less than or equal to the applicable groundwater cleanup level, then the soil concentrations measured at the site are protective.

(II) If the condition in (d)(vii)(B)(I) of this subsection is not met, then the soil concentrations measured at the site are not protective. In this situation, the four-phase partitioning model can be used in an iterative process to calculate protective soil concentrations.

(7) **Leaching tests.**

(a) **Overview.** This subsection specifies the procedures and requirements for deriving soil concentrations through the use of leaching tests. Leaching tests may be used to establish soil concentrations for the following specified metals: Arsenic, cadmium, total chromium, hexavalent chromium, copper, lead, mercury, nickel, selenium, and zinc (see (b) and (c) of this subsection). Leaching tests may also be used to establish soil concentrations for other hazardous substances, including petroleum hydrocarbons, provided sufficient information is available to correlate leaching test results with groundwater impacts (see (d) of this subsection). Testing of soil samples from the site is required for use of this method.

(b) **Leaching tests for specified metals.** If leaching tests are used to establish soil concentrations for the specified metals, the following two leaching tests may be used:

(i) EPA Method 1312, Synthetic Precipitation Leaching Procedure (SPLP). Fluid #3 (pH = 5.0), representing acid rain in the western United States, shall be used when conducting this test. This test may underestimate groundwater impacts when acidic conditions exist due to significant biological degradation or for other reasons. Underestimation of groundwater impacts may occur, for example, when soils contaminated with metals are located in wood waste, in municipal solid waste landfills, in high sulfur content mining wastes, or in other situations with a pH < 6. Consequently, this test shall not be used in these situations and the TCLP test should be used instead.

(ii) **EPA Method 1311, Toxicity Characteristic Leaching Procedure (TCLP).** Fluid #1 (pH = 4.93), representing organic acids generated by biological degradation processes, shall be used when conducting this test. This test is intended to represent situations where acidic conditions are present due to biological degradation such as in municipal solid waste landfills. Thus, it may underestimate groundwater impacts where this is not the case and the metals of interest are more soluble under alkaline conditions. An example of this would be arsenic occurring in alkaline (pH > 8) waste or soils. Consequently, this test shall not be used in these situations and the SPLP test should be used instead.

(c) **Criteria for specified metals.** When using either EPA Method 1312 or 1311, the analytical methods used for analysis of the leaching test effluent shall be sufficiently sensitive to quantify hazardous substances at concentrations at the groundwater cleanup level established under WAC 173-340-720. For a soil metals concentration derived under (b) of this subsection to be considered protective of groundwater, the leaching test effluent concentration shall meet the following criteria:

(i) For cadmium, lead and zinc, the leaching test effluent concentration shall be less than or equal to 10 times the applicable groundwater cleanup level established under WAC 173-340-720.

(ii) For arsenic, total chromium, hexavalent chromium, copper, mercury, nickel and selenium, the leaching test effluent concentration shall be less than or equal to the applicable groundwater cleanup level established under WAC 173-340-720.

(d) **Leaching tests for other hazardous substances.** Leaching tests using the methods specified in this subsection may also be used for hazardous substances other than the metals specifically identified in this subsection, including petroleum hydrocarbons. Alternative leaching test methods may also be used for any hazardous substance, including the metals specifically identified in this subsection. Use of the leaching tests specified in (b) and (c) of this subsection for other hazardous substances or in a manner not specified in (b) and (c) of this subsection, or use of alternative leaching tests for any hazardous substance, is subject to department approval and the user must demonstrate with site-specific field or laboratory data or other empirical data that the leaching test can accurately predict groundwater impacts. The department will use the criteria in WAC 173-340-702 (14), (15) and (16) to evaluate the appropriateness of these alternative methods under WAC 173-340-702 (14), (15) and (16).

(8) **Alternative fate and transport models.**

(a) **Overview.** This subsection specifies the procedures and requirements for establishing soil concentrations through the use of fate and transport models other than those specified in subsections (4) through (6) of this section. These alternative models may be used to establish a soil concentration for any hazardous substance. Site-specific data are required for use of these models.

(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:

(i) **Sorption.** Sorption values shall be derived in accordance with either subsection (4)(c) of this section or the methods specified in subsection (5)(b) of this section.

(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.

(iii) **Natural biodegradation.** Rates of natural biodegradation shall be derived from site-specific measurements.

(iv) **Dispersion.** Estimates of dispersion shall be derived from either site-specific measurements or literature values.

(v) **Decaying source.** Fate and transport algorithms may be used that account for decay over time.

(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.

(vii) **Infiltration.** Infiltration shall be derived in accordance with subsection (5)(f)(ii)(A) or (B) of this section.

(c) **Evaluation criteria.** Proposed fate and transport models, input parameters, and assumptions shall comply with WAC 173-340-702 (14), (15) and (16).

(9) **Empirical demonstration.**

(a) **Overview.** This subsection specifies the procedures and requirements for demonstrating empirically that soil concentrations measured at the site will not cause an exceedance of the applicable groundwater cleanup levels established under WAC 173-340-720. This empirical demonstration may be used for any hazardous substance. Site-specific data (e.g., groundwater and soil samples) are required under this method. If the demonstrations required under (b) of this subsection cannot be made, then a protective soil concentration shall be established under one of the methods specified in subsections (4) through (8) of this section.

(b) **Requirements.** To demonstrate empirically that measured soil concentrations will not cause an exceedance of the applicable groundwater cleanup levels established under WAC 173-340-720, the following shall be demonstrated:

(i) The measured groundwater concentration is less than or equal to the applicable groundwater cleanup level established under WAC 173-340-720; and

(ii) The measured soil concentration will not cause an exceedance of the applicable groundwater cleanup level established under WAC 173-340-720 at any time in the future. Specifically, it must be demonstrated that a sufficient amount of time has elapsed for migration of hazardous substances from soil into groundwater to occur and that the characteristics of the site (e.g., depth to groundwater and infiltration) are representative of future site conditions. This demonstration may also include a measurement or calculation of the attenuating capacity of soil between the source of the hazardous substance and the groundwater table using site-specific data.

(c) **Evaluation criteria.** Empirical demonstrations shall be based on methods approved by the department. Those methods shall comply with WAC 173-340-702 (14), (15) and (16).

(10) **Residual saturation.**

(a) **Overview.** To ensure the soil concentrations established under one of the methods specified in subsections (4) through (9) of this section will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720, the soil concentrations must not result in the accumulation of nonaqueous phase liquid on or in ground-

water (see subsection (2)(b) of this section). To determine if this criterion is met, either an empirical demonstration must be made (see (c) of this subsection) or residual saturation screening levels must be established and compared with the soil concentrations established under one of the methods specified in subsections (4) through (9) of this section (see (d) and (e) of this subsection). This subsection applies to any site where hazardous substances are present as a nonaqueous phase liquid (NAPL), including sites contaminated with petroleum hydrocarbons.

(b) **Definition of residual saturation.** When a nonaqueous phase liquid (NAPL) is released to the soil, some of the NAPL will be held in the soil pores or void spaces by capillary force. For the purpose of this subsection, the concentration of hazardous substances in the soil at equilibrium conditions is called residual saturation. At concentrations above residual saturation, the NAPL will continue to migrate due to gravimetric and capillary forces and may eventually reach the groundwater, provided a sufficient volume of NAPL is released.

(c) **Empirical demonstration.** An empirical demonstration may be used to show that soil concentrations measured at the site will not result in the accumulation of nonaqueous phase liquid on or in groundwater. An empirical demonstration may be used for any hazardous substance. Site-specific data (e.g., groundwater and soil samples) are required under this method. If the demonstrations required under (c)(i) of this subsection cannot be made, then a protective soil concentration shall be established under (d) and (e) of this subsection.

(i) **Requirements.** To demonstrate empirically that measured soil concentrations will not result in the accumulation of nonaqueous phase liquid on or in groundwater, the following shall be demonstrated:

(A) Nonaqueous phase liquid has not accumulated on or in groundwater; and

(B) The measured soil concentration will not result in nonaqueous phase liquid accumulating on or in groundwater at any time in the future. Specifically, it must be demonstrated that a sufficient amount of time has elapsed for migration of hazardous substances from soil into groundwater to occur and that the characteristics of the site (e.g., depth to groundwater and infiltration) are representative of future site conditions. This demonstration may also include a measurement or calculation of the attenuating capacity of soil between the source of the hazardous substance and the groundwater table using site-specific data.

(iii) **Evaluation criteria.** Empirical demonstrations shall be based on methods approved by the department. Those methods shall comply with WAC 173-340-702 (14), (15) and (16).

(d) **Deriving residual saturation screening levels.** Unless an empirical demonstration is made under (c) of this subsection, residual saturation screening levels shall be derived and compared with the soil concentrations derived under the methods specified in subsections (4) through (9) of this subsection to ensure that those soil concentrations will not result in the accumulation of nonaqueous phase liquid on or in groundwater. Residual saturation screening levels shall be derived using one of the following methods.

(i) **Default screening levels for petroleum hydrocarbons.** Residual saturation screening levels for petroleum hydrocarbons may be obtained from the values specified in Table 747-5.

(ii) **Site-specific screening levels.** Residual saturation screening levels for petroleum hydrocarbons and other hazardous substances may be derived from site-specific measurements. Site-specific measure-

ments of residual saturation shall be based on methods approved by the department. Laboratory measurements or theoretical estimates (i.e., those that are not based on site-specific measurements) of residual saturation shall be supported and verified by site data. This may include an assessment of groundwater monitoring data and soil concentration data with depth and an analysis of the soil's texture (grain size), porosity and volumetric water content.

(e) **Adjustment to the derived soil concentrations.** After residual saturation screening levels have been derived under (d) of this subsection, the screening levels shall be compared with the soil concentrations derived under one of the methods specified in subsections (4) through (9) of this subsection. If the residual saturation screening level is greater than or equal to the soil concentration derived using these methods, then no adjustment for residual saturation is necessary. If the residual saturation screening level is less than the soil concentration derived using these methods, then the soil concentration shall be adjusted downward to the residual saturation screening level.

(11) **Groundwater monitoring requirements.** The department may, on a case-by-case basis, require groundwater monitoring to confirm that hazardous substance soil concentrations derived under this section meet the criterion specified in subsection (2) of this section.

[Statutory Authority: Chapters 70A.305 and 70A.355 RCW. WSR 23-17-159 (Order 18-09), § 173-340-747, filed 8/23/23, effective 1/1/24. Statutory Authority: Chapter 70.105D RCW. WSR 01-05-024 (Order 97-09A), § 173-340-747, filed 2/12/01, effective 8/15/01.]

Reviser's note: The brackets and enclosed material in the text of the above section occurred in the copy filed by the agency.