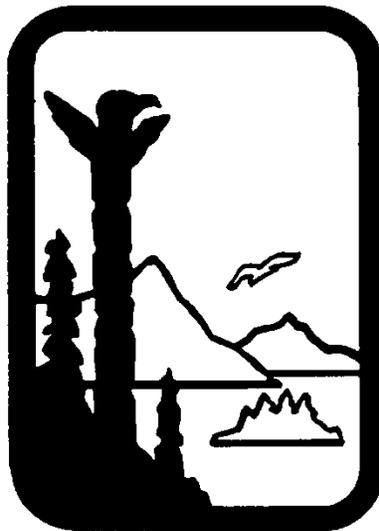## State of Alaska
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES PROGRAM

Implementing Guidance for the Method 3
Hydrocarbon Risk Calculator

February 25, 2011

Acronyms

AAC- Alaska Administrative Code
ADEC- Alaska Department of Environmental Conservation
BTEX- Benzene, Toluene, Ethylbenzene, Xylenes
CSP- Contaminated Sites Program
DRO- Diesel Range Organics
EPA- Environmental Protection Agency
EPH- Extractable aromatic and aliphatic Petroleum Hydrocarbons
FAA- Federal Aviation Administration
GRO- Gasoline Range Organics
HRC- Hydrocarbon Risk Calculator
IC- Institutional Control
NAPL- Non Aqueous Phase Liquid
NELAP- National Environmental Lab Approval Program
QA/QC- Quality Assurance/Quality Control
RP- Responsible Party
RRO- Residual Range Organics
SOC- Statement of Cooperation
TPH- Total Petroleum Hydrocarbons
VPH-Volatile aromatic and aliphatic Petroleum Hydrocarbons

Electronic version available at: http://decjnuapp/spar/csp/guidance.htm

IMPLEMENTING GUIDANCE FOR THE METHOD 3 HYDROCARBON RISK CALCULATOR

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1 Purpose

The purpose of this document is to provide guidance to ADEC Contaminated Sites Program staff and the public in the application of the Hydrocarbon Risk Calculator (HRC) and its results at sites in Alaska within the context of 18 AAC 75 and 18 AAC 78. The following sections give direction and provide clarity on a range of issues that may arise in the course of applying the HRC at sites in Alaska.

2 Background

The development of the HRC occurred under the oversight of the Statement of Cooperation (SOC) Work Group, which includes representatives from the following entities:

- Alaska Department of Environmental Conservation
- U.S. Environmental Protection Agency
- Federal Aviation Administration
- U.S. Department of the Interior
- Alaska National Guard
- Defense Energy Support Center
- U.S. Navy
- U.S. Army
- U.S. Air Force Army Corps of Engineers
- U.S. Coast Guard
- Alaska Intertribal Council

The HRC is an alternative, peer reviewed model for calculating site-specific risks to human health under ADEC's Method 3 (18 AAC 75.340(e) and 18 AAC 78.600 (d)) and Method 4 (18 AAC 75.340(f) and 18 AAC 78.600(e)). When used under Method 4, responsible parties must follow the ADEC's Risk Assessment Procedures Manual.

The HRC is designed for sites with petroleum contamination—specifically the petroleum fractions, BTEX, PAHs, and other compounds dissolved in petroleum—with the intention and purpose of providing an improved tool for assessing human health risk from this type of contamination. It employs a higher level of scientific rigor by applying either three-phase (dissolved, sorbed and vapor) or four-phase (dissolved, sorbed, vapor and non-aqueous phase liquid (NAPL)) equilibrium partitioning to model the behavior of contaminants and calculate human health risk.[1] In contrast, the ADEC Method 3 calculator is limited to a three-phase equilibrium partitioning approach, which does not calculate accurate migration-to-groundwater or outdoor air inhalation cleanup levels when NAPL is present. At most sites that have petroleum contamination above the Method 2, Table B2 levels, NAPL is present.

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[1] For detailed information about 4-phase partitioning, please refer to the companion document, Hydrocarbon Risk Calculator User Manual, October 2010. Available at: *http://dec.alaska.gov/spar/guidance.htm#csp*.

In addition to petroleum compounds, a subset of approximately 120 additional compounds, selected based upon their solubility characteristics[2] from ADEC's Table B1 of 18 AAC 75, are included in the HRC to allow representative cumulative risk calculations for these compounds when they are present as a constituent of a multi-constituent NAPL (such as from a leaking waste oil tank). The HRC does not address infinitely soluble or inorganic compounds. This differs from the current ADEC online calculator, which will perform calculations for all organic and inorganic contaminants listed in ADEC's tables B1 and B2 (but is not representative for organic compounds when NAPL is present).

The HRC should be considered another tool available to responsible parties for evaluating risk. As with all ADEC cleanup approaches, site characterization and risk evaluation work required to use the HRC needs to be conducted in accordance with the Site Cleanup Rules (18 AAC 75.325 through 75.396), Corrective Action (18 AAC 78.200 through 78.280) for leaking underground storage tank sites, other applicable regulations, and consistent with relevant guidance and policies.

3   Differences between the HRC and the Existing Method 3 Calculator

The following are primary differences between the hydrocarbon risk calculator and the ADEC Method 3 online risk calculator:

- The HRC applies either three-phase or four-phase partitioning equations, whichever is appropriate for the specific situation; whereas, the ADEC online calculator performs three-phase calculations exclusively and does not account for NAPL or recognize solubility and vapor pressure limits.

- The HRC requires collection of site specific data to further characterize the nature of the hydrocarbon contamination at each site. This includes NAPL source area samples analyzed using the Washington State EPH/VPH methods in addition to the ADEC methods for GRO, DRO and RRO. The Method 3 calculator does not utilize the EPH/VPH data and only evaluates only GRO (C_6-C_{10}), DRO (C_{10}-C_{25}), and RRO (C_{25}-C_{36}) petroleum hydrocarbon fractions. In the HRC, these hydrocarbon ranges are broken into narrower subsets and separated into aromatic and aliphatic hydrocarbon fractions.

- The HRC incorporates the Johnson and Ettinger vapor intrusion model. The ADEC online calculator does not assess risk associated with the vapor intrusion pathway.

- The HRC calculates the risk posed by the GRO, DRO and RRO aromatic and aliphatic groups rather than presenting a hydrocarbon alternative cleanup level. This approach allows the responsible party and ADEC to assess whether the site meets the risk criteria

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[2] Compounds classified as "sparingly soluble" are included. For the purposes of the Hydrocarbon Risk Calculator, sparingly soluble is defined as those compounds which are immiscible, not infinitely soluble, nor completely insoluble. No specific solubility value or range of values is associated with the term.

stipulated in 18 AAC 75 and 18 AAC 78. Consistent with ADEC Guidance, the HRC calculates risk for each of the hydrocarbon ranges, presents the numbers separately for each exposure pathway, and does not include those risks in the cumulative risk calculation for the site.

- The HRC accounts for saturated zone sources, whereas the ADEC online calculator assumes that the source is in the vadose zone only. The result is that if NAPL exists below the water table, common at many fuel spill sites, the default Dilution Attention Factor (DAF) of 13.2 in the online Method 3 Calculator cannot be modified with a value that represents this site condition (the appropriate DAF would be 1.0). In this situation the ADEC calculator could be less conservative than the HRC. The variable DAF in the HRC is generally more representative for saturated or seasonally saturated source areas.

4   Features of the HRC

4.1   Calculating Risk

The primary purpose of the HRC is to calculate both the current and potential future risk from contamination present at the site in soil and groundwater. It includes a baseline unrestricted residential land use scenario and alternative commercial/industrial, trench worker, and recreational use scenarios. Information from the alternative land use scenarios can be used to assess current risks for the purposes of risk management, such as ensuring worker or visitor safety and for prioritizing site work. The calculator assesses risk individually for each compound for each exposure pathway and cumulatively for all contaminants across all exposure pathways. The cumulative risk is rounded to one significant figure as described in the Cumulative Risk Guidance (ADEC, 2008). When assessing ultimate compliance with the risk standard, the HRC determines whether:

- the rounded cumulative risk value meets the regulatory risk standard;

- each compound is less than or equal to its risk-based concentration in soil for the direct contact pathway;

- each compound is less than or equal to its risk-based concentration for ingestion of groundwater; and

- the GRO, DRO and RRO fractions are less than or equal to the aromatic and aliphatic risk based concentrations for the soil direct contact, outdoor air inhalation, vapor intrusion, and groundwater ingestion exposure pathways.

The default site condition parameters, risk calculations, and the exposure assumptions used in the HRC are consistent with those used in the current DEC online Method 3 calculator.

4.2   Generating Cleanup Levels

The HRC may also be used iteratively to calculate proposed risk-based, site-specific alternative cleanup levels under Method 3 and, when used in accordance with the Risk Assessment

Procedures Manual, Method 4. Responsible Parties still must meet all applicable regulatory requirements.

Method 3 may be used to propose alternative soil cleanup levels for the "migration to groundwater" or "inhalation" pathways based on site specific soil data, or alternative soil cleanup levels for the "direct contact/ingestion" or "inhalation" pathways based on an approved industrial land use scenario. The Method 2 soil cleanup levels for the "direct contact/ingestion" pathway are not changed under Method 3 except by using an approved industrial land use scenario.

5   Site Characterization Data Requirements

The HRC allows the user to input site-specific data and concentrations of hydrocarbons (including fraction data) and other contaminants that are documented in soil and groundwater at the site. These inputs are described in the HRC manual in Table 3.

In order to use the HRC approach, responsible parties are required to submit a site characterization work plan for ADEC review and approval (the same as is required when using the online Method 3 calculator or a Method 4 approach). The work plan describes how each NAPL source area will be characterized, the HRC input parameters that will be modified, how the data for the parameters will be collected, and any data manipulation (such as statistical calculations). Guidance on these methods is provided in the site characterization section and Table 3 of the HRC User Manual. In general, the use of site-specific data is strongly encouraged over the use of the default values in the calculator.

5.1   95 UCL vs. Maximum Concentrations

The HRC requires a single contaminant concentration in soil be input to represent each contaminant within the NAPL source area. The work plan should describe how the input concentrations will be selected. Risks associated with contaminated soil may be evaluated either by using the maximum measured concentration of each contaminant in the NAPL source area or an approved 95% UCL (upper confidence limit) of the mean for each contaminant.

For assessing the exposure risk from the consumption of groundwater, the maximum concentration of each contaminant derived from recent rounds of groundwater monitoring will be required.

The statistical 95% UCL may be calculated by using EPA's ProUCL software.[3] The number of samples required to calculate the 95% UCL must be sufficient to produce a result that is representative of contamination present at the site. ADEC recommends a minimum of 10 data points be used to calculate the 95 UCL. However, responsible parties should bear in mind that even 10 data points may not yield a stable UCL if there is higher than normal heterogeneity in contaminant levels.

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[3] Available at: *http://www.epa.gov/osp/hstl/tsc/software.htm.*

When using ProUCL with the HRC (similar to when using the ADEC online calculator or in a Method 4 risk assessment) both hard copies and electronic copies of the input and output data from ProUCL shall be submitted to ADEC as part of the written site characterization report. The Responsible Party (RP) must provide supporting documentation for the ProUCL input values.

Sites with large source areas that exhibit significant variability in contaminant levels and/or heterogeneous soil properties across soil horizons may require additional data and/or separate evaluation. These site specific requirements should be part of the approved work plan. See Section 6.0 for further detail on using the HRC to evaluate sites with unique characteristics.

5.2 Required Analytical Methods for Petroleum Fraction Data

Petroleum concentrations in the NAPL source area must be characterized in two ways. Total petroleum concentrations must be analyzed using the AK series methods (AK 101, 102, and 103 for GRO, DRO, and RRO, respectively). The character of the GRO, DRO, and RRO is assessed by subdividing the GRO, DRO and RRO into smaller aromatic and aliphatic equivalent carbon groups (for example C_8-C_{10} aliphatics; C_{10}-C_{12} aromatics and C_{10}-C_{12} aliphatics, etc.) using EPH (for extractable aromatic and aliphatic petroleum hydrocarbons) and VPH (for volatile aromatic and aliphatic petroleum hydrocarbons) methods. The procedures to be followed for these methods are those developed by the State of Washington Department of Ecology.[4] Documentation of the method specific (EPH and VPH) lab approval, either state (e.g. Washington Department of Ecology) or national (e.g. NELAP) is required.[5]

Method-specified quality control (QC) criteria must be met for the EPH and VPH data that are used in the aliphatic and aromatic equivalent carbon characterization of GRO, DRO and RRO. The QC criteria for the EPH and VPH methods are as follows:

Surrogate	60% - 140% recovery
Laboratory Control Sample/Duplicate (LCS/LCSD)	70% - 130% recovery (for all fractions)
Relative Percent Difference (RPD)	$\pm$ 25%

The EPH and VPH concentration results must be converted to mass fractions prior to input into the HRC. The conversion procedure is described in Appendix A of this document. It may be completed by hand or via the HRC supplemental spreadsheet labeled, "Mass Fraction Spreadsheet" (available at: http://dec.alaska.gov/spar/guidance.htm#csp).

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[4] Available at: *http://www.ecy.wa.gov/pubs/97602.pdf*

[5] Information on Washington accredited labs can be found at *http://www.ecy.wa.gov/programs/eap/labs/search.html* and on NELAP at: http://www.nelac-institute.org/accred-labs.php

5.2.1 Fresh Fuels Data

Substituting fresh fuels data for site-specific petroleum fraction data will not be accepted as calculator inputs at this time. Site specific EPH and VPH data are required to assess the character of the GRO, DRO and RRO concentrations from the AK methods unless the ADEC approves the use of an alternative aromatic and aliphatic equivalent carbon characterization. ADEC is assessing the use of a conservative default and/or fresh fuel characterization. If this is approved in the future, an appendix detailing its application and use will be incorporated into this guidance.

5.2.2 Sites with Older Data

The HRC may be used to generate new or revised risk calculations at older sites. With concurrence from ADEC, historical data may be used in the site characterization effort required to execute the HRC. For example, sample results produced with EPA analytical methods TPH 418.1, 8100 or 8015 may be acceptable for characterizing the extent of the NAPL source area. On a site-specific basis, 8100 EPH (extractable petroleum hydrocarbons) and 8015 VPH (volatile petroleum hydrocarbons) data may be used for calculating the 95% UCL for the GRO, DRO and RRO concentrations, provided the hydrocarbon ranges are comparable to those of the current Alaska petroleum methods (AK101, AK102, and AK103), appropriate QA/QC data are available to demonstrate the results are usable, and the volatiles (GRO, BTEX, etc.) were collected utilizing methanol field preservation. Existing petroleum hydrocarbon fraction data from the WA EPH/VPH methods may be approved for use as long as appropriate QA/QC data are available to demonstrate the results are valid and usable.

 In the absence of appropriate historical data, current soil and groundwater analytical data will be necessary to characterize the petroleum ranges, using both Washington methods for EPH and VPH and the Alaska series methods as described in Section 5.2.

5.3 Chemical Properties

Chemical specific properties are provided for most compounds and cannot be modified by the user, except for the representative "equivalent carbon number" for the various aliphatic and aromatic petroleum hydrocarbon fractions.   These values are provided by the developer of the HRC and are suggested to be conservative and /or representative. The values are the midpoint of the narrower equivalent carbon ranges and an arbitrary but relatively low equivalent carbon value for the broader equivalent carbon ranges.

The default representative equivalent carbon values are as follows:

Carbon Range	Equivalent Carbon Number
Aromatic C_9-C_{10}	9.50
Aromatic C_{10}-C_{12}	11.00
Aromatic C_{12}-C_{16}	13.00
Aromatic C_{16}-C_{24}	17.00
Aromatic C_{24}-C_{35}	25.00
Aliphatic C_5-C_6	5.50
Aliphatic C_6-C_8	7.00
Aliphatic C_8-C_{10}	9.00
Aliphatic C_{10}-C_{12}	11.00
Aliphatic C_{12}-C_{16}	13.00
Aliphatic C_{16}-C_{24}	17.00
Aliphatic C_{24}-C_{35}	25.00

These values will typically remain unchanged; however there may be cases where site specific fuel characterization indicates that different EC numbers are more representative.

6 Instances where Use of the HRC may be Restricted

6.1 Multiple NAPL Source Areas, Non-hydrocarbon Sources and Co-Solvency

Certain contaminant or site characteristics at some sites may restrict use of the HRC due to limitations of the model. These may include sites where characterization data indicates the following:

a) Multiple NAPL sources;
b) Contamination that is limited to non-petroleum compounds, such as tetrachloroethylene spills at dry cleaner sites that are not co-located with petroleum hydrocarbon releases;
c) Mixtures of contaminants with a significant potential for co-solvency, such as a site contaminated with alcohol-blended gasoline; or
d) Background soil or groundwater properties, such as organic carbon content, pH, or salinity, which may elevate the solvency potential of an introduced contaminant.

The hydrocarbon risk calculator is designed to facilitate enhanced characterization of the potential risk posed by discrete, contiguous NAPL petroleum contaminant source areas. For sites with multiple source areas that are non-contiguous, the HRC should be used to generate separate risk calculations for each source. For sites with a contiguous NAPL source area that has a significantly different NAPL character across the source, the HRC could be used to generate separate risk calculations for different portions of the NAPL source area based on the NAPL character. This situation could result from releases of a single fuel type with different ages, or releases of different fuel types that have co-mingled to form a contiguous source.

The calculator is designed to evaluate sites with petroleum hydrocarbon contamination. With ADEC approval, it can also be used to assess sites where the contaminant plume includes fuel-related constituents such as methyl-tert butyl ether (MTBE) or compounds present in used oil profiles, such as solvents. The HRC is not intended for use at sites where contamination consists exclusively of non-petroleum compounds (for example pure tetrachloroethylene spills at dry cleaner sites).

Using the HRC at sites with mixtures of contaminants will require close consultation with ADEC due to uncertainties in how the contaminants may interact with each other. In particular, ADEC recognizes there is conflicting science on the issue of co-solvency and non-ideal dissolution; as the science develops in this area, adjustments to the calculator or restrictions in how it is used may be considered. In order to be adequately protective of human health and the environment, ADEC may elect to exclude sites where mixtures of petroleum and non-petroleum contaminants are present and data is lacking or inconclusive as to the risk or influence of co-solvency on contaminants in the mixture.

6.2   Soil Heterogeneity

Sites exhibiting significant heterogeneity in soil types either laterally or vertically may be evaluated using the HRC with ADEC's concurrence. Additional data to characterize the location, depth and extent of soil types with respect to the NAPL source area may be required. In most cases a representative infiltration rate can be derived at these types of sites however additional sampling or use of the highest concentration may be required in order to have confidence in the mean concentrations calculated. Sensitivity analysis using the HRC could be required for different soil types and concentrations in order to ensure the protectiveness of any decisions made on these kinds of sites.

6.3   Free Product Recovery and the HRC

The HRC does not address the requirement to recover free product to the extent practicable (see 18 AAC.75.325 (f) (1) (B) and 18 AAC 78.240(b)). When using the HRC, the online calculator, or conducting a Method 4 risk assessment, the extent and recoverability of free product must be thoroughly evaluated as part of the site characterization process. Methods for conducting this evaluation shall be articulated in the site characterization work plan, report, and, as appropriate, other documents submitted for ADEC approval.

6.4   Evaluating Vapor Intrusion Pathway with the HRC

The HRC evaluates the vapor intrusion pathway utilizing the Johnson and Ettinger model. Whether using the HRC, the online calculator, or a Method 4 risk assessment, sites with significant or potentially unique vapor-intrusion considerations will be evaluated on a site-specific basis and additional site characterization or monitoring may be necessary. Most fuel spill sites addressed using Method 3 or through a Method 4 risk assessment will require evaluation of the vapor intrusion pathway. For additional information, refer to the Draft Vapor Intrusion Guidance for Contaminated Sites (ADEC, 2009).

7   Site Closure Determinations and the HRC

Site closure determinations using the HRC, the online calculator, or a Method 4 risk assessment shall be made consistent with the provisions of 18 AAC 75 and 18 AAC 78. Reporting requirements, risk standards that must be met, and closure criteria are referred to in the regulations and in several other guidance documents posted on the ADEC website (http://dec.alaska.gov/spar/guidance.htm#csp).

7.1   Offsite Transport

As defined in 18 AAC 75.325(i) and 18 AAC 78.274(b), a responsible person shall obtain DEC approval before moving soil or groundwater from a site that is, or has been, subject to the site cleanup rules. This requirement applies to all sites whether they are addressed by the online calculator, the HRC or a Method 4 risk assessment. Information from the HRC calculations may be helpful in obtaining such approval but should not be misinterpreted as advance approval.

8   HRC Submittals

Responsible parties seeking to use the HRC to calculate risk under Method 3 or 4 must have an approved site characterization work plan. The work plan must describe the parameters that will be modified with site-specific data as well as the methods, procedures, and techniques that will be used for gathering the data. For additional information on the site characterization data required for the HRC, refer to the HRC User Manual.

As part of the site characterization report, the responsible party shall submit both an electronic version and a hard copy of the Microsoft Excel calculator with all site-specific inputs and accompanying results. A table listing the site-specific inputs and how the values were derived (data collection method, model, literature source, etc.) shall also be provided as part of the site characterization report.

9   Technical Issues

9.1   Calculator Security

A master file of the current version of the HRC is stored on the ADEC CSP website at http://dec.alaska.gov/spar/guidance.htm#csp. Subsequent versions will be distinguished by a new version number, and announcements of updates will be broadcast to the DEC contaminated sites listserv. To use the HRC, a copy is downloaded to the user's computer. Both the formulas and code underlying the "Calculate" button are password-protected. In addition the user may only modify a specific set of parameters (see Table 3 of the HRC User Manual for a complete list). Separate spreadsheets for each source area should be submitted electronically and will be used to verify the version and input parameters.

9.2 Technical Support and Trouble-Shooting

For technical support and trouble-shooting related to data inputs and execution of the calculator, refer to the HRC User Manual or contact the designated Contaminated Sites Program Project Manager. All bugs and other problems should also be reported to ADEC contact person for the HRC as identified on the Contaminated Sites website. These issues will then be relayed to the developer.

9.3 Ownership, Quality Control and Maintenance

- The Hydrocarbon Risk Calculator (HRC) and manual were developed by Geosphere, Inc. under contract to CH2M Hill and the Federal Aviation Administration (FAA), with input by members of the Statement of Cooperation (SOC) Working Group including staff from ADEC, FAA, U.S. Army, U.S. Army Corps of Engineers, and the Alaska Army National Guard.

- Peer reviews on the HRC were conducted by the University of Alaska, Fairbanks and SLR International Corporation.

- ADEC approves the use of the HRC (**version 1.1**) as an alternative, peer-reviewed model, and has agreed to make this version available on the Contaminated Sites Program (CSP) website.

- The HRC is an Excel workbook. Values and equations are password-protected.

- ADEC consents to posting the version that is finalized in early 2011. Review and minor modifications, such as updating revised toxicity values, are anticipated on an annual basis, subject to the availability of CSP resources. Ongoing or ad hoc revisions, updates, and improvements will be reviewed and approved on a case-by-case basis at the department's discretion and subject to the availability of CSP resources to review and approve such revisions.

- ADEC shall not be held responsible for any errors or bugs that may surface during the use and implementation by 3rd party users of the HRC, but will make every effort to ensure such issues are resolved promptly by the developer. If issues or inconsistencies with state regulations, guidance or policy emerge during the course of its use which cannot be overcome by simple and timely revisions or other fixes, ADEC reserves the right to remove the HRC from its website and suspend acceptance/use of the worksheet until such issues are resolved.

Appendix A – Calculating Mass Fractions

The HRC uses GRO, DRO and RRO results from the AK101, 102 and 103 test methods to calculate exposure point concentrations for input to the HRC and VPH and EPH data to assess the distribution of GRO, DRO and RRO mass within aromatic and aliphatic equivalent carbon groups. A spreadsheet has been developed to help HRC users calculate 1) the soil GRO, DRO and RRO aromatic fractions which are input values in cells C14 to C16 of the HRC and 2) the mass fractions within the GRO aliphatic, DRO aromatic, and DRO aliphatic equivalent carbon groups which are input values to cells D75 to D77 and D79 to D84 of the HRC. The "Mass Fraction Spreadsheet" may be downloaded from the CSP website at http://dec.alaska.gov/spar/guidance.htm#csp .

To use the spreadsheet, open the file and click to the tab labeled, "EPH &VPH-soils." Enter the EPH and VPH concentration data from the more heavily contaminated portions of the source area into Tables 6A and 6B. The values needed by the HRC will be calculated automatically and displayed in Table 6D. To transfer the values from Table 6D of the spreadsheet to the HRC it is advised to copy the values and use the "paste special values" option to paste the values into the appropriate cells of the HRC. The "paste special values" option is recommended because it will preserve the significant digits presentation in the HRC and, most importantly, the aromatic and aliphatic fractions will sum to 100% when input into the HRC.   Note that the table numbers shown in the spreadsheet are examples only and may be changed by the user.

The spreadsheet performs the following procedure to convert EPH and VPH data into the mass fractions required by the HRC. An example follows to illustrate this procedure.

1) The spreadsheet calculates the average concentration value within each carbon fraction (e.g., $C_8 – C_{10}$ aromatics). When calculating these average values, the spreadsheet by default assigns a numerical value equal to the method detection limit to all non-detect concentration data.

2) The spreadsheet pulls the average concentrations in the aromatic and aliphatic equivalent carbon groups from the VPH and EPH tests into a summary table (Table 6C). For carbon fractions measured by both the VPH and EPH methods, the spreadsheet by default selects the higher of the two average concentrations. If the user has reason to believe that lower of the overlapping ranges is a more representative value, the lower value may be entered by changing the cell references as appropriate.

3) The spreadsheet adds the concentrations within each aromatic and aliphatic equivalent carbon group to calculate a total average hydrocarbon concentration.

4) The spreadsheet calculates the mass fraction within each aromatic and aliphatic equivalent carbon group by dividing the average concentration within the group by the total concentration. Results are presented in the row labeled, "Fraction of TPH mass in A&A EC groups".

5) The spreadsheet calculates the mass fraction of each aromatic and aliphatic equivalent carbon group within the larger GRO aliphatic, DRO aromatic and DRO aliphatic groups by dividing the mass fraction of each aromatic and aliphatic equivalent carbon group by the sum of the mass fractions within the larger group (*e.g.*, the fraction of $C_{10} - C_{12}$ aliphatics within the DRO aliphatic group = C_{10}-C_{12} aliphatic mass fraction /(C_{10}-C_{12} aliphatic mass fraction + C_{12} –C_{16} aliphatic mass fraction + C_{16} –C_{21} aliphatic mass fraction). These values are inputs for cells D75 to D77 and cells D79 to D84 of the HRC and are shown in Table 6D in a format in which they can be cut and pasted into the HRC.

6) The spreadsheet calculates the aromatic fraction of GRO, DRO and RRO as the sum of the GRO aromatic mass fractions divided by the sum of the GRO aromatic and aliphatic fractions. These values are inputs to cells C14 to C16 of the HRC.

Example

Tables 1, 2 and 3 (on the following page) correspond to Steps 1, 2 and 3 of the spreadsheet calculations explained previously.

Table 1: Average concentration of each carbon fraction (from EPH and VPH data)		
Analytical Method	**Carbon Fraction**	**Average (mg/kg)**
EPH	AL: 8-10	38.5
EPH	AL: 10-12	282.5
EPH	AL: 12-16	936.3
EPH	AL: 16-21	551.4
EPH	AL: 21-34	85.1
EPH	AR: 8-10	2.6
EPH	AR: 10-12	58.1
EPH	AR: 12-16	318.2
EPH	AR: 16-21	514.1
EPH	AR: 21-34	109.5
VPH	AL: 5-6	5.5
VPH	AL: 6-8	29.5
VPH	AL: 10-12	31.9
VPH	AL: 10-12	64.6
VPH	AR: 8-10	93.6
VPH	AR: 10-12	266.8
VPH	AR: 12-13	220.6

Table 2: Higher average concentration for each carbon fraction	
Carbon Fraction	**Average (mg/kg)**
AR: 8-10	93.6
AR: 10-12	266.8
AR: 12-16	318.2
AR: 16-21	514.1
AR: 21-34	109.5
AL: 5-6	5.5
AL: 6-8	29.5
AL: 8-10	38.5
AL: 10-12	282.5
AL: 12-16	936.3
AL: 16-21	551.4
AL: 21-34	85.1

Table 3: Average concentration for each group	
Group	**Average (mg/kg)**
GRO Aromatics (C8-C10)	93.6
DRO Aromatics (C10-C21)	1,099.1
RRO Aromatics (C21-C34)	109.5
GRO Aliphatics (C5-C10)	73.5
DRO Aliphatics (C10-C21)	1,770.2
RRO Aliphatics (C21-C34)	85.1

Step 4 requires calculation of the mass fraction of each carbon fraction within its group. For example, to calculate the mass fraction of the $C_{12} – C_{16}$ aromatic carbon fraction, we divide the

average concentration of $C_{12} - C_{16}$ aromatics by the average concentration of DRO ($C_{10} - C_{21}$) aromatics, as follows:

$$\frac{\dfrac{318.2\,\text{mg}\,C_{12} - C_{16}\,\text{aromatics}}{1\,\text{kg sample}}}{\dfrac{1099.1\,\text{mg DRO aromatics}}{1\,\text{kg sample}}} = 0.2895\,\frac{\text{mg}\,C_{12} - C_{16}\,\text{aromatics}}{\text{mg DRO aromatics}}$$

Table 4 summarizes these values, which are inputs for the HRC. Note that GRO aromatics, RRO aromatics and RRO aliphatics each contain only one carbon fraction and thus no mass fraction calculations are required for these groups.

The final step is calculation of the fraction aromatic of GRO, DRO and RRO using the values in Table 3. To calculate the fraction aromatic of RRO, divide the average concentration of RRO aromatics by the sum of the average concentrations of RRO aromatics and RRO aliphatics, as follows:

$$\frac{\dfrac{109.5\,\text{mg RRO aromatics}}{1\,\text{kg sample}}}{\dfrac{109.5\,\text{mg RRO aromatics}}{1\,\text{kg sample}} + \dfrac{85.1\,\text{mg RRO aliphatics}}{1\,\text{kg sample}}} = 0.563\,\frac{\text{mg RRO aromatics}}{\text{mg RRO}}$$

The fraction aromatic calculations are summarized in Table 5. These three values are required by the HRC.

Table 4: Mass fractions by group		
	Carbon Fraction	**Mass Fraction**
DRO aromatics	Aromatic C_{10}-C_{12}	0.243
	Aromatic C_{12}-C_{16}	0.290
	Aromatic C_{16}-C_{21}	0.468
GRO aliphatics	Aliphatic C_5-C_6	0.075
	Aliphatic C_6-C_8	0.401
	Aliphatic C_8-C_{10}	0.524
DRO aliphatics	Aliphatic C_{10}-C_{12}	0.160
	Aliphatic C_{12}-C_{16}	0.529
	Aliphatic C_{16}-C_{21}	0.311

Table 5: Aromatic fraction by group	
Group	**Aromatic fraction**
GRO	0.560
DRO	0.383
RRO	0.563