



**New Jersey Department of Environmental Protection  
Site Remediation Program**

**PROTOCOL FOR ADDRESSING EXTRACTABLE PETROLEUM HYDROCARBONS  
(Version 3.0, January 14, 2010)**

**DISCLAIMER**

This New Jersey Department of Environmental Protection (Department) guidance is written based upon the method "*Analysis of Extractable Petroleum Hydrocarbon Compounds (EPH) in Aqueous and Soil/Sediment/Sludge Matrices*" (NJDEP EPH 10/08 Revision 2) being certified by the Department for general use. The specific date for the certification is November 10, 2009.

The Department will allow a phase-in period of six months for the use of this guidance.

- The time frames and options outlined in the two tables below are contingent upon a remedial action workplan (RAWP) or remedial action report (RAR) that has been approved by the Department or filed by a Licensed Site Remediation Professional (LSRP) with the Department for the remediation of either (a) Number 2 (No. 2) fuel oil and/or diesel fuel oil contamination or (b) contamination from all non-volatile petroleum hydrocarbon mixtures other than No. 2 fuel oil and/or diesel fuel oil (including but not limited to Number 4 fuel oil, Number 6 fuel oil, hydraulic oil, cutting oil, waste oil).
- If remediation is conducted and a RAWP or RAR has not been approved by the Department or filed by the LSRP, or if the Department issues a Notice Of Violation (NOV) for an approved/filed document, then the person responsible for conducting the remediation must use the analytical method, remediation criterion, contingency analyses, and remediation standards applicable at the time the work is performed.

**PHASE-IN TIME FRAME FOR NUMBER 2 FUEL OIL and DIESEL FUEL OIL**

Time Frame	Analytical Method for PHC	TPHC/EPH Criterion	Contingency Analyses	Contingency Sample Remediation Standards
September 30, 2007 through September 16, 2008	USEPA SW846 Method 8015B or NJDEP OQA-QAM-025	10,000 mg/kg	Analyze highest 25% of soil samples that exceed 1,000 mg/kg TPHC for VO+10	Soil Cleanup Criteria (SCC)
September 17, 2008 through March 17, 2009	USEPA SW846 Method 8015B or NJDEP OQA-QAM-025 rev. 7	10,000 mg/kg or 5,100 mg/kg	Analyze highest 25% of soil samples that exceed 1,000 mg/kg TPHC for either VO+10 or BN+15	Either SCC or Soil Remediation Standards (SRS)
March 18, 2009 through May 9, 2010	USEPA SW846 Method 8015B/C* or NJDEP OQA-QAM-025 rev. 7*	5,100 mg/kg	Analyze highest 25% of soil samples that exceed 1,000 mg/kg EPH for 2-methylnaphthalene and naphthalene	SRS
On or after May 10, 2010	"Analysis of Extractable Petroleum Hydrocarbon Compounds (EPH) in Aqueous and Soil/Sediment/Sludge Matrices" (aka NJDEP EPH 10/08 Revision 2)	5,100 mg/kg (residential) or 54,000 mg/kg (non-residential)	Analyze highest 25% of soil samples that exceed 1,000 mg/kg EPH for 2-methylnaphthalene and naphthalene	SRS

\* The person responsible for conducting the remediation may choose to use the "Analysis of Extractable Petroleum Hydrocarbon Compounds (EPH) in Aqueous and Soil/Sediment/Sludge Matrices" (aka NJDEP EPH 10/08 Revision 2) prior to May 10, 2010, provided that a New Jersey certified laboratory performs the analyses.

**PHASE-IN TIME FRAME FOR NON-VOLATILE PETROLEUM HYDROCARBON MIXTURES OTHER THAN NUMBER 2 FUEL OIL and DIESEL FUEL OIL**

Time Frame	Analytical Method for PHC	TPHC/EPH Criterion	Contingency Analyses	Contingency Sample Remediation Standards
September 30, 2007 through September 16, 2008	NJDEP OQA-QAM-025	10,000 mg/kg	Pursuant to Technical Requirements for Site Remediation (TRSR), Table 2-1	SCC
September 17, 2008 through March 17, 2009	NJDEP OQA-QAM-025 rev. 7	10,000 mg/kg	Pursuant to TRSR, Table 2-1	Either SCC or SRS
March 18, 2009 through May 9, 2010	NJDEP OQA-QAM-025 rev. 7*	10,000 mg/kg*	Pursuant to TRSR, Table 2-1	SRS
On or after May 10, 2010	"Analysis of Extractable Petroleum Hydrocarbon Compounds (EPH) in Aqueous and Soil/Sediment/Sludge Matrices" (aka NJDEP EPH 10/08 Revision 2)	Sample-specific criterion using EPH Calculator	Pursuant to TRSR, Table 2-1	SRS

\* The person responsible for conducting the remediation may choose to use the "Analysis of Extractable Petroleum Hydrocarbon Compounds (EPH) in Aqueous and Soil/Sediment/Sludge Matrices" (aka NJDEP EPH 10/08 Revision 2) prior to May 10, 2010, provided that a New Jersey certified laboratory performs the analyses. Note that if this method is used to analyze the soil samples for mixtures other than No. 2 fuel oil/diesel fuel oil, then the EPH Calculator must be used to determine the sample-specific EPH soil remediation criterion.

## INTRODUCTION

This New Jersey Department of Environmental Protection (Department) guidance document will provide direction on how to address petroleum hydrocarbon mixture discharges except for those that originate from the more volatile petroleum hydrocarbon mixtures (i.e., gasoline, kerosene, jet fuel, and mineral spirits). Volatile petroleum hydrocarbon mixtures are to be investigated pursuant to the Technical Requirements for Site Remediation (TRSR). Analytical requirements remain as defined pursuant to Table 2-1 (<http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>). Historically, the Department has used a value of 10,000 mg/kg, which was based on the field capacity to remediate total petroleum hydrocarbon discharges. The Department is mandated by N.J.S.A. 58:10B-12 to employ a health-based approach when developing remediation standards. This guidance document provides a health-based approach to accomplish the remediation of petroleum hydrocarbon mixtures.

It should be noted that this guidance document does not preclude compliance with any other Site Remediation Program policies, including the sheen policy (<http://www.nj.gov/dep/srp/guidance/sheen/>). In addition, the person responsible for conducting the remediation shall also comply with the TRSR including, but not limited to, the requirements to remove and/or treat free and/or residual product (N.J.A.C. 7:26E-6.1(d), <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>). Furthermore, the Department is establishing an ecological screening value of 1,700 mg/kg (established at "Updates to Petroleum Hydrocarbon (PHC) Guidance"; [http://www.nj.gov/dep/srp/guidance/rs/phc\\_update.htm](http://www.nj.gov/dep/srp/guidance/rs/phc_update.htm)) that is applicable to all petroleum hydrocarbon discharges if and only if a sensitive environmental resource is potentially impacted by petroleum hydrocarbon contamination as determined by a baseline ecological evaluation (N.J.A.C. 7:26E-3.11). In these situations, an ecological risk assessment shall be conducted pursuant to N.J.A.C. 7:26E-4.7 in order to establish a site-specific ecological criterion. Note that pursuant to the TRSR, a baseline ecological evaluation is not required at an area of concern that consists of an underground storage tank storing heating oil for on-site consumption in a one to four family residential building (N.J.A.C. 7:26E-3.11(a); <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>).

## PROTOCOL

The initial task in the protocol is to determine the current and historical petroleum hydrocarbon mixtures stored and potentially discharged at the area of concern being investigated, and based on this information, to determine the appropriate Category of discharge being investigated. As noted above, this guidance document does not apply to the more volatile organic compound mixtures:

**Category 1** consists of discharges of only Number 2 (No. 2) fuel oil and/or diesel fuel.

**Category 2** consists of discharges of petroleum hydrocarbon mixtures other than No. 2 fuel oil and/or diesel fuel (i.e., Number 4 fuel oil, Number 6 fuel oil, hydraulic oils, cutting oils, crude oil, lubricating oil, waste oil, waste vehicular crankcase oil, and waste mineral oil).

For those situations where multiple petroleum hydrocarbon mixtures are involved, the evaluation must address all the types known to be present. For those situations where the product type is unknown, sampling and analytical parameters for waste oil shall be applied.

The method "*Analysis of extractable petroleum hydrocarbon (EPH) compounds in non-aqueous and aqueous matrices*" (NJDEP EPH 10/08 Revision 2) will be used as the principal evaluation tool when investigating areas of concern involving both Category 1 and Category 2 discharges. The results of this method will be termed extractable petroleum hydrocarbons (EPH).

The second task in the protocol is to determine the human health based EPH remedial goal. For sites with residential exposure scenarios where a Category 1 discharge has occurred, the EPH human health value has already been calculated to be 5,100 mg EPH/kg (see "Frequently Asked Questions for Petroleum Hydrocarbons," Question #9 for a discussion on the derivation of 5,100 mg/kg; [http://www.nj.gov/dep/srp/guidance/rs/eph\\_faq.htm](http://www.nj.gov/dep/srp/guidance/rs/eph_faq.htm)). In order to perform this calculation, the Department

conducted a field study to determine a typical chemical composition for No. 2 fuel oil. Using this average composition, appropriate toxicity information, and current USEPA risk assessment equations, the health-based criterion was developed. For Category 1 discharges at sites with non-residential exposure scenarios, the EPH human health value has already been calculated to be 54,000 mg EPH/kg (see "Frequently Asked Questions for Petroleum Hydrocarbons," Question #9 for a discussion on the derivation of 54,000 mg/kg; [http://www.nj.gov/dep/srp/guidance/rs/eph\\_faq.htm](http://www.nj.gov/dep/srp/guidance/rs/eph_faq.htm)). The person responsible for conducting the remediation shall apply the 54,000 mg EPH/kg criterion as part of the EPH Protocol.

The Department has made a policy determination that compliance for Category 1 discharges will use these fixed EPH values, rather than calculated sample-specific values. This decision was reached after consultation with the Department units directly involved with the use and implementation of these criteria.

The user should be aware that the Department will continue to evaluate this policy in the future. For Category 2 discharges at sites with both residential and non-residential exposure scenarios, the calculation of the EPH human health value will be accomplished using the spreadsheet provided by the Department at [http://www.nj.gov/dep/srp/guidance/srra/EPHCalculator\\_v1.0.xls](http://www.nj.gov/dep/srp/guidance/srra/EPHCalculator_v1.0.xls). Step by step guidance for the completion of the process will be provided for each of these Category/Exposure Scenario situations following the descriptions of the tasks in the protocol.

The third task in the protocol is to address any contingency analysis requirements. For Category 1 discharges, analytical requirements for all contingency samples are restricted to only 2-methylnaphthalene and naphthalene. For No. 2 fuel and/or diesel this contingency testing is required if the post-remediation EPH concentrations to remain at the site exceed 1,000 mg EPH/kg. Based on the results of the field study, it was determined that 2-methylnaphthalene and naphthalene, as well as other contaminants, were not of regulatory concern when EPH concentrations were below 1,000 mg/kg. For Category 2 discharges, analytical requirements pursuant to the TRSR, Table 2-1 ("Analytical Requirements for Petroleum Storage and Discharge Areas," <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>) apply. This completes the EPH and/or compound specific human health value evaluations.

The final task in the protocol is to evaluate the calculated human health based value against the residual product/free product value; comply with the sheen policy; and apply the ecological values (if appropriate). The final remedial goal will be the applicable value or action that addresses all of the concerns just noted, whether the value or action is EPH based or otherwise.

A tabular summary of the protocol is provided as Appendix 1. The user shall be aware that deviations from this protocol require Department approval. The Department will consider technical impracticability as a basis for not completing the remediation pursuant to this protocol.

**CATEGORY 1 - Discharges of only Number 2 (No. 2) fuel oil or diesel fuel for a residential exposure scenario**

The following assumes that for a Category 1 discharge an unrestricted use is the endpoint of the remedial activities at a residential site.

STEP 1. Evaluate all EPH sample results relative to the 5,100 mg EPH/kg soil remediation standard:

- A. All EPH sample results are less than or equal to 5,100 mg EPH/kg. **Remediation is complete for EPH. Go to Step 2 to determine whether contingency analyses are required. If remediation is not complete, then go to Step 1.B.**
- B. One or more EPH sample results are greater than 5,100 mg EPH/kg. **Conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 1.A. Alternatively, consider conditional remediation closure** (i.e., implementation of institutional and engineering controls) as well as address any other relevant rules, policies, and /or requirements. **Go to Step 2 to determine whether contingency analyses required.**

STEP 2. Evaluate all EPH sample results relative to 1,000 mg EPH/kg contingency analysis trigger:

- A. All EPH sample results are less than or equal to 1,000 mg EPH/kg. **Remediation is complete for 2-methylnaphthalene and naphthalene. Go to Step 7. If remediation is not complete, then go to Step 2.B.**
- B. If one or more EPH sample results are greater than 1,000 mg EPH/kg, then contingency analyses for 2-methylnaphthalene and naphthalene are required. **Go to Step 3.**

STEP 3. Determine the number of contingency samples:

# Samples >1,000 mg EPH/kg	# Contingency Samples
1-4	1
5-8	2
9-12	3

Pursuant to the Technical Requirements for Site Remediation, Table 2-1 ("Analytical Requirements for Petroleum Storage and Discharge Areas," <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>), contingency samples shall be those with the greatest EPH concentration(s).

**Go to Step 4.**

STEP 4. Evaluate whether any measured 2-methylnaphthalene concentration exceeds the impact to ground water exposure pathway screening level of 5 mg/kg or any measured naphthalene concentration exceeds the inhalation exposure pathway residential direct contact criterion of 6 mg/kg.

- A. If there are no exceedances for both 2-methylnaphthalene and naphthalene for all contingency samples, then **remediation is complete for 2-methylnaphthalene and naphthalene. Go to Step 7. If remediation is not complete, then go to Step 4.B.**
- B. If there is an exceedance for 2-methylnaphthalene for any contingency sample, then **go to Step 5.** If there is an exceedance for naphthalene for any contingency sample, then **go to Step 6.** If there is an exceedance for both 2-methylnaphthalene and naphthalene for any contingency sample, then **go to both Step 5 and Step 6.**

STEP 5. Options for 2-methylnaphthalene contingency sample exceedances:

- A. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 1,000 mg EPH/kg. **Remediation is complete for 2-methylnaphthalene. Go to Step 7. If remediation is not complete or Step 5.A is not implemented, then go to Step 5.B.**
- B. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 5 mg 2-methylnaphthalene/kg. **Remediation is complete for 2-methylnaphthalene and go to Step 7. If remediation is not complete or Step 5.B is not implemented, then go to Step 5.C.**
- C. Conduct the Synthetic Precipitation Leachate Procedure (SPLP) as outlined below.

**NOTE:** The Class II ground water 2-methylnaphthalene leachate criterion (LC) equals 390 micrograms per liter (ug/L), calculated as follows:

Ground water quality standard (GWQS) = 30 ug/L  
Dilution attenuation factor (DAF) = 13

$LC = GWQS \times DAF = 30 \times 13 = 390 \text{ ug/L}$

**NOTE:** The following protocol departs from the protocol found in "Guidance for the Use of the Synthetic Precipitation Leaching Procedure to Develop Site-Specific Impact to Ground Water Remediation Standards"

([http://www.nj.gov/dep/srp/guidance/rs/splp\\_guidance.pdf](http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf)) and is applicable only under the circumstances specified here.

- i. If one or two of the contingency samples analyzed exceed 5 mg 2-methylnaphthalene/kg, then conduct SPLP analysis on those samples.
  - a. All sample leachate concentrations are less than or equal to 390 ug/L. **Remediation is complete for 2-methylnaphthalene. Go to Step 7. If remediation is not complete, then go to Step 5.C.i.b.**
  - b. For samples with leachate concentrations greater than 390 ug/L, **conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 5.A, 5.B, or 5.C**, as well as address any other relevant rules, policies, and /or requirements. **Alternatively, other options for addressing impacts to ground water from 2-methylnaphthalene are available** at [http://www.nj.gov/dep/srp/guidance/rs/igw\\_intro.htm](http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm). **Perform remediation as required and then go to Step 7.**
- ii. If three or more of the contingency samples analyzed exceed 5 mg 2-methylnaphthalene/kg, then conduct SPLP analysis pursuant to "Guidance for the Use of the Synthetic Precipitation Leaching Procedure to Develop Site-Specific Impact to Ground Water Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_guidance.pdf](http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf)). Evaluate data using the Department "SPLP Spreadsheet" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_spreadsheet.xls](http://www.nj.gov/dep/srp/guidance/rs/splp_spreadsheet.xls)).
  - a. All 2-methylnaphthalene concentrations are below the greatest remediation standard determined by the SPLP Spreadsheet. **Remediation is complete for 2-methylnaphthalene. Go to Step 7. If remediation is not complete, then go to Step 5.C.ii.b.**

- b. If any 2-methylnaphthalene concentration exceeds greatest remediation standard determined by the SPLP Spreadsheet, then **conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 5.A, 5.B, or 5.C**, as well as address any other relevant rules, policies, and /or requirements. **Alternatively, other options for addressing impacts to ground water from 2-methylnaphthalene are available at [http://www.nj.gov/dep/srp/guidance/rs/igw\\_intro.htm](http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm). Perform remediation as required and then go to Step 7.**

STEP 6. Options for naphthalene exceedances:

- A. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 1,000 mg EPH/kg. **Remediation is complete for naphthalene. Go to Step 7. If remediation is not complete or Step 6.A is not implemented, then go to Step 6.B.**
- B. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 6 mg naphthalene/kg. **Remediation is complete for naphthalene. Go to Step 7. If remediation is not complete or Step 6.B is not implemented, then go to Step 6.C.**
- C. Perform compliance averaging using "Guidance Document for Implementing the Inhalation Exposure Pathway Soil Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/compl\\_ars\\_inhalation.pdf](http://www.nj.gov/dep/srp/guidance/rs/compl_ars_inhalation.pdf)) and appropriate analytical data.
  - i. Actual analytical data for naphthalene must be used. These may include naphthalene results from samples with less than 1,000 mg EPH/kg if sample selection is consistent with the TRSR (N.J.A.C. 7:26E; <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>) and the "Guidance Document for Implementing the Inhalation Exposure Pathway Soil Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/compl\\_ars\\_inhalation.pdf](http://www.nj.gov/dep/srp/guidance/rs/compl_ars_inhalation.pdf)).
  - ii. Compliance requirements satisfied: **Remediation is complete for naphthalene. Go to Step 7. If remediation is not complete, then go to Step 6.C.iii.**
  - iii. Failure to achieve compliance: **Conduct additional soil remediation (excavate/treat contaminated soil ) and return to Step 6.A, Step 6.B, or Step 6.C. Alternatively, consider conditional remediation closure** (i.e., implementation of institutional and engineering controls) as well as address any other relevant rules, policies, and /or requirements and then **go to Step 7.**

STEP 7. Determine whether any measured EPH concentration is greater than the residual product/free product limit. EPH cannot exceed the residual product/free product limit of 8,000 mg EPH/kg for No. 2 fuel and/or diesel fuel (see Appendix 2 for a discussion of the derivation of the residual product/free product concentration).

- A. All measured EPH concentrations are less than 5,100 mg/kg and therefore are also less than 8,000 mg EPH/kg. **Remediation is complete for residual product/free product. Go to Step 8. If remediation is not complete, then go to Step 7.B.**
- B. If any measured EPH concentration is greater than 8,000 mg EPH/kg, then additional remediation is required for EPH to achieve the 8,000 mg EPH/kg residual product/free product limit. Following additional remediation, **go to Step 8.** Note that both an institutional control (i.e., Deed Notice) and engineering control(s) must be established for all areas exceeding 5,100 mg EPH/kg.



- STEP 8. If applicable, evaluate for the presence of sheen pursuant to the Department policy (<http://www.nj.gov/dep/srp/guidance/sheen/>). If not applicable, then **go to Step 9.**
- A. Sheen that needs to be addressed pursuant to the sheen policy is not present. Therefore, there is no need to remediate sheen, **go to Step 9. Otherwise, go to Step 8.B.**
  - B. Sheen is present that needs to be addressed pursuant to the sheen policy. Take the necessary corrective actions. **Go to Step 9.**

STEP 9. Evaluate for ecological concern:

- A. There are no EPH values exceeding 1,700 mg EPH/kg (see "Frequently Asked Questions for Petroleum Hydrocarbons," Question #11 for derivation; [http://www.nj.gov/dep/srp/guidance/rs/eph\\_faq.htm](http://www.nj.gov/dep/srp/guidance/rs/eph_faq.htm)). **The entire remediation is complete. If remediation is not complete, then go to Step 9.B.**
- B. Determine whether a Baseline Ecological Evaluation (BEE) is appropriate. A BEE is appropriate at all areas of concern excluding those that consist of an underground storage tank storing heating oil for on-site consumption in a one to four family residential building (TRSR, N.J.A.C. 7:26E-3.11(a)). If a BEE is not appropriate, then **the entire remediation is complete. If remediation is not complete, then go to Step 9.C.**
- C. A BEE is appropriate:
  - i. If there is no contaminant of concern or no potential pathway or no sensitive ecological resource present based on the BEE, then **the entire remediation is complete. If remediation is not complete, then go to Step 9.C.ii.**
  - ii. If the BEE finds that a potential contaminant of concern has a potential pathway to a sensitive ecological resource, then take the necessary actions and address the ecological concern. **The entire remediation is complete.**
    - Note that if the EPH concentration does not exceed 1,700 mg/kg measured at the sensitive ecological resource, the ecological remediation is considered complete.
    - Be advised that the maximum ecological remediation goal has been set at 4,000 mg EPH/kg measured at the sensitive ecological resource. This value applies only to the terrestrial environment. For other environments (e.g., benthic), the TRSR are to be followed to determine the appropriate remediation.

**CATEGORY 1 - Discharges of only Number 2 (No. 2) fuel oil or diesel fuel for a non-residential exposure scenario**

The following assumes that for a Category 1 discharge that a non-residential use is the endpoint of the remedial activities at the non-residential site. This will require an institutional control (i.e., Deed Notice) if any contaminant concentrations remaining at the site exceed their respective residential exposure scenario soil remediation standards.

STEP 1. Determine EPH compliance by following the steps below:

- A. Use the EPH analytical method to determine the EPH concentration for each sample. **Then go to Step 1.B.**
- B. Use 54,000 mg EPH/kg as the EPH compliance value. **Go to Step 1.C.**
- C. All EPH sample results are less than or equal to 54,000 mg EPH/kg. **Remediation is complete for EPH. Go to Step 2 to determine whether contingency analyses are required. If remediation is not complete, then go to Step 1.D.**
- D. One or more EPH sample results are greater than 54,000 mg EPH/kg. **Conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 1.A. If no additional soil remediation is conducted, then go to Step 1.E. The user is cautioned that the residual product/free product evaluation in Step 7 will require remediation for all areas above 8,000 mg EPH/kg.**
- E. **Alternatively, consider conditional remediation closure** (i.e., implementation of institutional and engineering controls) as well as address any other relevant rules, policies, and /or requirements. **Go to Step 2 to determine whether contingency analyses required.**

STEP 2. Evaluate all EPH sample results relative to 1,000 mg EPH/kg contingency analysis trigger:

- A. All EPH sample results are less than or equal to 1,000 mg EPH/kg **Remediation is complete for 2-methylnaphthalene and naphthalene. Go to Step 7. If remediation is not complete, then go to Step 2.B.**
- B. If one or more EPH sample results are greater than 1,000 mg EPH/kg, then contingency analyses for 2-methylnaphthalene and naphthalene are required. **Go to Step 3.**

STEP 3. Determine the number of contingency samples:

# Samples >1,000 mg EPH/kg	# Contingency Samples
1-4	1
5-8	2
9-12	3

Pursuant to the Technical Requirements for Site Remediation, Table 2-1 ("Analytical Requirements for Petroleum Storage and Discharge Areas," <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>), contingency samples shall be those with the greatest EPH concentration(s).

**Go to Step 4.**

STEP 4. Evaluate whether any measured 2-methylnaphthalene concentration exceeds the impact to ground water exposure pathway screening level of 5 mg/kg or any measured naphthalene

concentration exceeds the impact to ground water exposure pathway screening level of 16 mg/kg.

- A. If there are no exceedances for both 2-methylnaphthalene and naphthalene for all contingency samples, **then remediation is complete for 2-methylnaphthalene and naphthalene. Go to Step 7. If remediation is not complete, then go to Step 4.B.**
- B. If there is an exceedance for 2-methylnaphthalene for any contingency sample, then **go to Step 5.** If there is an exceedance for naphthalene for any contingency sample, then **go to Step 6.** If there is an exceedance for both 2-methylnaphthalene and naphthalene for any contingency sample, then **go to both Step 5 and Step 6.**

STEP 5. Options for 2-methylnaphthalene contingency sample exceedances:

- A. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 1,000 mg EPH/kg. **Remediation is complete for 2-methylnaphthalene. Go to Step 7. If remediation is not complete or Step 5.A is not implemented, then go to Step 5.B.**
- B. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 5 mg 2-methylnaphthalene/kg. **Remediation is complete for 2-methylnaphthalene and go to Step 7. If remediation is not complete or Step 5.B is not implemented, then go to Step 5.C.**
- C. Conduct the Synthetic Precipitation Leachate Procedure (SPLP) as outlined below.

**NOTE:** The Class II ground water 2-methylnaphthalene leachate criterion (LC) equals 390 micrograms per liter (ug/L), as follows:

Ground water quality standard (GWQS) = 30 ug/L  
Dilution attenuation factor (DAF) = 13

$LC = GWQS \times DAF = 30 \times 13 = 390 \text{ ug/L}$

**NOTE:** The following protocol departs from the protocol found in "Guidance for the Use of the Synthetic Precipitation Leaching Procedure to Develop Site-Specific Impact to Ground Water Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_guidance.pdf](http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf)) and is applicable only under the circumstances specified here.

- i. If one or two of the contingency samples analyzed exceed 5 mg 2-methylnaphthalene/kg, then conduct SPLP analysis on those samples.
  - a. All sample leachate concentrations are less than or equal to 390 ug/L. **Remediation is complete for 2-methylnaphthalene. Go to Step 7. If remediation is not complete, then go to Step 5.C.i.b.**
  - b. For samples with leachate concentrations greater than 390 ug/L, **conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 5.A, 5.B, or 5.C,** as well as address any other relevant rules, policies, and /or requirements. **Alternatively, other options for addressing impacts to ground water from 2-methylnaphthalene are available at [http://www.nj.gov/dep/srp/guidance/rs/igw\\_intro.htm](http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm). Perform remediation as required and then go to Step 7.**
- ii. If three or more of the contingency samples analyzed exceed 5 mg 2-methylnaphthalene/kg, then conduct SPLP analysis pursuant to "Guidance for the

Use of the Synthetic Precipitation Leaching Procedure to Develop Site-Specific Impact to Ground Water Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_guidance.pdf](http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf)). Evaluate data using the Department "SPLP Spreadsheet" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_spreadsheet.xls](http://www.nj.gov/dep/srp/guidance/rs/splp_spreadsheet.xls)).

- a. All 2-methylnaphthalene concentrations are below greatest remediation standard determined by the SPLP Spreadsheet. **Remediation is complete for 2-methylnaphthalene. Go to Step 7. If remediation is not complete, then go to Step 5.C.ii.b.**
- b. If any 2-methylnaphthalene concentration exceeds greatest remediation standard determined by the SPLP Spreadsheet, then **conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 5.A, 5.B, or 5.C**, as well as address any other relevant rules, policies, and/or requirements. **Alternatively, other options for addressing impacts to ground water from 2-methylnaphthalene are available at [http://www.nj.gov/dep/srp/guidance/rs/igw\\_intro.htm](http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm). Perform remediation as required and then go to Step 7.**

STEP 6. Options for naphthalene exceedances:

- A. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 1,000 mg EPH/kg. **Remediation is complete for naphthalene. Go to Step 7. If remediation is not complete or Step 6.A is not implemented, then go to Step 6.B.**
- B. Excavate/treat contaminated soils until they are confirmed to be less than or equal to 16 mg naphthalene/kg (impact to ground water exposure pathway screening level). **Remediation is complete for naphthalene. Go to Step 7. If remediation is not complete or Step 6.B is not implemented, then go to Step 6.C.**
- C. Conduct the Synthetic Precipitation Leachate Procedure (SPLP) as outlined below.

**NOTE:** The Class II ground water naphthalene leachate criterion (LC) equals 3,900 micrograms per liter (ug/L), calculated as follows:

Ground water quality standard (GWQS) = 300 ug/L  
Dilution attenuation factor (DAF) = 13

$$LC = GWQS \times DAF = 300 \times 13 = 3,900 \text{ ug/L}$$

**NOTE:** The following protocol departs from the protocol found in "Guidance for the Use of the Synthetic Precipitation Leaching Procedure to Develop Site-Specific Impact to Ground Water Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_guidance.pdf](http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf)) and is applicable only under the circumstances specified here.

- i. If one or two of the contingency samples analyzed exceed 16 mg naphthalene/kg, then conduct SPLP analysis on those samples.
  - a. All sample leachate concentrations are less than or equal to 3,900 ug/L. **Remediation is complete for naphthalene. Go to Step 6.D. If remediation is not complete, then go to Step 6.C.i.b.**
  - b. For samples with leachate concentrations greater than 3,900 ug/L, **conduct additional soil remediation (excavate/treat contaminated soil) and return to**

**Step 6.A, 6.B, or 6.C**, as well as address any other relevant rules, policies, and /or requirements. **Alternatively, other options for addressing impacts to ground water from naphthalene are available** at [http://www.nj.gov/dep/srp/guidance/rs/igw\\_intro.htm](http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm). **Perform remediation as required and then go to Step 7.**

- ii. If three or more of the contingency samples analyzed exceed 16 mg naphthalene/kg, then conduct SPLP analysis pursuant to "Guidance for the Use of the Synthetic Precipitation Leaching Procedure to Develop Site-Specific Impact to Ground Water Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_guidance.pdf](http://www.nj.gov/dep/srp/guidance/rs/splp_guidance.pdf)). Evaluate data using the Department "SPLP Spreadsheet" ([http://www.nj.gov/dep/srp/guidance/rs/splp\\_spreadsheet.xls](http://www.nj.gov/dep/srp/guidance/rs/splp_spreadsheet.xls)).
  - a. All naphthalene concentrations are below the greatest remediation standard determined by the SPLP Spreadsheet. **Remediation is complete for naphthalene. Go to Step 6.D. If remediation is not complete, then go to Step 6.C.ii.b.**
  - b. If any naphthalene concentration exceeds greatest remediation standard determined by the SPLP Spreadsheet, then **conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 6.A, 6.B, or 6.C**, as well as address any other relevant rules, policies, and /or requirements. **Alternatively, other options for addressing impacts to ground water from naphthalene are available** at [http://www.nj.gov/dep/srp/guidance/rs/igw\\_intro.htm](http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm). **Perform remediation as required. If all remaining naphthalene concentrations are less than or equal to 17 mg/kg, then go to Step 7. Otherwise go to Step 6.D.**
- D. If naphthalene concentrations exceed 17 mg/kg, then perform compliance averaging using "Guidance Document for Implementing the Inhalation Exposure Pathway Soil Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/compl\\_ars\\_inhalation.pdf](http://www.nj.gov/dep/srp/guidance/rs/compl_ars_inhalation.pdf)) and appropriate analytical data.
  - i. Actual analytical data for naphthalene must be used. These may include naphthalene results from samples with less than 1,000 mg EPH/kg if sample selection is consistent with the TRSR (N.J.A.C. 7:26E; <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>) and the "Guidance Document for Implementing the Inhalation Exposure Pathway Soil Remediation Standards" ([http://www.nj.gov/dep/srp/guidance/rs/compl\\_ars\\_inhalation.pdf](http://www.nj.gov/dep/srp/guidance/rs/compl_ars_inhalation.pdf)).
  - ii. Compliance requirements satisfied: **Remediation is complete for naphthalene. Go to Step 7. If remediation is not complete, then go to Step 6.D.iii.**
  - iii. Failure to achieve compliance: **Conduct additional soil remediation (excavate/treat contaminated soil ) and return to Step 6.A, Step 6.B, or Step 6.D. Alternatively, consider conditional remediation closure** (i.e., implementation of institutional and engineering controls) as well as address any other relevant rules, policies, and /or requirements and then **go to Step 7.**

STEP 7. Determine whether any measured EPH concentration is greater than the residual product/free product limit. EPH cannot exceed the residual product/free product limit of 8,000 mg EPH/kg for No. 2 fuel and/or diesel fuel (see Appendix 2 for a discussion of the derivation of the residual product/free product concentration).

- A. All measured EPH concentrations are less than the 54,000 mg EPH/kg remediation criterion and are also less than 8,000 mg EPH/kg. **Remediation is complete for residual product/free product. Go to Step 8. If remediation is not complete, then go to Step 7.B.** Note that at a minimum, an institutional control (i.e., Deed Notice) must be established for all areas exceeding 5,100 mg EPH/kg.
- B. If any measured EPH concentration is less than the 54,000 mg EPH/kg remediation criterion but is greater than 8,000 mg EPH/kg, then additional remediation is required for EPH to achieve the 8,000 mg EPH/kg residual product/free product limit. Following additional remediation, **go to Step 8.** Note that at a minimum, an institutional control (i.e., Deed Notice) must be established for all areas exceeding 5,100 mg EPH/kg.

STEP 8. If applicable, evaluate for the presence of sheen pursuant to the Department policy (<http://www.nj.gov/dep/srp/guidance/sheen/>). If not applicable, then **go to Step 9.**

- A. Sheen that needs to be addressed pursuant to the sheen policy is not present. Therefore, there is no need to remediate sheen, **go to Step 9. Otherwise, go to Step 8.B.**
- B. Sheen is present that needs to be addressed pursuant to the sheen policy. Take the necessary corrective actions. **Go to Step 9.**

STEP 9. Evaluate for ecological concern:

- A. There are no EPH values exceeding 1,700 mg EPH/kg (see "Frequently Asked Questions for Petroleum Hydrocarbons," Question #11 for derivation; [http://www.nj.gov/dep/srp/guidance/rs/eph\\_faq.htm](http://www.nj.gov/dep/srp/guidance/rs/eph_faq.htm)). **The entire remediation is complete. If remediation is not complete, go to then Step 9.B.**
- B. A BEE is appropriate:
  - i. If there is no contaminant of concern or no potential pathway or no sensitive ecological resource present based on the BEE, then **the entire remediation is complete. If remediation is not complete, then go to Step 9.B.ii.**
  - ii. If the BEE finds that a potential contaminant of concern has a potential pathway to a sensitive ecological resource, then take the necessary actions and address the ecological concern. **The entire remediation is complete.**
    - Note that if the EPH concentration does not exceed 1,700 mg/kg measured at the sensitive ecological resource, the ecological remediation is considered complete.
    - Be advised that the maximum ecological remediation goal has been set at 4,000 mg EPH/kg measured at the sensitive ecological resource. This value applies only to the terrestrial environment. For other environments (e.g., benthic), the TRSR are to be followed to determine the appropriate remediation.

**CATEGORY 2 - Discharges of petroleum hydrocarbon mixtures other than No. 2 fuel oil and/or diesel fuel, including: Number 4 and 6 Fuel Oils, Hydraulic Oils, Cutting Oils, Crude Oil, Lubricating Oil, Waste Oil, Waste Vehicular Crankcase Oil, and Waste Mineral Oil for both the residential and non-residential exposure scenarios**

The following assumes that for a Category 2 discharge an unrestricted use is the endpoint of the remedial activities at sites where the residential exposure scenario applies. For sites where the non-residential exposure scenario applies, non-residential use is assumed to be the goal. The use of a non-residential exposure scenario based value will require an institutional control (i.e., deed notice) to ensure the protectiveness of this value. This assumes contaminant concentrations remaining at the site will exceed their respective most stringent direct contact soil remediation standards. The calculated EPH human health value will be different depending on the exposure scenario (residential or non-residential) inputted into the provided spreadsheet calculator. The remaining Steps are the same for both exposure scenarios.

STEP 1. Determine EPH compliance by following the steps below:

- A. Use the EPH analytical method to determine the EPH concentration for each sample .  
**Then go to Step 1.B.**
- B. Use the Department provided spreadsheet to calculate the sample-specific, human health-based EPH Soil Remediation Criterion (EPH SRC) for each sample, taking into account the applicable exposure scenario (i.e., residential or non-residential). **Then go to Step 1.C.**
- C. Each EPH sample result is less than or equal to its associated calculated EPH SRC.
  - i. If the residential exposure scenario applies, then the **remediation is complete for EPH. Go to Step 2 to determine whether contingency analyses are required. If remediation is not complete, then go to Step 1.D.**
  - ii. If the non-residential exposure scenario applies, then the **remediation is complete for EPH, but an institutional control is required if the residential EPH SRC is exceeded. Go to Step 2 to determine whether contingency analyses are required. If remediation is not complete, then go to Step 1.D.**
- D. One or more EPH sample results are greater than its associated calculated EPH SRC. **Conduct additional soil remediation (excavate/treat contaminated soil) and return to Step 1.A. If no additional soil remediation is conducted, then go to Step 1.E.**
- E. **Alternatively, consider conditional remediation closure** (i.e., implementation of institutional and engineering controls) as well as address any other relevant rules, policies, and /or requirements. **Go to Step 2 to determine whether contingency analyses required.**

STEP 2. Determine contingency analysis requirements by addressing the following:

Required additional analyses depend upon the petroleum hydrocarbon mixture discharged. These requirements are detailed in the TRSR, Table 2-1 ("Analytical Requirements for Petroleum Storage and Discharge Areas," <http://www.nj.gov/dep/srp/regs/techrule/techrule.pdf>). Address all additional analyses that apply.

The user should always consult the most up-to-date version of the TRSR to ensure that the correct contingency analyses are performed.

**Go to Step 3.**

- STEP 3. Perform the required contingency analysis. **If a remedial action is required, perform it, or consider conditional remediation closure** (i.e., implementation of institutional and engineering controls [excluding impact to ground water and free/residual product issues]) as well as address any other relevant rules, policies, and/or requirements. **Go to Step 4.**
- STEP 4. Address all impact to ground water concerns for the identified contaminants related to the discharge as per the guidance provided at [http://www.nj.gov/dep/srp/guidance/rs/igw\\_intro.htm](http://www.nj.gov/dep/srp/guidance/rs/igw_intro.htm) (**note:** exceptions to the SPLP analytical protocol for Category 1 discharges are not to be used for Category 2 discharges). **Go to Step 5.**
- STEP 5. Determine whether any measured EPH concentration is greater than the residual product/free product limit. EPH cannot exceed the residual product/free product limit of 17,000 mg EPH/kg for petroleum hydrocarbon mixtures heavier than No. 2 fuel oil and diesel (see Appendix 2 for a discussion of the derivation of the residual product/free product concentration).
- A. All measured EPH concentrations are less than the calculated EPH SRC and are also less than 17,000 mg EPH/kg. **Remediation is complete for residual product/free product. Go to Step 6. If remediation is not complete, then go to Step 5.B.** Note that if the non-residential exposure scenario applies, at a minimum, an institutional control (i.e., Deed Notice) must be established for all areas exceeding the residential EPH SRC.
  - B. If any measured EPH concentration is less than its calculated EPH SRC but is greater than 17,000 mg EPH/kg, then additional remediation is required for EPH to achieve 17,000 mg EPH/kg residual product/free product limit. Following additional remediation, **Go to Step 6.** Note that if the non-residential exposure scenario applies, at a minimum, an institutional control (i.e., Deed Notice) must be established for all areas exceeding the residential EPH SRC.
- STEP 6. If applicable, evaluate for the presence of sheen pursuant to the Department policy (<http://www.nj.gov/dep/srp/guidance/sheen/>). If not applicable, then **go to Step 7.**
- A. Sheen that needs to be addressed pursuant to the sheen policy is not present. Therefore, there is no need to remediate sheen, **go to Step 7. Otherwise, go to Step 6.B.**
  - B. Sheen is present that needs to be addressed pursuant to the sheen policy. Take the necessary corrective actions. **Go to Step 7.**
- STEP 7. Evaluate for ecological concern:
- A. There are no EPH values exceeding 1,700 mg EPH/kg (see "Frequently Asked Questions for Petroleum Hydrocarbons," Question #11 for derivation; [http://www.nj.gov/dep/srp/guidance/rs/eph\\_faq.htm](http://www.nj.gov/dep/srp/guidance/rs/eph_faq.htm)). **The entire remediation is complete. If remediation is not complete, then go to Step 7.B.**
  - B. A BEE is appropriate:
    - i. If there is no contaminant of concern or no potential pathway or no sensitive ecological resource present based on the BEE, then **the entire remediation is complete. If remediation is not complete, then go to Step 7.B.ii.**



- ii. If the BEE finds that a potential contaminant of concern has a potential pathway to a sensitive ecological resource, then take the necessary actions and address the ecological concern. **The entire remediation is complete.**
- Note that if the EPH concentration does not exceed 1,700 mg/kg measured at the sensitive ecological resource, the ecological remediation is considered complete.
  - Be advised that the maximum ecological remediation goal has been set at 4,000 mg EPH/kg measured at the sensitive ecological resource. This value applies only to the terrestrial environment. For other environments (e.g., benthic), the TRSR are to be followed to determine the appropriate remediation

**APPENDIX 1**

EPH Protocol Summary

Type	Category 1		Category 2	
	Residential	Non-residential	Residential	Non-residential
<b>Exposure scenario</b>	Residential	Non-residential	Residential	Non-residential
<b>EPH Soil Remediation Criterion</b>	5,100 mg/kg	54,000 mg/kg	Calculated	Calculated
<b>EPH Trigger Concentration for Contingency Analyses</b>	1,000 mg/kg	1,000 mg/kg	Pursuant to Technical Requirements for Site Remediation (TRSR), Table 2-1	Pursuant to TRSR, Table 2-1
<b>Contingency Analyses (if required)</b>	2-methylnaphthalene and naphthalene	2-methylnaphthalene and naphthalene	Pursuant to TRSR, Table 2-1	Pursuant to TRSR, Table 2-1
<b>EPH Product Determination</b>	8,000 mg/kg or greater	8,000 mg/kg or greater	17,000 mg/kg or greater	17,000 mg/kg or greater
<b>Sheen Evaluation</b>	Pursuant to Department "Sheen Remediation Policy Initiative" ( <a href="http://www.nj.gov/dep/srp/guidance/sheen/">http://www.nj.gov/dep/srp/guidance/sheen/</a> )	Pursuant to Department Policy	Pursuant to Department Policy	Pursuant to Department Policy
<b>Ecological Screening Criterion*</b>	1,700 mg/kg	1,700 mg/kg	1,700 mg/kg	1,700 mg/kg

\* Ecological evaluation not required at most homeowner sites or where there is no significant ecological receptor

## APPENDIX 2

Residual saturation values for No. 2 fuel oil, diesel, and heavier TPH products

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Health-based screening levels for No. 2 fuel oil, diesel fuel, other fuel oils, and lubricating oils may be very high under certain conditions (e.g., non-residential scenarios). For this reason, it is necessary to develop maximum allowed concentrations for total petroleum hydrocarbons in soil to protect against other undesired effects of these contaminants when present at high levels. The presence of nonaqueous phase liquid (NAPL) when the soil saturation limit ( $C_{sat}$ ) is exceeded is one parameter that has been used as an upper limit on individual contaminant concentrations in soil (USEPA, 1996; New Jersey Soil Remediation Standards: New Jersey Administrative Code 7:26D, accessed 2009). However, for petroleum products, this concentration has been calculated to be quite low, and far below health-based screening levels. For example, a  $C_{sat}$  concentration of 18 mg/kg has been estimated for diesel, compared to the NJDEP residential health-based concentration of 5,100 mg/kg (Brost and DeVaul, 2000). Thus, the  $C_{sat}$  concentration is not a useful parameter to use as an upper limit concentration for petroleum hydrocarbon products. A more practical parameter, the residual saturation point, has been defined as the concentration below which NAPL becomes discontinuous and is immobilized by capillary forces within the soil (Mercer and Cohen, 1990). This is analogous to the field capacity parameter for soil moisture. Above this concentration, NAPL may become mobile and be subject to downward drainage due to the effects of gravity. The fraction of the NAPL above the residual saturation point has been termed "free product," or "flowable product," and is generally not allowed by the NJDEP to remain in soil after remedial action is taken. The residual saturation concentration is therefore suitable as an upper limit for petroleum product concentrations in soil when the health-based screening criterion is very high. This parameter has also been utilized by Washington State [Washington Administrative Code 173-340-747, accessed 2009], Ohio [Ohio Administrative Code C 3745-300-09, accessed 2009] and Alaska (Alaska Statement of Cooperation Working Group, 2006).

The American Petroleum Institute recently reviewed available measurements of residual saturation points of various petroleum fuels as a function of soil type (Brost and DeVaul, 2000). This review includes the work of Cohen and Mercer (1990), Fussell et al. (1981), Hoag and Marley (1986), API (1980), and others. The residual saturation point is dependent on contaminant properties (especially viscosity) and upon soil properties (particularly soil texture). Low viscosity fuels, such as gasoline, have lower residual saturation points, while higher viscosity fuels, such as No. 2 heating oil, have higher values. Residual fuels, such as No. 6 fuel oil, are high viscosity products and may have residual saturation points many times higher than gasoline. Finer soil textures (such as silt) exhibit higher residual saturation points than coarser textures (such as sand).

The compiled data from Brost and DeVaul indicate that residual saturation concentrations for "middle distillates" (i.e., No. 2 fuel oil and diesel) ranged from 2,300-23,000 mg/kg as soil texture ranged from coarse gravel to silt (data from Fussell et al.). API (1980) reports a value for residual saturation diesel in "soil" as 34,000 (moisture content unknown). Sand was selected by the NJDEP as a reasonably conservative soil texture for determination of a default upper limit concentration for No. 2 fuel oil and diesel based on the residual saturation point. The results of Fussell et al. indicate that the residual saturation point for "medium sand" ranged from of 8,000-13,000 mg/kg. The soil moisture in these measurements was approximately 0.04 (v/v), which is in between median values for the wilt point (~0.02) and the field capacity (~0.06) for subsurface sand (Carsel et al., 1988). Since infiltrating petroleum would

likely displace some of the soil moisture being held at field capacity, this soil moisture content was felt to be appropriate.

As is discussed in Brost and DeVaul, the residual saturation concentrations from the study of Fussell et al. tend to be lower than those from other studies. This is illustrated by comparing the range of residual saturation points of gasoline in medium sand by Fussell et al. (3,000-6,000 mg/kg), with a range of 20,000-44,000 mg/kg reported for medium sand under similar moisture contents (Hoag and Marley, 1986). Thus, the residual saturation points of Fussell et al. appear to be conservative relative to other studies. Based on this assessment, Brost and DeVaul recommend a residual saturation concentration of 8,000 mg/kg for medium sand soil and middle distillates (i.e., diesel and No. 2 fuel oil). The NJDEP concurs that this value appears reasonable as a generic concentration to use as an upper limit for these fuel types in order to prevent the occurrence of mobile free product.

Using a similar analysis for "fuel oils" (i.e., fuel oils heavier than diesel and No. 2 fuel oil), the compiled data from Brost and DeVaul indicate that residual saturation concentrations for heavier fuel oil ranged from 5,000-51,000 mg/kg as soil texture ranged from coarse gravel to silt (data from Fussell et al.). API (1980) reports a value for residual saturation fuel oil and lubricating oil in "soil" as 53,000 (moisture content unknown). Again, looking at the results for medium sand from Fussell et al., where soil moistures were judged to be appropriate, the residual saturation point was estimated to be in the range of 17,000-30,000 mg/kg, and the recommended value for residual saturation for fuel oils heavier than diesel is 17,000 mg/kg. The NJDEP concurs with this assessment.

Data for lubricating oils other than mineral oil, as reported in Brost and DeVaul, is scarce. Furthermore, many of the reported results either do not include soil moisture contents or were inappropriately run on dry soil. For this reason, Brost and DeVaul do not recommend a residual saturation concentration for lubricating oils. However, review of the Brost and DeVaul report yields residual saturation values for mineral oil in glacial till and alluvium with water contents of 0.02 and 0.03, respectively. The reported residual saturation values are 11,000-19,000 mg/kg for glacial till and 61,000 mg/kg for alluvium. Both of these materials may vary widely in soil texture, but glacial till is more likely to be similar to sandy soils than alluvial material. Given that the residual saturation value selected for heavier fuel oils lies within the range reported for mineral oil in glacial till, it is judged by the NJDEP that the value of 17,000 mg/kg used for heavier fuel oil is also adequately protective for lubricating oils.

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