

# **DEPARTMENT OF ENVIRONMENTAL CONSERVATION**

## **DIVISION OF SPILL PREVENTION AND RESPONSE CONTAMINATED SITES REMEDIATION PROGRAM**



### **GUIDANCE FOR CLEANUP OF PETROLEUM CONTAMINATED SITES**



## Table of Contents

INTRODUCTION .....	5
Spill Reporting .....	5
Hazardous Waste .....	6
Buried Heating Oil Tanks .....	6
SITE CHARACTERIZATION.....	7
Site Characterization Work Plan.....	7
Site Characterization Report .....	8
FREE PRODUCT .....	9
SOIL SAMPLING .....	11
Site characterization samples.....	11
Confirmation Sampling.....	12
Field Screening .....	12
Laboratory samples.....	13
Excavations.....	13
Stockpiles.....	14
SOIL STORAGE AND DISPOSAL .....	15
SOIL CLEANUP LEVELS .....	15
<i>Method one</i> .....	16
Table A1 – Cleanup Levels in Non-arctic Zones.....	16
Table A2 - Arctic Zone .....	20
<i>Method two</i> .....	21
Table B1 - Petroleum Related Chemicals.....	21
Table B2 - Petroleum Hydrocarbons .....	26
Maximum Allowable Concentrations.....	27
Fuel Additives.....	27
<i>Method three</i> .....	27
<i>Method four</i> .....	28
<i>Biogenic Interference</i> .....	28
GROUNDWATER SAMPLING.....	29
GROUNDWATER CLEANUP LEVELS .....	31
Groundwater-Surface Water Interaction.....	32
Long-term Monitoring .....	33
LABORATORY ANALYSIS .....	34
Soil and Groundwater Analysis .....	34
Surface water .....	41
CLEANUP ALTERNATIVES .....	41
Soil Treatment Technologies .....	41
<i>Oversized Material</i> .....	41
<i>Asphalt recycling</i> .....	42
<i>Bioremediation</i> .....	42
Cell bioremediation.....	42
In-situ bioremediation.....	42
Landfarming.....	43

Landspreading.....	43
<i>Soil Washing</i> .....	43
<i>Solidification and fixation</i> .....	43
<i>Thermal desorption</i> .....	44
<i>Vapor extraction systems</i> .....	44
In-situ vapor extraction .....	44
Prepared cell vapor extraction .....	45
Groundwater Technologies .....	45
<i>Air sparging</i> .....	45
<i>Groundwater pump and treat</i> .....	45
<i>Monitored Natural Attenuation</i> .....	46
REFERENCES .....	48
APPENDIX A: Background information about method two .....	51
Indicators.....	51
Surrogates .....	51
Physical and Chemical Properties of Petroleum Hydrocarbon Fractions.....	54
Total GRO, DRO, RRO versus Aromatic/Aliphatic fractions.....	57
Maximum Allowable Concentrations .....	58

## TABLES

TABLE 1: NUMBER OF SAMPLES TO VERIFY CLEANUP OF EXCAVATED SOIL	14
TABLE 2: BTEX CLEANUP LEVELS FROM TABLE B1 OF 18 AAC 75.341(C)	16
TABLE 3: SOIL CLEANUP LEVELS FOR PETROLEUM-RELATED CHEMICALS	22
TABLE 4: GROUNDWATER CLEANUP LEVELS FOR PETROLEUM-RELATED COMPOUNDS	32
TABLE 5: INDICATOR CONTAMINANTS FOR PETROLEUM CONTAMINATED SITES	51
TABLE 6: PETROLEUM HYDROCARBON TOXICITY AND SURROGATE FRACTIONS	53
TABLE 7: CHEMICAL SPECIFIC PARAMETERS FOR PETROLEUM HYDROCARBONS	54
TABLE 8: PETROLEUM HYDROCARBON DEFAULT COMPOSITIONS	57

## INTRODUCTION

On August 27, 2000, the Alaska Department of Environmental Conservation (DEC) amended regulations at 18 AAC 75, Article 3, entitled *Oil and Hazardous Substances Pollution Control Regulations, Discharge Reporting, Cleanup, and Disposal of Oil and Other Hazardous Substances*. The regulations establish site cleanup rules to protect human health, safety, and welfare and the environment. This guidance applies to petroleum-contaminated sites regulated under 18 AAC 75.325 through 18 AAC 75.390, the Site Cleanup Rules. This guidance does not apply to releases from underground storage tanks subject to 18 AAC 78 or to oil and gas reserve pits or permitted solid waste storage or disposal facilities regulated under 18 AAC 60, 18 AAC 62, or 42 U.S.C. 6901-6992k.

The purpose of this guidance is to provide technical information to help characterize and clean up petroleum-contaminated sites. The guidance is intended to help environmental consultants and project managers who conduct or oversee site investigations and cleanups of petroleum product spills. The 18 AAC 75 regulations and this guidance replace the following three obsolete DEC guidance documents:

- *Interim Guidance for Non-UST Contaminated Cleanup Levels*, dated July 17, 1991;
- *Guidance for Storage, Remediation, and Disposal of Non-UST Petroleum Contaminated Soils*, dated July 29, 1991; and
- *Petroleum Cleanup Guidance, Public Review Draft*, dated December 1996.

### Spill Reporting

"Oil" means petroleum products of any kind and in any form, whether crude, refined, or a petroleum by-product, including petroleum, fuel oil, gasoline, lubricating oils, oily sludge, oily refuse, oil mixed with other wastes, liquefied natural gas, propane, butane, and other liquid hydrocarbons regardless of specific gravity.

Notification requirements to report spills and discharges of oil and other hazardous substances are described at 18 AAC 75.300. Spills of oil to water, or spills of greater than 55 gallons of oil to land (outside of an impermeable secondary containment area), shall be immediately reported to DEC. Spills to land greater than 10 gallons but less than 55 gallons (or spills into an impermeable secondary containment area) shall be reported within 48 hours after knowledge of the spill. A person in charge of a facility or operation shall maintain, and provide to DEC monthly, a written record each discharge or release, including a cumulative discharge or release, of one gallon to 10 gallons of oil solely to land.

To report a spill during normal business hours, contact the nearest DEC Area Response Team office at one of the following numbers:

- Central Alaska Response Team: Anchorage, 269-3063; Fax 269-7648
- Northern Alaska Response Team: Fairbanks, 451-2121; Fax 451-2362
- Southeast Alaska Response Team: Juneau, 465-5340; Fax 465-2237

Outside normal business hours, call 1-800-478-9300.

### Hazardous Waste

This guidance does not address Resource Conservation Recovery Act (RCRA) hazardous wastes. Under federal law, hazardous wastes include solid waste (such as contaminated soil or debris) if it has a listed substance or exhibits any of the characteristics identified in 40 CFR Part 261. Federal requirements for handling or disposing listed or characteristic RCRA hazardous wastes are not addressed in this guidance. In Alaska, the U. S. Environmental Protection Agency (EPA) administers the RCRA hazardous waste program. For information regarding hazardous waste, phone the Alaska Hazardous Waste Information line at 1-800-550-7272, or contact the U.S. EPA Alaska Operations Office at 222 W. 7<sup>th</sup> Avenue in Anchorage at phone number (907) 271-5083.

### Buried Heating Oil Tanks

DEC does not require removal of residential heating oil tanks if they are not suspected to cause a release of contaminants to the environment. However, any spill to the environment, including spills due to overfilling or leaking tanks or pipes, should be reported to the nearest DEC Area Response Team office. The investigation and cleanup of heating oil tank spills shall be managed under 18 AAC 75.

Any of the following signs can indicate that a spill has occurred:

- unusually high fuel consumption;
- holes or cracks in the tank or piping;
- pooled oil, sheen on puddles or in nearby surface water;
- fuel odors or stained soil;
- dead or absent vegetation;
- contaminated groundwater (may be detected by taste or odor); or
- a complaint is made or a report is filed about a spill.

If a heating oil tank is emptied and removed from the ground, soil sampling is necessary if the area appears to be contaminated. After tank removal, use field screening to identify potentially contaminated soil below and at each end of the tank pit and at areas near the fill pipe and supply lines. Laboratory samples are not necessary if there is no indication of soil or groundwater contamination based on field screening results combined with any odor or visual indicators and known spill history.

If contamination is suspected, it should be reported to the appropriate DEC office. Samples for laboratory analysis should be collected from areas with the highest potential contamination levels. Analytical methods to use depend on the type of product stored in the tank. Refer to Table 6 in the Laboratory Analysis section of this guidance for a listing of analytical methods based on the type of product released to the environment.

## SITE CHARACTERIZATION

Under state law, “oil” is considered a hazardous substance as provided in statute at AS 46.03.826. “Contaminated” soil or groundwater as defined at 18 AAC 75.990 has a concentration of a hazardous substance that exceeds the applicable cleanup level determined under the site cleanup rules (18 AAC 75.325). A “site” is an area that is contaminated and includes areas contaminated by the migration of hazardous substances, regardless of property ownership.

The goal of the site characterization is to determine the source and extent of contaminated media and to identify potential impacts to human health and the environment. The data collected should help determine the need for cleanup, establish appropriate cleanup levels, and evaluate cleanup alternatives.

Before site characterization work begins in the field, regulations require submittal of a site characterization workplan for department approval (18 AAC 75.335). Follow occupational safety requirements and guidelines during any sampling, excavation, well installation, or other field activities. Make sure utility locates have been performed and that property boundaries are known. Beware of overhead electric lines or other potential hazards in the area.

As an alternative to the conventional state oversight approach to site cleanup, DEC has recently developed a streamlined Voluntary Cleanup Program to address lower priority sites contaminated with petroleum and/or inorganic compounds. To participate, an applicant needs to submit a Notice of Intent form, which DEC reviews to determine if the site meets eligibility criteria. For more information, refer to the *Handbook for Conducting Cleanups of Contaminated Sites And Regulated Underground Storage Tanks under the Voluntary Cleanup Program* (ADEC, 2000a).

### Site Characterization Work Plan

The purpose of the work plan is to describe the procedures proposed to find the source and define the extent of contamination at a particular site. The complexity of the site will influence the extent of detail required in the work plan. DEC reviews the work plan and, if necessary, provides comments on the plan. After comments are adequately addressed and issues resolved, DEC approves the work plan before the start of the site characterization fieldwork.

A qualified person, as defined at 18 AAC 75.990 should prepare the work plan. A qualified person means a person who actively practices environmental science or engineering, geology, physical science, hydrology, or a related field and who has a bachelor’s degree or equivalent from a nationally or internationally accredited post-secondary institution in one of those fields. The qualified person should have at least one year of professional experience after obtaining the degree in environmental science or engineering, geology, physical science, hydrology, or a related field.

Site characterization objectives for a petroleum-contaminated site are to:

- verify that a discharge or release of oil has occurred;
- locate sources of known site contamination, including a description of potential releases into soil, sediment, groundwater or surface water;
- identify site conditions that could result in ongoing site contamination, including the potential for contaminant leaching and the presence of leaking barrels, drums, tanks, or other containers;
- evaluate the potential threat to human health, safety, and welfare, and to the environment from the site contamination;
- identify any needed interim removal action;
- identify the concentration and extent of contamination of each hazardous substance at the site
- evaluate the size of the contaminated area, including the concentrations and extent of any soil, sediment, groundwater, or surface water contamination;
- identify the soil type and determine if the soil is a continuing source for groundwater contamination;
- identify the vertical depth to groundwater and the horizontal distance to nearby wells, surface water, and water supply intakes; and
- evaluate the potential for surface water runoff from the site and the potential for surface water or sediment contamination.

Several geophysical techniques can be employed to help find source areas or to focus sampling efforts. But geophysical techniques alone are generally not sufficient to fully characterize a contaminated site. Soil sampling and oftentimes groundwater sampling and sometimes surface water and sediment sampling may be necessary to evaluate the size, concentrations, and extent of a contaminated area. Samples should be collected by a qualified, impartial third party. DEC may waive the requirement for use of an impartial third party if a qualified, objective person performs the work.

Some common geophysical site characterization techniques include ground penetrating radar, electromagnetic conductivity, metal detection, seismic refraction, soil gas monitoring, and direct push technologies. A more in-depth discussion of these and other techniques can be found at (EPA, 1997a).

#### Site Characterization Report

The site characterization report documents the findings after the site is characterized in the field. The report describes the extent of contamination and evaluates different cleanup strategies for the site. The report should contain the following elements:

- description of the activities performed;
- description of and rationale for any deviations with the approved workplan;
- analytical results of sampling summarized in tabular form;
- description of the horizontal and vertical extent of the contamination;
- proposed cleanup levels and related information used to calculate the proposed level;
- evaluation of existing cleanup technologies and the proposed specific cleanup strategy;

- A site map that depicts known or potential release areas (such as tanks, piping or drums), sampling locations, test-pits, wells, surface water bodies, and other pertinent site information;
- Soil types, boring logs, well construction drawings, groundwater table maps (with groundwater elevations correlated to a standard datum, such as mean sea level); and
- Field-notes, chain of custody forms, copies of laboratory analysis data reports, photographs, sketches, or other pertinent site information gathered during the site characterization activities.

## **FREE PRODUCT**

The regulations at 18 AAC 75.990 define free product as a concentration of petroleum that is present as a nonaqueous phase liquid, which is a liquid that is not dissolved in water. Differences in the physical and chemical properties of water and free petroleum product prevent the two fluids from mixing. “Nonaqueous phase liquid” (NAPLs) are generally divided into two groups based on the density of the product. In the subsurface, NAPLs that are less dense than water are called “light nonaqueous phase liquids” or LNAPLs. NAPLs that are more dense than water are referred to as “dense nonaqueous phase liquids” or DNAPLs.

For petroleum hydrocarbons, the term nonaqueous phase liquid includes both liquid phase and residual phase hydrocarbons. Liquid phase product can usually flow into wells or excavations. Residual phase product does not generally flow as a liquid because it occurs as globules or discrete liquid blobs lodged within fractures or pores of soil or bedrock (EPA, 1996b). In the subsurface, mobile free product tends to move downward through the vadose zone due to gravity and capillary forces. As underlying soil becomes saturated with released petroleum, the front edge of the liquid migrates deeper and leaves behind the residual, less mobile hydrocarbons. The soil type and composition can greatly influence the retention capacity of the soil. Fine-grained soil with high organic matter levels will generally retain more residual hydrocarbons than coarse-grained soil with low organic matter levels.

After a petroleum release, the bulk of the hydrocarbon mass occurs either in the liquid or the residual phase; both are considered secondary contaminant sources. In comparison to liquid and residual hydrocarbons, a relatively small percentage of the petroleum hydrocarbon mass dissolves into the aqueous phase or adsorbs to soil particles. Therefore, site cleanup actions should focus first on reducing the mass of free product and residual phase hydrocarbons wherever it is practicable to do so.

The regulations require that free product be recovered to the maximum extent practicable. The term “practicable” is defined at 18 AAC 75.990 and means capable of being designed, constructed, and implemented in a reliable and cost-effective manner, taking into consideration existing technology, site location, and logistics. When considering cost, an alternative is not considered practicable if the incremental cost of the alternative is substantial and disproportionate to the incremental degree of protection when compared to a lower cost alternative.

To assess the need to recover free product, evaluate site data to determine the horizontal and

vertical extent of the free product. Test pits, soil borings and monitoring wells can be used to determine the thickness of free product at various points near the source location. However, without sufficient accumulation of free product on the water table, a free product recovery system is ineffective. The best place to recover free product is typically located where the free product thickness is greatest.

It is important to recognize that free product recovery is generally an initial step, not a final step to site cleanup. Free product recovery is a short-term step to limit impacts to soil, groundwater, and other resources. Long-term site cleanup may involve one or more cleanup techniques to treat, contain, or reduce exposure to vapor, aqueous, and residual phases of hydrocarbons at the site.

Removal of vadose zone soil or shallow smear zone soil for subsequent aboveground treatment and disposal is a common cleanup strategy at many petroleum-contaminated sites. It can be particularly effective for dealing with residual phase hydrocarbons if the contaminated soil is accessible and shallow (less than twenty feet deep). It is important to consider how to treat the soil after excavation rather than to stockpile soil without a plan for treatment and disposal. Factors to consider include transportation costs, emissions of volatile constituents, location of structures and nearby water bodies, and leachate management.

Four methods of free product recovery are generally employed:

- Skimming systems
- Water table depression
- Vapor extraction/groundwater extraction
- Dual phase (liquid and vapor) recovery

Each method involves the installation of recovery equipment such as skimmers, pumps, filters, absorbent materials, etc. Phase separation, storage and treatment processes are other aspects of each product recovery method.

Skimming systems are often used during emergency or interim removal actions to recover free product (without groundwater) from wells or trenches. Product volume recovered may be relatively small due to limited areas of influence within wells or open trenches.

Recovery with water table depression involves removing free product and groundwater from wells or trenches by pumping groundwater to create a cone of water table depression. This technique can be used at sites with deep water tables, but requires moderately permeable soils. It generally takes more than one year to complete the cleanup action and groundwater treatment can be expensive.

Vapor extraction/groundwater extraction involves applying vacuum to well(s) above the water table to remove vapor phase and residual hydrocarbons. Flowing product and/or groundwater is recovered from a different set of wells using pumps. It can operate in low to moderately permeable soils and is often used to increase the mass of hydrocarbons recovered.

Dual phase recovery can recover both liquids and vapors from the same well with minimized groundwater production. It can operate in low permeability soils and requires a surface seal to prevent short-circuiting of vacuum.

Recovery trenches and drain systems are used to recover mobile LNAPL at shallow depths (usually less than 20 feet). Trenches are usually excavated perpendicular to groundwater flow direction immediately downgradient or within suspected areas with mobile LNAPL. For containment, the trench length should be at least as long as the width of the suspected mobile product plume and the trench should be several feet deeper than the lowest expected seasonal water table elevation. Trenches should not penetrate a low permeability strata if present, thus allowing further downward migration of the product. Low permeability barriers can be installed on the downgradient side of the trench to slow the mobile product while allowing water to flow through. Skimmer pumps can be used in open trenches or trenches can be converted to drains by backfilling with gravel and installing sumps to collect LNAPL.

Recovery wells can be designed to remove mobile LNAPL only, LNAPL and water separately, or both LNAPL and water mixed. Well screens should intercept the air/LNAPL interface and be long enough to accommodate water level changes due to pumping or seasonal variations. Although recovery systems can reduce product thickness to less than 0.1 inches, cost effective recovery of mobile product from recovery wells generally requires a measurable product thickness accumulation of at least one inch (EPA, 1996b).

## SOIL SAMPLING

The collection and analysis of soil samples is necessary to characterize the extent of contamination at a site or to verify that a site meets the applicable cleanup requirements. For petroleum-related contamination, collect representative samples at the site as **discrete grab samples** in accordance with an approved plan. Collect samples with clean, decontaminated sampling equipment.

### Site characterization samples

Collect discrete grab samples for laboratory analysis at locations with the highest potential concentrations of petroleum hydrocarbons indicated by field screening, visual or other evidence such as odors. Collect samples from obviously stained areas and at or near known or suspected points of release, such as leaking pipe joints, sumps, or damaged storage containers.

For soil borings, use a hollow stem auger and split spoon sampler or Shelby tube to collect samples. When using an auger, advance the drill hole to the desired depth; then withdraw the center rods of the auger from the drill hole and remove the plug and pilot bit from the center rods. Attach the sampling device to the correct length of drill rod and drive it ahead of the auger flights to collect a relatively undisturbed sample. After retrieving the split spoon or Shelby tube back out of the boring, immediately remove the desired sample section from the sampling device and use only soil from the middle portion of the spoon; discard soil from the ends of the spoon as they often contain disturbed soils. Use a clean sampling tool to quickly collect the sample from

the undisturbed portion with a minimum of disturbance. Quickly cap, seal, and label the sample container.

Remove a minimum of six inches of soil from freshly uncovered soil before sample collection. If the excavation has been open for longer than one hour, remove at least 18 inches of soil immediately before sample collection. If sampling excavation equipment buckets, remove at least six inches of soil immediately before collection and collect the sample from the center of the bucket, away from the bucket sides.

#### Confirmation Sampling

Confirmation sampling is conducted during cleanup operations to verify that approved cleanup levels are met. The locations of confirmation samples should be specified in a sampling and analysis plan. Sampling and analysis should be conducted or supervised by a qualified, impartial third party unless DEC waives this requirement. Confirm that treated excavated soil meets cleanup requirements by collecting verification samples from the location and depth of areas where field screening indicates the highest levels of contamination. If confirmation samples indicate that cleanup levels were not met, additional cleanup work or sampling may be required.

#### Field Screening

Field screening involves use of portable devices capable of detecting petroleum contaminants on a real-time basis or by a rapid field analytical technique. Many field-screening instruments and techniques are available for detecting petroleum contaminants in the field on a rapid or real-time basis. Common techniques include headspace volatile detection, infrared spectrophotometry, turbidimetric immunoassay, and colorimetric immunoassay. Although these methods do not generally correlate well quantitatively with laboratory analytical results, they can be used to approximate areas with hydrocarbon contamination and to provide semi-quantitative estimates of the contaminated soil area or volume.

Use field screening to help assess locations where contamination is suspected, such as near piping joints or valves, visibly stained areas, areas with hydrocarbon odors, near leaking drums, or within excavation pit bottoms and side walls. To assess piping runs, collect field screening samples at areas of suspected or obvious contamination, at low points, below piping joints, elbows, connections, and damaged piping components, and adjacent to and below sumps or fuel dispensers. Determine sample locations for laboratory analysis based on field screening results, but do not use field screening in place of laboratory analysis of samples.

Use the following headspace analytical screening procedure to obtain and analyze field-screening samples with photoionization detectors (PIDs) and flame ionization detectors (FIDs):

1. Calibrate PID and FID field instruments properly before collecting samples;
2. Partially fill (one-third to one-half) a clean jar or clean ziplock bag with the sample to be analyzed. Total capacity of the jar or bag may not be less than eight ounces (approximately 250 ml), but the container should not be so large as to allow vapor diffusion and stratification effects to significantly affect the sample;
3. If the sample is collected from a split spoon, transfer it to the jar or bag for headspace analysis immediately after opening the split-spoon. If the sample is collected from an

- excavation or soil pile, collect it from freshly uncovered soil;
4. If a jar is used, quickly cover its top with clean aluminum foil or a jar lid and use screw tops or thick rubber bands to tightly seal the jar. If a ziplock bag is used, quickly seal it shut;
  5. Allow headspace vapors to develop in the container for at least 10 minutes but no longer than one hour. Shake or agitate containers for 15 seconds at the beginning and end of the headspace development period to assist volatilization. Warm the headspace to at least 40° F (approximately 5° C). Be sure the instrument is calibrated for the appropriate temperature;
  6. After headspace development, insert the instrument-sampling probe to a point about one-half the headspace depth. Minimize the container opening and carefully avoid uptake of water droplets and soil particles into the probe device;
  7. After probe insertion, take the highest meter reading and record it; normally, this will occur between two and five seconds after probe insertion. If erratic meter response occurs at high organic vapor concentrations or conditions of elevated headspace moisture, record a note to that effect to include with the headspace data;
  8. Record all field-screening results in the field record or logbook.

During excavation activities, use field screening results to segregate soils based on apparent degrees of contamination. Field screen at least one soil sample from each 10 cubic yards of stockpiled soil; obtain samples from various depths in the stockpile, but none less than 18 inches beneath the exposed surface of the pile.

#### Laboratory samples

Minimize sample collection errors by using the following procedures:

- (1) Collect all samples with disposable or clean, decontaminated tools;
- (2) Wear disposable gloves and change them between sample collections;
- (3) Fill sample containers quickly;
- (4) Place soil samples into sample containers in the order of volatility. For example, take volatile organic aromatic samples first, gasoline range organics next, heavier range organics next, and soil classification samples last;
- (5) Seal sample containers quickly and adequately. Clean rims before tightening lids. Use tape only if known not to affect sample analysis;
- (6) Properly label sample containers; and
- (7) Immediately preserve containers according to proper procedures. Unless specified otherwise, at a minimum, cool the samples immediately to  $4 \pm 2^{\circ}\text{C}$  and maintain this temperature throughout delivery to the laboratory until the samples are analyzed.

#### Excavations

Within excavations to remove contaminated soil, collect field-screening samples directly from the excavation or from the excavation equipment's bucket. Use field-screening results to help determine the amount of soil to be removed for treatment. Collect at least one field screening sample from each 10 cubic yards of excavated soil or one representative field-screening sample for every 100 square feet of excavation bottom.

After contaminated soil is removed, collect laboratory samples within the excavated area where contamination is most likely to occur. Collect samples no more than two feet beneath the sump or bottom of the excavation at areas where obviously stained or contaminated soils were removed. If horizontal migration of petroleum contamination was observed or is suspected, obtain an additional laboratory sample from each wall of the excavation where the migration was indicated. If there are two or more distinct areas from which contaminated soils have been removed, then a minimum of two samples should be collected from each of these areas.

To verify that all contaminated soil was removed, establish a sampling grid and collect field screening samples for each 100 square feet (10 feet by 10 feet grid squares) of exposed ground surface. Based on the highest field-screening results, collect at least three laboratory samples for excavations of up to 250 square feet of exposed ground surface area and collect at least one additional laboratory sample for each additional 250 square feet of excavated surface area.

For excavations greater than 2,500 square feet or in areas with shallow groundwater, DEC may allow reductions to the number of samples collected. Field screening should still be combined with a grid sample collection system to ensure that laboratory samples are collected from areas with the highest potential levels of contamination.

For treated excavated soils, use the following table to verify the minimum number of cleanup confirmation grab samples to submit for each laboratory analytical method employed:

**Table 1: Number of Samples to Verify Cleanup of Excavated Soil**

<b>Cubic Yards of Soil</b>	<b>Minimum Number of Samples</b>
0-10 (0-15 tons)	1
11-50 (16-75 tons)	2
51-100 (76-150 tons)	3
101-500 (151-750 tons)	5
501-1000	7
1001-2000	10
More than 2000	10 samples plus + one (1) sample for each additional 500 cubic yards, or as prescribed by DEC

Stockpiles

For untreated stockpiled soils, collect at least two grab samples for laboratory analysis from stockpiles of 50 cubic yards or less, and collect at least one additional sample from each additional 50 cubic yards of soil. Based on field screening results, laboratory samples should represent areas within the stockpile with the highest potential to be contaminated.

## **SOIL STORAGE AND DISPOSAL**

Soil storage and disposal requirements are set out at 18 AAC 75.370. The regulations allow soil to be stockpiled on a liner. The contaminated soil must be 200 feet or more from a water source serving a Class A or Class B public water system and at least 100 feet from surface water, a private water system, or a Class C public water system. At all sites, contaminated soil that is temporarily stockpiled should be treated to meet cleanup levels within two years.

Contaminated soil should not be blended with uncontaminated soil (unless approved by DEC). If the site has multiple sources, segregate the soil into different stockpiles based on source types. Segregate soil based on field screening results and knowledge of historical activities, visual observations, and the type of products spilled. For example, segregate gasoline-contaminated soil from diesel or waste oil-contaminated soil.

The regulations set out bottom liner specifications for stockpiles in Table D of 18 AAC 75.370. For petroleum-contaminated soil, a 10-mil thick liner is required for short-term storage (less than 180 days). For long-term storage (more than 180 days), a 20-mil thick bottom liner is required. Contaminated stockpiles must be covered with a 6-mil or greater thickness of reinforced polyethylene liner. The liner should protect the contaminated stockpile from weather. The edges of the cover liner should lap over the bottom liner to prevent water from running through the soil in the stockpile. Use tires, ropes, or other materials to hold the cover in place. Inspect and maintain the stockpile regularly to ensure the cover and bottom liner material remains intact and that any liquid leachate from the soil is contained and does not migrate.

Prior DEC approval is required for offsite storage or disposal of soil or groundwater subject to the site cleanup rules (18 AAC 75.325(i)). If soil is transported offsite for treatment, it should be moved as a covered load in a manner that prevents loss of material during transport. In some cases, the disposal site may require approval of the DEC Solid Waste Program (18 AAC 60.025).

## **SOIL CLEANUP LEVELS**

The regulations provide four different methods to determine soil cleanup levels at petroleum contaminated sites. Method one involves a table to calculate a matrix score and the cleanup level depends on the matrix score. Method two employs two different tables, one for individual contaminants and one for petroleum hydrocarbon ranges. Method three allows substitution of site-specific data parameters used in the method two equations. Method four involves the development and DEC approval of a site-specific risk assessment.

Early in the site cleanup process, the responsible party should carefully consider each of the four methods for determining the cleanup levels. The different methods have different data requirements and various advantages and disadvantages depending on the cleanup objectives and site-specific conditions.

*Method one*

Method one involves a table to determine the soil cleanup level for three different hydrocarbon ranges: gasoline range organics (GRO), diesel range organics (DRO), and residual range organics (RRO). Two different tables are provided at 18 AAC 75.341. Table A1 applies to non-arctic zones and Table A2 applies to manmade gravel pads in arctic zones. “Arctic zone” is defined at 18 AAC 75.990 and generally means areas north of latitude 68 degrees North. Other areas may be considered “arctic zone” based on a demonstration that the site is underlain by continuous permafrost.

Table A1 – Cleanup Levels in Non-arctic Zones

Table A1 is used to determine soil cleanup levels for GRO, DRO, and RRO. A matrix table is used to tally scores for five parameters: Depth to Groundwater, Mean Annual Precipitation, Soil Type, Potential Receptors, and Volume of Contaminated Soil. Each parameter has four to six possible scores, depending on site conditions. The five individual scores are added together to determine a total matrix score. Table A1 includes several notes to define terms and to assist with determining scores.

The matrix score is used to determine the soil cleanup level for GRO, DRO, and RRO. Based on the total matrix score, the site falls into one of four categories: Category A, Category B, Category C, or Category D. Each category has corresponding cleanup levels for GRO and DRO. The cleanup level for RRO is the same (2,000 mg/kg) for all categories.

For site cleanup under method one, sampling is not required for polynuclear aromatic compounds (PAHs) unless DEC requires a modification or site-specific analysis under 18 AAC 75.340(i). However, in addition to the soil cleanup levels for GRO, DRO, and RRO at Table A1, the site needs to also meet the most stringent levels for benzene, toluene, ethylbenzene, and total xylenes for the applicable exposure pathway as follows:

**Table 2: BTEX cleanup levels from Table B1 of 18 AAC 75.341(c)**

CHEMICAL NAME (Carcinogenics in Bold Type)	Under 40 Inch Zone			Over 40 Inch Zone		
	Ingestion	Inhalation	Migration to Groundwater (mg/kg)	Ingestion	Inhalation	Migration to Groundwater (mg/kg)
<b>Benzene</b>	290	9	0.02	230	6.4	0.02
Ethylbenzene	10000	89	5.5	8300	89	5
Toluene	20300	180	5.4	17000	180	4.8
Xylenes (total)	203000	81	78	166000	81	69

**TABLE A1. METHOD ONE – PETROLEUM HYDROCARBON SOIL CLEANUP LEVELS IN NONARCTIC ZONES**

(See notes to table for further requirements)

**Part A: Determine score for each item\***

<p><b>1. Depth to Groundwater</b></p> <p>Less than 5 feet (10)</p> <p>5 feet to 15 feet (8)</p> <p>More than 15 feet to 25 feet (6)</p> <p>More than 25 feet to 50 feet (4)</p> <p>More than 50 feet (1)</p>	
<p><b>2. Mean Annual Precipitation</b></p> <p>More than 40 inches (10)</p> <p>More than 25 inches to 40 inches (5)</p> <p>15 inches to 25 inches (3)</p> <p>Less than 15 inches (1)</p>	
<p><b>3. Soil Type (Unified Soil Classification)</b></p> <p>Clean, coarse-grained soils (10)</p> <p>Coarse-grained soils with fines (8)</p> <p>Fine-grained soils (low organic carbon) (3)</p> <p>Fine-grained soils (high organic carbon) (1)</p>	
<p><b>4. Potential Receptors</b> (Select the most applicable category)</p> <p>a. Public water system within 1000 feet, or private water system within 500 feet (15)</p> <p>b. Public/private water system within 1/2 mile (12)</p> <p>c. Public/private water system within one mile (8)</p> <p>d. No water system within one mile (4)</p> <p>e. Nonpotable groundwater (1)</p>	
<p><b>5. Volume of Contaminated Soil</b></p> <p>More than 500 cubic yards (10)</p> <p>More than 100 cubic yards to 500 cubic yards (8)</p> <p>More than 25 cubic yards to 100 cubic yards (5)</p> <p>10 cubic yards to 25 cubic yards (2)</p> <p>Less than 10 cubic yards (0)</p>	

\*The items to be scored are defined in note 1 to this table.

**Part B: Add scores from Part A to determine matrix score and cleanup level**

Matrix Score for Each Category	Cleanup Level in mg/kg		
	Gasoline Range Organics	Diesel Range Organics	Residual Range Organics
Category A: More than 40	50	100	2000
Category B: More than 26 to 40	100	200	2000
Category C: 21-26	500	1000	2000
Category D: Less than 21	1000	2000	2000

**Notes to Table A1:**

1. The following definitions for items 1 - 5 in Part A, apply for purposes of using method one:
  - a. "depth to groundwater" means the measurement from the lowest point of the zone of soil contamination to the seasonal high groundwater table; a responsible person may not claim a lower matrix score for soil by moving contaminated soil to a higher elevation relative to the groundwater table;
  - b. "mean annual precipitation" is defined at 18 AAC 75.990 and means the measurement of average yearly rainfall and the water equivalent of snowfall; this measurement may be obtained from the nearest weather station;
  - c. "soil type" means the predominant Unified Soil Classification (USC) soil type between the deepest point of contamination and the seasonal high groundwater table; a responsible person may seek to demonstrate that otherwise coarse-grained soil has an organic carbon content that might enable a lower point classification. Soil types using the USC system are further defined as shown in Figure 1:

**Figure 1.**

<b>SOIL TYPE</b>	<b>UNIFIED SOIL CLASSIFICATIONS</b>
Clean coarse-grained	GW, GP, SW, SP
Coarse-grained with fines	GM, GC, SM, SC, GP-GC, SP-SM, GW-GM, SW-SM, SW-SC
Fine-grained with low organic carbon	ML, CL, HM, CH
Fine-grained with high organic carbon	OL, OH, Pt

- d. for the "potential receptors" categories,
    - (i) "public water system" and "private water system" have the meaning given those terms in 18 AAC 80.1990;
    - (ii) "nonpotable" means unusable for drinking water due to a water quality condition, such as salinity, that was not caused by or that does not arise from contamination at the site;
  - e. "volume of contaminated soil" means the total estimated volume of soil that is contaminated above the applicable cleanup level before a responsible person begins a removal or cleanup action.
2. For the potential receptors categories, a responsible person shall submit a demonstration supporting the score assigned, including the results of an approved water well survey; the most conservative score must be used to determine the proximity of potential receptors; for example, if a water system is within one-quarter mile, the category "public/private water system within one mile" that would score 8 would be superseded by the category "public/private water system within 1/2 mile" that would score 12.

3. The identity of a released refined petroleum product must be assumed to be unknown unless a responsible person demonstrates that the product is only gasoline, or only a refined nongasoline product; the department will waive the requirement that a product be identified by analysis if a responsible person demonstrates that only one type of product was stored or distributed at the site; the soil cleanup levels in Part B are based on gas chromatographic analytical measurements corresponding to a specific measured range of petroleum hydrocarbons as follows:

a. gasoline range organics: light-range petroleum products such as gasoline, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of C<sub>6</sub> to the beginning of C<sub>10</sub> and a boiling point range between approximately 60° Centigrade and 170° Centigrade;

b. diesel range organics: mid-range petroleum products such as diesel fuel, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of C<sub>10</sub> to the beginning of C<sub>25</sub> and a boiling point range between approximately 170° Centigrade and 400° Centigrade;

c. residual range organics: heavy-range petroleum products such as lubricating oils, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of C<sub>25</sub> to the beginning of C<sub>36</sub> and a boiling point range between approximately 400° Centigrade and 500° Centigrade.

4. In addition to meeting the soil cleanup levels in Part B, a responsible person shall ensure that the site meets the most stringent standards for benzene, toluene, ethylbenzene, and total xylenes for the applicable exposure pathway in Table B1 in (c) of this section.

(b) If a responsible person uses method one for an Arctic zone under 18 AAC 75.340, the soil cleanup levels must be based on Table A2 in this subsection.

Table A2 - Arctic Zone

Table A2, shown below; can be used to determine soil cleanup levels for GRO, DRO, and RRO at manmade pads and roads in the arctic zone. Additional sampling and analysis for other compounds is not required if a site contaminated by only petroleum is cleaned to Table A2 cleanup levels. PAH sampling is not required if a site is cleaned to Table A2 cleanup levels.

The applicable laboratory analytical methods are the Alaska Series AK101, AK 102, and AK 103. The aromatic/aliphatic analytical methods (AK101AA, AK102AA, and AK103AA) are not applicable for this method.

<b>TABLE A2. METHOD ONE - PETROLEUM HYDROCARBON SOIL CLEANUP LEVELS IN THE ARCTIC ZONE</b>			
<b>PRODUCT</b>	<b>Cleanup Level in mg/kg</b>		
	<b>Diesel Range Petroleum Hydrocarbons</b>	<b>Gasoline Range Petroleum Hydrocarbons</b>	<b>Residual Range Petroleum Hydrocarbons</b>
Gasoline	N/A	100	N/A
Diesel	200*	N/A	N/A
Unknown/Crude	200	100	N/A
Residual	N/A	N/A	2000

In this table, “N/A” means “not applicable.”

\* If a responsible party demonstrates that contamination is due to a diesel spill, that levels of benzene, toluene, ethylbenzene, and total xylene isomers (BTEX) are less than 15 mg/kg, that benzene levels are less than 0.5 mg/kg, and that other site conditions are favorable, and if the department determines that a less stringent level is protective of human health, safety, and welfare, and of the environment, the department will allow a cleanup level of 500 mg/kg for diesel range petroleum hydrocarbons.

The Arctic Zone numeric cleanup levels in this table cover only contamination related to manmade pads and roads. The department will determine the cleanup levels for undisturbed tundra or other undisturbed native vegetation on a site-specific basis, depending upon whether a cleanup action would cause more severe or long-term damage than would the discharge or release alone.

### *Method two*

The method two soil cleanup levels were designed to protect humans from three different potential exposure pathways: direct ingestion of soil, inhalation of volatile contaminants, and migration from soil to groundwater and the subsequent ingestion of contaminated groundwater. For carcinogenic substances, the human health risk based cleanup levels were set at an excess lifetime cancer risk of one-in-one-hundred thousand ( $1 \times 10^{-5}$ ). For noncarcinogenic substances, the human health risk based cleanup levels were based on a Hazard Quotient of 1.0. A hazard quotient is the ratio of the exposure point value to the reference dose for the hazardous substance.

The equations used to calculate method two soil cleanup levels were adopted by reference in the regulations at 18 AAC 75.325 (g) and are available in the *Guidance on Cleanup Levels Equations and Input Parameters* (ADEC, 1999). For additional background information about the development of method two cleanup levels for petroleum hydrocarbons, see Appendix A.

#### Table B1 - Petroleum Related Chemicals

Method two soil cleanup levels for 110 hazardous substances are listed in Table B1 of 18 AAC 75.341. Table B1 includes soil cleanup levels for a number of petroleum-related chemicals including benzene, ethylbenzene, toluene, xylenes, and twelve polynuclear aromatic hydrocarbons (PAHs). The table on the next page summarizes the cleanup levels for petroleum-related chemicals.

PAH analysis is required for most cleanups of petroleum products under method two. DEC does not usually require collection of as many PAH soil samples at a site as BTEX, GRO and DRO samples. During site characterization, one or two samples should be collected at the highest suspected contaminated areas and analyzed for PAH compounds to determine if further sampling is needed during the cleanup operation phase. During cleanup operations, at least one PAH confirmation sample should be collected at the highest suspected contaminated area and analyzed to verify whether cleanup levels were met.

**Table 3: Soil Cleanup Levels for Petroleum-related Chemicals**

**(From Table B1 of 18 AAC 75.341(c))**

CAS NUMBER <sup>4</sup>	CHEMICAL NAME	Arctic Zone <sup>1</sup>			Under 40 inch Zone <sup>2</sup>			Over 40 inch Zone <sup>3</sup>		
		Ingestion <sup>5</sup> (mg/kg)	Inhalation <sup>6</sup> (mg/kg)	Migration to Groundwater <sup>7</sup> (N/A)	Ingestion (mg/kg)	Inhalation (mg/kg)	Migration to Groundwater (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)	Migration to Groundwater (mg/kg)
	<b>ORGANICS</b>									
83-32-9	Acenaphthene <sup>15</sup>	8200			6100		210	5000		190
120-12-7	Anthracene <sup>15</sup>	41000			30000		4300	24900		3900
71-43-2	<b>Benzene</b> <sup>15</sup>	390	13		290	9	0.02	230	6.4	0.02
56-55-3	<b>Benzo(a)anthracene</b> <sup>15</sup>	15			11		6	9		5.5
205-99-2	<b>Benzo(b)fluoranthene</b> <sup>15</sup>	15			11		20	9		17
207-08-9	<b>Benzo(k)fluoranthene</b> <sup>15</sup>	150			110		200	93		170
50-32-8	<b>Benzo(a)pyrene</b> <sup>15</sup>	1.5			1		3	0.9		2.4
218-01-9	<b>Chrysene</b> <sup>15</sup>	1500			1100		620	930		550
53-70-3	<b>Dibenzo(a,h)anthracene</b> <sup>15</sup>	1.5			1		6	0.9		5
100-41-4	Ethylbenzene <sup>15</sup>	13700	89 <sup>12</sup>		10000	89 <sup>12</sup>	5.5	8300	89 <sup>12</sup>	5
206-44-0	Fluoranthene	5500			4100		2100	3300		1900
86-73-7	Fluorene <sup>15</sup>	5500			4100		270	3300		240
193-39-5	<b>Indeno(1,2,3-c,d)pyrene</b> <sup>15</sup>	15			11		54	9		50
91-20-3	Naphthalene <sup>15</sup>	5500			4100		43	3300		38
129-00-0	Pyrene <sup>15</sup>	4100			3000		1500	2500		1400
108-88-3	Toluene <sup>15</sup>	27400	180 <sup>12</sup>		20300	180 <sup>12</sup>	5.4	17000	180 <sup>12</sup>	4.8
1330-20-7	Xylenes (total) <sup>15</sup>	274000	81 <sup>12</sup>		203000	81 <sup>12</sup>	78	166000	81 <sup>12</sup>	69

CAS NUMBER <sup>4</sup>	CHEMICAL NAME	Arctic Zone <sup>1</sup>			Under 40 inch Zone <sup>2</sup>			Over 40 inch Zone <sup>3</sup>		
		Ingestion <sup>5</sup> (mg/kg)	Inhalation <sup>6</sup> (mg/kg)	Migration to Groundwater <sup>7</sup> (N/A)	Ingestion (mg/kg)	Inhalation (mg/kg)	Migration to Groundwater (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)	Migration to Groundwater (mg/kg)
	<b>(Carcinogenics in Bold Type)</b>									
	INORGANICS									
7440-38-2	<b>Arsenic</b>	8			5.5		2	4.5		1.8
7440-39-3	Barium	9600			7100		1100	5800		982
7440-43-9	Cadmium	140			100		5	83		4.5
7440-47-3	Chromium (Total)	680			510		26	420		23
16065-83-1	Chromium +3	137,000			100000		>1000000	83000		>1000000
18540-29-9	Chromium +6	680			510		26	420		23
7439-92-1	Lead <sup>11</sup>									
7440-02-0	Nickel	2700			2000		87	1700		78
7440-62-2	Vanadium	960			710		3400	580		3050

### Notes to Tables B1 and B2:

For PCB-free mineral oils, the department will approve alternate levels or exposure pathways, if the department determines that the alternative levels or exposure pathways are protective of human health, safety, and welfare, and of the environment. Although migration to groundwater is not applicable to the Arctic zone, site-specific levels must be protective of migration to surface water. Concentrations of hazardous substances in soil must be calculated and presented on a per dry weight basis. For volatile organic hazardous substances for which toxicity data is not currently available, the cleanup level that applies at a site is the calculated saturation concentration determined using the equations set out in *Guidance on Cleanup Levels Equations and Input Parameters*, adopted by reference in 18 AAC 75.325. The cleanup level from Table B1 or B2 that applies at a site is the most stringent of the applicable exposure pathway-specific cleanup levels based on ingestion, inhalation, or migration to groundwater. In Table B1, a blank space means not available or not applicable.

1. "Arctic zone" is defined at 18 AAC 75.990.
2. "under 40 inch zone" means a site that receives mean annual precipitation of less than 40 inches each year.
3. "over 40 inch zone" means a site that receives mean annual precipitation of 40 or more inches each year.
4. "CAS Number" means the Chemical Abstract Service (CAS) registry number uniquely assigned to chemicals by the American Chemical Society and recorded in the CAS Registry System.
5. "Ingestion" means a potential pathway of exposure to hazardous substances in soil through direct consumption of the soil.
6. "Inhalation" means a potential pathway of exposure to volatile organic hazardous substances in the soil through volatilization.
7. "Migration to groundwater" means a potential exposure to hazardous substances in soil through direct ingestion of groundwater contaminated with concentrations of hazardous substances at levels listed in Table C at 18 AAC 75.345(b)(1) as a result of movement of hazardous substances through soil to the groundwater; this exposure pathway is not applicable to the Arctic zone, where soil cleanup levels protective of migration to surface water must be determined on a site-specific basis.
8. Dioxin cleanup levels must be determined on a site-specific basis.
9. For residential land use, the cleanup level for PCBs in surface soil is 1 mg/kg; for commercial or industrial land use, the cleanup level for PCBs in surface soils is 10 mg/kg and for PCBs in subsurface soil is 25 mg/kg; a responsible person may also propose an alternative cleanup level through an approved site-specific risk assessment, conducted according to the *Risk Assessment Procedures Manual*, adopted by reference at 18 AAC 75.340.
10. Cyanide expressed as free or physiologically available cyanide.
11. Lead cleanup levels must be determined on a site-specific basis, based on land use; for residential land use, the soil cleanup level is 400 mg/kg, and for commercial or industrial land use, that level is 1,000 mg/kg; through an approved site-specific risk assessment, conducted according to the *Risk Assessment Procedures Manual*, adopted by reference at 18 AAC 75.340, approved exposure models may be used to evaluate exposure to a child resident or an adult worker; a responsible person may also propose an alternative cleanup level, through a site-specific risk assessment conducted according to the *Manual*, and based on a chemical speciation of the lead present at the site.
12. These levels are based on soil saturation level (Csat) using the equations set out in *Guidance on Cleanup Levels Equations and Input Parameters*, adopted by reference in 18 AAC 75.325.
13. Ingestion value is adjusted by a factor of 0.5 to account for dermal exposure.
14. This level is the concentration of C<sub>6</sub> - C<sub>10</sub>, C<sub>10</sub> - C<sub>25</sub>, or C<sub>25</sub> - C<sub>36</sub> petroleum hydrocarbon range in surface and subsurface soil that, if exceeded, indicates an increased potential for hazardous substance migration or for risk to human health, safety, or welfare, or to the environment; the level of a petroleum hydrocarbon may not remain at a concentration above the maximum allowable concentration unless a responsible person demonstrates that the petroleum hydrocarbon will not migrate and will not pose a significant risk to human health, safety, or welfare, or to the environment. Free product must be recovered as required by 18 AAC 75.325(f).
15. If using method two or method three, the applicable petroleum hydrocarbon cleanup levels must be met in addition to the applicable chemical-specific cleanup levels for benzene, toluene, ethylbenzene, and total xylenes; the chemical-specific cleanup levels for the polynuclear aromatic hydrocarbons acenaphthene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, and pyrene must also be met unless the department determines that those cleanup levels need not be met to protect human health, safety, and welfare, and the environment. (Eff. 1/22/99, Register 149)

TABLE B2. METHOD TWO - PETROLEUM HYDROCARBON SOIL CLEANUP LEVELS (from 18 AAC 75.341)										
Petroleum Hydrocarbon Range	Arctic Zone			Under 40 Inch Zone			Over 40 Inch Zone			Maximum Allowable Concentrations <sup>14</sup> mg/kg
	Ingestion (mg/kg)	Inhalation (mg/kg)	Migration to Groundwater (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)	Migration to groundwater (mg/kg)	Ingestion (mg/kg)	Inhalation (mg/kg)	Migration to Groundwater (mg/kg)	
<b>For Laboratory Analysis using AK Methods 101, 102, and 103</b>										
C <sub>6</sub> -C <sub>10</sub> GRO Using AK 101	1400	1400	n/a	1400	1400	300	1400	1400	260	1400
C <sub>10</sub> -C <sub>25</sub> DRO Using AK 102	12500	12500	n/a	10250	12500	250	8250	12500	230	12500
C <sub>25</sub> -C <sub>36</sub> RRO Using AK 103	13700	22000	n/a	10000	22000	11000	8300	22000	9700	22000
<b>For Laboratory Analysis using AK Aliphatic and Aromatic Fraction Methods 101AA, 102AA, and 103AA</b>										
C <sub>6</sub> -C <sub>10</sub> Aliphatics	1000	1000	n/a	1000	1000	270	1000	1000	240	1000
C <sub>6</sub> -C <sub>10</sub> Aromatics	1000	1000	n/a	1000	1000	150	1000	1000	130	1000
C <sub>10</sub> -C <sub>25</sub> Aliphatics	10000	10000	n/a	10000	10000	7200	8300	10000	6400	10000
C <sub>10</sub> -C <sub>25</sub> Aromatics	5000	5000	n/A	4100	5000	100	3300	5000	90	5000
C <sub>25</sub> -C <sub>36</sub> Aliphatics	20000	20000	n/a	20000	20000	20000	20000	20000	20000	20000
C <sub>25</sub> -C <sub>36</sub> Aromatics	4100	10000	n/a	3000	10000	3300	2500	10000	2900	10000
See notes to table for further requirements. "n/a" means not applicable.										

## Table B2 - Petroleum Hydrocarbons

Method two soil cleanup levels for petroleum hydrocarbons are listed in Table B2 of 18 AAC 75.341. Perform the following tasks to determine the appropriate method two cleanup levels using Table B1 and Table B2.

1. *Determine the appropriate climatic zone for the site.*

There are three possible climatic zones. The “Arctic Zone” generally means areas north of latitude 68 North. The “Under 40 Inch Zone” means a site that receives mean annual precipitation of less than 40 inches each year. The “Over 40 Inch Zone” means a site that receives mean annual precipitation of more than 40 inches of precipitation each year. Precipitation includes snow and rain. Precipitation data can be obtained from the nearest weather station. Another good source of weather data is found at the Alaska Department of Community and Regional Affairs DCRA Community Database web site.

2. *Determine the applicable exposure pathway.*

Three exposure pathways are listed in the table for each zone. The pathways are ingestion, inhalation, or migration to groundwater. The migration to groundwater pathway does not apply to sites in the Arctic zone; however, site-specific cleanup levels in the arctic need to be protective of surface waters. For other zones, if groundwater is known or suspected to exist at the site, the migration to groundwater pathway must be considered. Of the applicable exposure pathways, select the lowest table value for each indicator compound and for GRO, DRO, and RRO.

A conceptual site model should be developed to determine applicable exposure pathways. Conceptual site models are flow charts or diagrams used to evaluate completed exposure pathways for human health or ecological receptors. The conceptual site model should evaluate other potential pathways such as:

- accumulation of vapors in buildings;
- inhalation of fugitive dust;
- sediment contamination;
- impacts to surface water;
- impacts to ecological receptors; and
- recreation, agricultural, or subsistence uses of the site.

If other pathways are identified DEC may require modifications to the Table B1 or Table B2 cleanup levels to protect human health, safety, welfare, or the environment.

3. *Compare soil concentrations to cleanup levels*

Compare detected soil concentrations from the site to the applicable value from Table B1 or Table B2. Cleanup is required for each chemical or carbon range with a soil concentration that exceeds the corresponding cleanup levels from Table B1 or Table B2 unless method three or method four soil cleanup levels are developed.

### Maximum Allowable Concentrations

Maximum allowable concentrations for petroleum hydrocarbons are listed in Table B2 of 18 AAC 75.341. Note that several of the values listed in the ingestion, inhalation, or migration to groundwater columns in Table B2 are based on maximum allowable concentrations rather than calculations using equations from the *Guidance on Cleanup Levels Equations and Input Parameters* (ADEC, 1999). These maximum allowable concentrations represent an increased potential for migration and may cause toxic impacts to plants or reduce the ability for seeds to germinate.

Maximum allowable concentrations should not be exceeded unless a demonstration is made under method three or method four that the petroleum hydrocarbons will not migrate and will not pose an unacceptable risk to human health, safety or welfare, or the environment.

DEC established maximum allowable concentrations after reviewing information provided in the American Petroleum Institute publication, *A guide to the Assessment and Remediation of Underground Petroleum Releases* (API, 1996). The maximum allowable concentrations for DRO and RRO were developed based on estimates of soil saturation in a coarse to fine sandy silt soil type. Because GRO is more mobile than DRO or RRO, the maximum allowable concentrations for GRO were developed based on estimates of soil saturation in a coarse gravel soil type.

### Fuel Additives

Ethylene dibromide (EDB) and Ethylene dichloride (EDC or 1,2 dichloroethane) were used as lead scavengers in some leaded gasoline, and may be considered contaminants of concern when present. They are both potential carcinogens and are highly mobile in the environment. EDC is listed in Table B1 and in Table C as 1,2, dichloroethane.

Methyl 1tert-butylether (MTBE) is another gasoline additive that is potentially carcinogenic and highly mobile. If EDB or MTBE is potentially present at a site, samples should be analyzed to determine concentrations detected in soil or groundwater. Contact the ADEC Contaminated Sites Remediation Program risk assessor for help with questions about chemical specific data to use to determine appropriate cleanup levels.

### *Method three*

Method three soil cleanup levels can be calculated for each site using site-specific information. Method three soil cleanup levels are termed *alternative cleanup levels (ACLs)*. Site-specific information can be substituted for some, but not all default parameters used to derive the method two levels.

There are three options for determining site-specific alternative cleanup levels for soil under method three:

1. The Table B1 or B2 migration to groundwater or inhalation cleanup levels can be modified using site-specific soil data and the equations set out in the DEC's *Guidance on Cleanup Levels Equations and Input Parameters* (ADEC, 1999).

2. The Table B1 or B2 migration to groundwater cleanup levels may be modified using site specific data and a fate and transport model that meets the requirements set out in the DEC's *Guidance on Fate and Transport Modeling* (ADEC, 1998).
3. The Table B1 or B2 ingestion or inhalation cleanup levels may be modified using the commercial/industrial exposure parameters set out in the *Guidance on Cleanup Levels Equations and Input Parameters*.

The following default parameters may be modified using site-specific data:

- dry soil bulk density;
- total soil porosity;
- water-filled porosity;
- air-filled porosity;
- average soil moisture content;
- fraction organic carbon of soil;
- dilution factor;
- aquifer hydraulic conductivity;
- hydraulic gradient;
- mixing zone gradient;
- source length parallel to groundwater flow;
- infiltration rate; and
- aquifer thickness

The following parameter modifications are applied if ingestion-based or inhalation-based alternative cleanup levels are developed using commercial/industrial exposure parameters:

- averaging time for noncarcinogens (changes to 25 years);
- body weight (changes to 70 kg);
- exposure duration (changes to 25 years);
- exposure frequency (changes to 250 days/year);
- soil ingestion rate (changes to 50 mg/day);

#### *Method four*

Method four cleanup levels are alternative cleanup levels developed as part of a site-specific risk assessment that meets the requirements of the DEC *Risk Assessment Procedures Manual*.

Method four soil cleanup levels are determined after an evaluation of numerous exposure pathways and determination of risk levels for carcinogenic and non-carcinogenic substances.

The risk assessment approach is intended primarily for high priority, complex sites. It is generally costly, requires the most detailed site information, and may involve a high degree of DEC oversight. For more information on risk assessment process and method four cleanups, refer to 18 AAC 75.340 (c)(2) and DEC's *Risk Assessment Procedures Manual* (ADEC, 2000b).

#### *Biogenic Interference*

Biogenic compounds are naturally-occurring organic compounds found in organic matter and plant and animal oils. When analyzing for DRO and RRO with the AK Methods 102 and 103, in

addition to petroleum-related contaminants, the resulting DRO and RRO concentrations can include naturally occurring biogenic compounds. If sufficient biogenic material is in the soil, it can cause artificially high DRO or RRO analytical results.

Background sampling may be conducted at a site to evaluate the degree that DRO or RRO concentrations may be affected by potential biogenic interference. To do this, first, identify background sample locations in the characterization or cleanup work plan. Collect samples near the site in areas that are not influenced by known or suspected contamination. Collect background samples at similar depths and from similar soil types as samples collected to characterize the extent of DRO and RRO contamination. DEC may require copies of the chromatograms and a written interpretation of the analytical results provided by the laboratory. If DEC concurs with the interpretation of background sampling analytical results, the DRO and RRO concentrations at the site may be reduced to account for background concentrations.

## **GROUNDWATER SAMPLING**

Groundwater wells or well points are necessary to properly collect groundwater samples. Water samples collected directly from an excavation generally do not represent normal groundwater conditions.

Install groundwater monitoring wells in accordance with the DEC's *Recommended Practices for Monitoring Well Design, Installation, and Decommissioning* (ADEC, 1992). If the direction of groundwater flow is known, install at least three monitoring wells and collect groundwater samples, one upgradient and two downgradient of the potential contamination source. If the direction of groundwater flow is unknown, install a sufficient number of wells to characterize the groundwater flow using horizontal and vertical control measures. Groundwater elevations should be correlated to a standard datum such as mean sea level.

Decontaminate well drilling equipment before drilling at each new location. Drive wells with a hollow stem auger or cable drill, unless other methods are approved by DEC before the well is installed. Record the following details of well construction:

- well location, determined by reference to site bench mark;
- total depth of boring;
- depth to groundwater at time of drilling;
- diameter of boring;
- depth to top and bottom of screened interval;
- diameter of screened interval;
- diameter of casing;
- well construction material;
- depth of packed filter interval;
- depth and thickness of seals;
- type of surface cap;
- names of drilling firm and drilling personnel; and

- soil log completed using the Unified Soil Classification System.

Before sampling a monitoring well, check the column of water in the well for the presence of nonaqueous phase liquids, including free petroleum products that might be floating on top of the water or in a separate layer at the bottom of the casing. Identify nonaqueous phase liquids by:

- (1) carefully lowering a clean bailer, in a manner that will create minimum disturbance, into the well before purging and observing the liquids removed from the top and the bottom of the water column;
- (2) using a paste type of detector with ingredients that will not lead to cross-contamination; or;
- (3) using an electronic device designed to detect nonaqueous liquids and to measure the thickness of the nonaqueous layer.

If free product is present, bail or pump the well to remove the product and then monitor the well recharge rate.

Before sampling wells, determine the depth to groundwater by manual or electronic means. Calibrate water level measurement devices before use to an accuracy of at least 0.02-foot. Sample the well upgradient of the site first to minimize cross-contamination.

Then, purge the monitoring well before sampling using the following procedure:

- (1) remove at least three casing volumes of water from the well before sample collection or, for low yield wells, remove water until the well bore is evacuated; or instead of purging three casing volumes, measure the purge water temperature, pH, and conductivity until these parameters are stable to within 10 percent variability between measurements;
- (2) carefully collect all purged water, containerize and store it for proper disposal. Evaluate groundwater sample results and the applicable federal, state, and local water quality criteria to determine the acceptable method for disposal of the purge water; and
- (3) purge upgradient wells before downgradient wells to help minimize possible cross contamination.

Follow the procedures below to collect samples with a bailer:

- (1) Allow sufficient time after purging the well for the well to equilibrate and fines to settle. If full recovery exceeds two hours, extract samples as soon as sufficient volume is available;
- (2) Measure the water level again after purging is complete and the water level returns to the static level;
- (3) Rinse the sampler with analyte-free distilled or deionized water; collect a portion of this rinsate into a container appropriate for the most volatile analyte suspected (typically BTEX). Preserve and analyze this equipment blank (also termed decontamination blank) according to the Table 1 procedures for that analyte;
- (4) Properly decontaminate all bailers before use. Bailers must be made of glass, Teflon, stainless steel, other suitable materials, or of disposable materials. Do not use plastic

- bailers or bailers made of polyethylene or polyvinyl chloride (PVC) for sampling volatile organic compounds;
- (5) Attach a new bailer line to the bailer e for each well sampled. Only personnel wearing decontaminated or disposable gloves should handle the bailer or the line;
  - (6) Slowly lower the bailer to minimize disturbance of the well and water column. Try to prevent contact of the bailing line with the outside of the well, equipment, and clothing. Take special care to minimize disturbance of the water table interface when inserting the bailer;
  - (7) Obtain samples as close as possible to the water level/air interface, unless analysis indicates that contamination is at a different depth;
  - (8) Do not mix or composite samples; obtain discrete grab samples;
  - (9) Lift the bailer slowly and transfer the contents to a clean sample container while minimizing disturbance and agitation to prevent loss of volatile compounds. Transfer samples to containers in the order of their volatility. Minimize headspace in the sample container by filling the sample jar until a positive meniscus is present;
  - (10) Seal containers quickly; clean container rims and threads before tightening lids. Unless otherwise specified, use Teflon-lined screw caps to seal the jar;
  - (11) Properly label each sample container;
  - (12) Preserve containers preserved immediately. Unless specified otherwise, cool samples immediately to  $4\pm 2^{\circ}\text{C}$  and maintain this temperature through delivery to the laboratory until the samples are analyzed.

## **GROUNDWATER CLEANUP LEVELS**

The cleanup levels for contaminated groundwater are provided at 18 AAC 75.345. The Table C groundwater cleanup levels were developed based on Safe Drinking Water Act maximum contaminant levels, solubility considerations, and equations provided in the *Guidance on Cleanup Levels Equations and Input Parameters*. As described at 18 AAC 75.345 (b), if certain conditions are met, the groundwater cleanup level may be increased to a concentration equal to ten times the Table C levels, or may be set to levels based on the results of an approved site-specific risk assessment.

Groundwater cleanup levels need to be attained throughout the site from the uppermost level of the saturated zone down to the lowest depth that could potentially be affected, unless an alternative point of compliance is approved. Alternative points of compliance may be proposed, but need to be within the existing groundwater contamination plume. Alternative points of compliance should be within the property boundary, unless attainment of the groundwater cleanup level is not practicable and the responsible person provides an alternative source of water for affected persons.

The table on the next page shows compounds most commonly found in petroleum products.

**Table 4: Groundwater Cleanup Levels for Petroleum-related compounds**

(From 18 AAC 75.345, Table C)

HAZARDOUS SUBSTANCE	CLEANUP LEVEL (mg/L)	HAZARDOUS SUBSTANCE	CLEANUP LEVEL (mg/L)
<b>Petroleum Hydrocarbons</b>		<b>Polynuclear Aromatic Hydrocarbons (PAHs)</b>	
GRO (C6 – C10) <sup>1</sup>	1.3	Acenaphthene <sup>3</sup>	2.2
DRO (C10 – C25) <sup>3</sup>	1.5	Anthracene <sup>3</sup>	11.0
RRO (C25 – C36) <sup>3</sup>	1.1	Benzo(a)anthracene <sup>3</sup>	0.001
C6 – C10 Aliphatics <sup>1</sup>	1.3	Benzo(a)pyrene <sup>2</sup>	0.0002
C6 – C10 Aromatics <sup>3</sup>	7.3	Benzo(b)fluoranthene <sup>3</sup>	0.001
C10 – C25 Aliphatics <sup>1</sup>	0.1	Benzo(k)fluoranthene <sup>3</sup>	0.01
C10 – C25 Aromatics <sup>3</sup>	1.5	Chrysene <sup>3</sup>	0.1
C25 – C36 Aliphatics	N/A (insoluble)	Dibenzo(a,h)anthracene <sup>3</sup>	0.0001
C25 – C36 Aromatics <sup>3</sup>	1.1	Fluorene <sup>3</sup>	1.46
		Indeno(1,2,3-cd)pyrene <sup>3</sup>	0.001
<b>Volatiles (BTEX)</b>		Naphthalene <sup>3</sup>	1.46
Benzene <sup>2</sup>	0.005	Pyrene <sup>3</sup>	1.1
Toluene <sup>2</sup>	1.0		
Ethylbenzene <sup>2</sup>	0.7	<b>Inorganics</b>	
Xylenes (Total) <sup>2</sup>	10.0	Arsenic	0.05
		Barium	2.0
<b>Additives</b>		Cadmium <sup>2</sup>	0.005
1,2-dichloroethane (EDC) <sup>2</sup>	0.005	Chromium (Total) <sup>2</sup>	0.1
		Chromium (+3) <sup>2</sup>	36.5
		Chromium (+6) <sup>3</sup>	0.1
		Lead	0.015
		Nickel <sup>2</sup>	0.1
		Vanadium <sup>3</sup>	0.26
<sup>1</sup> = based on estimated solubility <sup>2</sup> = based on maximum contaminant level <sup>3</sup> = based on Equation 2 of <i>Guidance on Cleanup Levels Equations and Input Parameters</i>			

#### Groundwater-Surface Water Interaction

If potentially contaminated groundwater closely connects hydrologically to nearby surface water, the groundwater must not cause a surface water quality violation. Groundwater entering surface water may not cause a visible sheen upon the surface of the water and surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration. Shoreline or bottom sediments should not have petroleum hydrocarbons that cause deleterious effects to aquatic life. The applicable surface water quality standards for petroleum hydrocarbons, oils and grease are provided in the Water Quality Standards at 18 AAC 70.020(b).

### Long-term Monitoring

For sites with groundwater contamination, long-term groundwater monitoring may be required if concentrations exceed applicable cleanup levels. Provide details of the monitoring program in the plans developed as part of the cleanup operations requirements. Unless otherwise approved, DEC requires quarterly monitoring for at least one year to determine if a concentration trend exists. Check for the presence of free product before sampling any monitoring well. Water level elevations should be reported along with the analytical results to help evaluate whether contaminant concentration trends correlate with water level fluctuations. Based on the results, DEC will evaluate whether further cleanup actions or continued monitoring are needed.

## LABORATORY ANALYSIS

Under the site cleanup rules, laboratory analysis needs to be performed by a DEC-approved laboratory. A list of DEC-approved laboratories is accessible from the DEC Storage Tank Program web page.

### Soil and Groundwater Analysis

Petroleum derived products such as gasoline, diesel, or Bunker fuel oil typically contain hundreds of individual organic chemicals in various amounts depending on the crude oil source, type of refining processes, and other variables. Sampling and analysis requirements for individual compounds and for different hydrocarbon ranges depend on the type of petroleum product spilled at a site.

The regulations require that analysis for petroleum contamination follow the Alaska methods for petroleum hydrocarbons referred to in Table 1 of the *Underground Storage Tank Procedures Manual*. Table 1 on the following pages is a reproduction from the December 1, 1999 version of the *Underground Storage Tank Procedures Manual*. It specifies the laboratory techniques for analysis of soil or groundwater and includes analysis for aromatic and aliphatic hydrocarbons, GRO, DRO, RRO, benzene, toluene, ethylbenzene, xylenes, polynuclear aromatic hydrocarbons, some chlorinated compounds, and some inorganic compounds. The table may occasionally be updated to reflect changes to laboratory analytical procedures. Copies of the *Underground Storage Tank Procedures Manual* can be downloaded from the above-mentioned DEC Storage Tank Program web page by clicking on the regulations tab and navigating down the page to the procedures manual.

The Alaska Series AK101, AK102, and AK103 methods can be used to determine total GRO, DRO, or RRO in soil or total GRO and DRO in groundwater. In August 1999, the DEC State Chemistry Laboratory granted approval to several laboratories to perform the new Alaska Series AK101AA, AK102AA, and AK103AA laboratory methods that quantify aromatic and aliphatic hydrocarbons in soil or groundwater. The Alaska Series AK101AA, 102AA, and 103AA methods can be used to determine aromatic and aliphatic GRO, DRO and RRO in soil and aromatic and aliphatic GRO and DRO and aromatic RRO in groundwater.

The following table lists soil and groundwater laboratory analytical methods for several different petroleum products.

**Reference Guide to Sample Collection and Laboratory Analysis  
Part A: Soils, Sediments, Sludges, and Fill Materials**

<b>Parameter</b>	<b>Preparation/ Analytical Method<sup>1</sup></b>	<b>Method Detection Limit<sup>2</sup></b>	<b>Practical Quantitation Limit<sup>3</sup></b>	<b>Container Description (Minimum) [Clear glass may be substituted for amber if samples are protected from exposure to light, this exception does not apply metals]</b>	<b>Preservation/ Holding Time</b>
Gasoline range organics	AK101*	2 mg/kg	20 mg/kg	4 oz. amber glass, TLS	Methanol preservative, <25°C / 28 days
Diesel range organics	AK102*	2 mg/kg	20 mg/kg	4 oz. amber glass, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Residual range organics	AK103*	10 mg/kg	100 mg/kg	4 oz. amber glass, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Aliphatic gasoline range organics	AK101AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar with teflon lined silicon rubber septum seal	Methanol preservative / 28 days from sampling
Aromatic gasoline range organics	AK101AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar with teflon lined silicon rubber septum seal	Methanol preservative / 28 days from sampling
Aliphatic diesel range organics	AK102AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar, TLC	No preservative / 14 days to extraction, less than 40 days to analysis of extract
Aromatic diesel range organics	AK102AA*	2 mg/kg	20 mg/kg	4 oz. wide-mouth amber glass jar, TLC	No preservative / 14 days to extraction, less than 40 days to analysis of extract
Aliphatic residual range organics	AK103AA*	10 mg/kg	100 mg/kg	4 oz. wide-mouth amber glass jar, TLC	No preservative / 14 days to extraction, less than 40 days to analysis of extract
Aromatic residual range organics	AK103AA*	10 mg/kg	100 mg/kg	4 oz. wide-mouth amber glass jar, TLC	No preservative / 14 days to extraction of sample, less than 40 days to analysis of extract
Benzene	AK101 <sup>+</sup> , 8021B, or 8260B	0.007 mg/kg	0.02 mg/kg	4 oz. amber glass, TLS	Methanol preservative, <25°C / 28 days
Toluene	AK101 <sup>+</sup> , 8021B, or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, <25°C / 28 days
Ethylbenzene	AK101 <sup>+</sup> , 8021B, or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, <25°C / 28 days
Total xylenes	AK101 <sup>+</sup> , 8021B, or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, <25°C / 28 days
Total BTEX	AK101 <sup>+</sup> , 8021B, or 8260B	0.007 mg/kg	0.05 mg/kg	4 oz. amber glass, TLS	Methanol preservative, <25°C / 28 days
Polynuclear Aromatic Hydrocarbons (PAH)	8270C or 8310	0.1 mg/kg	1.0 mg/kg	4 oz. amber glass, TLS	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Total Volatile Chlorinated Solvents**	8260B or 8021B	0.008 mg/kg	0.08 mg/kg	4 oz. amber glass, TLS	Methanol preservative, <25°C / 28 days
Polychlorinated biphenyls (PCBs)	8082	0.01 mg/kg	0.05 mg/kg	4 oz amber glass, TLC	Cool 4° ± 2°C / 14 days to extraction, less than 40 days to analysis of extract
Total Arsenic	6010B, 6020, 7060A, or 7061A	1 mg/kg	10 mg/kg	4 oz amber glass, TLC	Cool 4° ± 2°C / 6 months
Total Cadmium	6010B, 6020, 7130, or 7131A	1 mg/kg	10 mg/kg	4 oz amber glass, TLC	Cool 4° ± 2°C / 6 months

Reference Guide to Sample Collection and Laboratory Analysis Part A: Soils, Sediments, Sludges, and Fill Materials					
Parameter	Preparation/ Analytical Method <sup>1</sup>	Method Detection Limit <sup>2</sup>	Practical Quantitation Limit <sup>3</sup>	Container Description (Minimum) [Clear glass may be substituted for amber if samples are protected from exposure to light, this exception does not apply metals]	Preservation/ Holding Time
Total Chromium	6010B, 6020, 7190, or 7191	1 mg/kg	10 mg/kg	4 oz amber glass, TLC	Cool 4° ± 2°C / 6 months
Total Lead	6010B, 6020, 7420, 7421	1 mg/kg	10 mg/kg	4 oz amber glass, TLC	Cool 4° ± 2°C / 6 months
Total Barium	6010B, 6020, 7080A, or 7081	1 mg/kg	10 mg/kg	4 oz. amber glass, TLC	Cool 4° ± 2°C / 6 months
Total Nickel	6010B, 6020, 7520, or 7521	1 mg/kg	10 mg/kg	4 oz. amber glass, TLC	Cool 4° ± 2°C / 6 months
Total Vanadium	6010B, 7911, 6020, or 7910	1 mg/kg	10 mg/kg	4 oz. amber glass, TLC	Cool 4° ± 2°C / 6 months

**Legend to follow Part B**

**Notes to Table, Part A:**

<sup>1</sup> Unless otherwise noted, all preparation and analytical methods refer to those contained in EPA's *Test Methods for the Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, adopted by reference in 18 AAC 78.090.

<sup>2</sup> Method detection limits (MDL), specified in 40 C.F.R., Part 136, Appendix B, revised as of July 1, 1996, adopted by reference, are determined at the department's chemistry laboratory.

<sup>3</sup> Practical quantitation limits (PQL), like method detection limits, are instrument specific. PQLs must be established by each laboratory and must equal or have a value lower than the PQL in the table. For purposes of this chapter, PQL = 10 x MDL, except for PCBs which are PQL= 5 x MDL (56 C.F.R. 26511), and BTEX which is PQL = 7.14 x MDL.

\* ADEC Analytical Methods AK101, AK102, and AK103 are included in Appendix D. ADEC Analytical Methods AK101AA, AK102AA, and AK103AA are included in Appendix E.

\*\* May be analyzed out of AK101 methanol preserved sample, if not used, then sample must be preserved with methanol in the field.

⊥ The AK101 method can be extended for specific determination of volatile aromatics (BTEX) as specified in EPA Method 8021B for solids utilizing methanol preservation option only. All AK101 samples must be preserved with methanol.

**Reference Guide to Sample Collection and Laboratory Analysis (cont.)  
Part B: Ground, Surface, Waste, and Marine Waters<sup>4</sup>**

<b>Parameter</b>	<b>Preparation/ Analytical Method<sup>1</sup></b>	<b>Method Detection Limit<sup>2</sup></b>	<b>Practical Quantitation Limit<sup>3</sup></b>	<b>Container Description</b>	<b>Preservation/ Holding Time</b>
Gasoline range organics	AK101*	10 µg/L	100 µg/L	40 mL VOA, TLS	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C /14 days from sampling
Diesel range organics	AK102*	80 µg/L	800 µg/L	1 L amber glass, TLC	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C /7 days to extraction, 40 days to analysis of extract
Residual range organics	AK 103*	50 µg/L	250 µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H <sub>2</sub> SO <sub>4</sub> or HNO <sub>3</sub> / 7 days to extraction, 40 days to analysis of extract
Aliphatic gasoline range organics	AK101AA**	2 µg/L	10 µg/L	40 ml VOA with teflon lined silicon rubber septum seal	HCL to a pH of 2 / 14 days from sampling
Aromatic gasoline range organics	AK101AA**	0.2 µg/L	1 µg/L	40 ml VOA with teflon lined silicon rubber septum seal	HCL to a pH of 2 / 14 days from sampling
Aliphatic diesel range organics	AK102AA**	20 µg/L	100 µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H <sub>2</sub> SO <sub>4</sub> or HNO <sub>3</sub> / 7 days to extraction, 40 days to analysis of extract
Aromatic diesel range organics	AK102AA**	20 µg/L	100 µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H <sub>2</sub> SO <sub>4</sub> or HNO <sub>3</sub> / 7 days to extraction, 40 days to analysis of extract
Aliphatic residual range organics	--	--	--	--	--
Aromatic residual range organics	AK103AA**	50 µg/L	250µg/L	1 L amber glass, TLC	Acidify to a pH of 2 using HCL, H <sub>2</sub> SO <sub>4</sub> or HNO <sub>3</sub> / 7 days to extraction, 40 days to analysis of extract
Benzene	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C /14 days
Toluene	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C /14 days
Ethylbenzene	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C /14 days
Total xylenes	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C /14 days
Total BTEX	AK101, 8021B, or 8260B	0.7 µg/L	5 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C /14 days
Polynuclear Aromatic Hydrocarbons (PAH)	8270C or 8310	1 µg/L	10 µg/L	1 L amber glass, TLS	4 <sup>o</sup> ± 2°C, Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> , dark / 7 days to extraction, 40 days to analysis of extract
Total Volatile Chlorinated Solvents	8021B or 8260B	0.8 µg/L	8 µg/L	duplicate 40 mL vials/sample, TLS	HCL to pH less than 2, 4 <sup>o</sup> ± 2°C / 14 days
Polychlorinated biphenyls (PCBs)	8081A or 8082	1 µg/L	5 µg/L	1 L amber glass, TLC	4 <sup>o</sup> ± 2°C / 7 days to extraction / 40 days to analysis of extract
Total Arsenic †	6010B, 6020, 7060, or 7061	5 µg/L	50 µg/L	min. 100 mL HDPE <sup>5</sup>	HNO <sub>3</sub> to pH less than 2 / 6 months max. total holding time
Total Cadmium †	6010B, 6020, 7130, or 7131A	10 µg/L	100 µg/L	min. 100 mL HDPE <sup>5</sup>	HNO <sub>3</sub> to pH less than 2 / 6 months max. total holding time
Total Chromium †	6010B, 6020, 7190, or 7191	100 µg/L	1000 µg/L	min. 100 mL HDPE <sup>5</sup>	HNO <sub>3</sub> to pH less than 2 / 6 months max. total holding time
Total Lead †	6010B, 6020, 7420, or 7421	1.5 µg/L	15 µg/L	min. 100 mL HDPE <sup>5</sup>	HNO <sub>3</sub> to pH less than 2 / months max. total holding time
Total Barium	6010B, 6020, 7080A, or 7081	5 µg/L	50 µg/L	min. 100 mL HDPE <sup>5</sup>	HNO <sub>3</sub> to pH less than 2 / months max. total holding time

Total Nickel	6010B, 6020, 7520, or 7521	10 µg/L	100 µg/L	min. 100 mL HDPE <sup>5</sup>	HNO <sub>3</sub> to pH less than 2 / months max. total holding time
Total Vanadium	6010B, 6020, 7910, or 7911	10 µg/L	100 µg/L	min. 100 mL HDPE <sup>5</sup>	HNO <sub>3</sub> to pH less than 2 / months max. total holding time

**Notes to Table, Part B:**

<sup>1</sup> Unless otherwise noted, all preparation and analytical methods refer to those contained in EPA's *Test Methods for the Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, (PB84128677), adopted by reference in 18 AAC 78.090.

<sup>2</sup> Method detection limits (MDL), specified in 40 C.F.R., Part 136, Appendix B, revised as of July 1, 1996, adopted by reference, are determined at the department's chemistry laboratory.

<sup>3</sup> Practical quantitation limits (PQL), like method detection limits, are instrument specific. PQLs must be established by each laboratory and must equal or have a value lower than the PQL in the table. For purposes of this chapter, PQL = 10 x MDL, except for PCBs which are PQL= 5 x MDL (56 C.F.R. 26511), and BTEX which is PQL = 7.14 x MDL.

<sup>4</sup> Sample collection and laboratory analyses for water collected from drinking water sources must be done in accordance with 18 AAC 80.

<sup>5</sup> HDPE, High Density Polyethylene sample collection bottles, critically cleaned for trace metals analysis.

\* ADEC Analytical Methods AK101, AK102, and AK103 are included in Appendix D. ADEC Analytical Methods AK101AA, AK102AA, and AK103AA are included in Appendix E.

† Analytical methods 6010B, 7080A, 7130, 7420, 7520, and 7910 are for high contaminant level screening only. These can be used for closure only if site specific MDL criteria are met. Analytical methods 6020, 7031A, 7060, 7061, 7081A, 7190, 7191, 7421, 7521, and 7911 are acceptable for closure.

**Legend to Table:**

**PAH** = naphthalene, fluorene, anthracene, pyrene, benzo-a-anthracene, acenaphthene, chrysene, benzo-a-pyrene, dibenzo-a,h-anthracene, benzo-b-fluoranthene, benzo-k-fluoranthene, ideno-123-cd-pyrene;

**VOA** = Volatile Organic Analysis;

**TLC** = Teflon lined screw caps;

**TLS** = Teflon lined septa sonically bonded to screw caps

The following table lists analytical methods for determining the concentrations of hydrocarbons in the C6 – C10, C10 – C25, or C25 – C36 carbon ranges and methods for determining concentrations of petroleum related compounds.

**Recommended Soil and Groundwater (GW) Analytical Methods  
For Various Petroleum Products**

	C6 – C10 HYDROCARBONS Gasoline Range Organics (GRO)		C10 – C25 HYDROCARBONS Diesel Range Organics (DRO)		C25 – C36 HYDROCARBONS Residual Range Organics (RRO)		Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)	Polynuclear Aromatic Hydrocarbon (PAH)	Arsenic	Cadmium	Chromium	Lead	Polychlorinated biphenyls (PCBs)	Volatile Chlorinated Compounds
	Total GRO	Aliphatic & Aromatic GRO	Total DRO	Aliphatic & Aromatic DRO	Total RRO	Aliphatic & Aromatic RRO								
<b>Leaded Gasoline</b>	AK101	AK101AA					AK 101 or 8021B	8270C or 8310				6010B, 6020, 7420, or 7421		
<b>Aviation Gasoline</b>	AK101	AK101AA					AK 101 or 8021B	8270C or 8310				6010B, 6020, 7420, or 7421		
<b>Gasoline</b>	AK101	AK 101AA					AK 101 or 8021B	8270C or 8310						
<b>JP-4</b>	AK101	AK101AA	AK102	AK102AA			AK 101 or 8021B	8270C or 8310						
<b>JP-5, JP-8, or Jet A</b>	AK101	AK101AA	AK102	AK102AA	AK103	AK103AA	AK 101 or 8021B	8270C or 8310						
<b>Kerosene</b>	AK101	AK101AA	AK102	AK102AA			AK 101 or 8021B	8270C or 8310						
<b>Diesel #1 or Arctic Diesel</b>	AK101	AK101AA	AK102	AK102AA			AK 101 or 8021B	8270C or 8310						
<b>#2 Diesel</b>			AK102	AK102AA			AK 101 or 8021B	8270C or 8310						
<b>#3 -#6 Diesel</b>			AK102	AK102AA	AK103	AK103AA	AK 101 or 8021B	8270C or 8310						
<b>Waste or Used Oil</b>	AK101	AK101AA	AK102	AK102AA	AK103	AK103AA	AK 101, 8021B, or 8260B	8270C or 8310	6010B, 6020, 7060A, or 7061A	6010B, 6020, 7130, or 7131A	6010B, 6020, 7190, or 7191	6010B, 6020, 7420, or 7421	8081A or 8082	8021B or 8260B
<b>Unknown</b>	AK101	AK101AA	AK102	AK102AA	AK103	AK103AA	AK 101, 8021B, or 8260B	8270C or 8310	6010B, 6020, 7060A, or 7061A	6010B, 6020, 7130, or 7131A	6010B, 6020, 7190, or 7191	6010B, 6020, 7420, or 7421	8081A or 8082	8021B or 8260B



### Surface water

The water quality criteria for petroleum hydrocarbons, oil, and grease are set out in a table in regulation at 18 AAC 70.020 (b). Laboratory analysis is needed to determine surface water column concentrations of total aromatic hydrocarbons (TAH) and total aqueous hydrocarbons (TAqH). “Total aromatic hydrocarbons” and “total aqueous hydrocarbons” are defined in regulation at 18 AAC 70.990. TAH is the sum of concentrations of benzene, toluene, ethylbenzene, and xylene isomers, commonly called BTEX. TAqH is the sum of concentrations of TAH (BTEX) plus the polynuclear aromatic hydrocarbons (PAH) in the water column.

For petroleum hydrocarbons, the same laboratory analysis requirements apply to both freshwater and marine water. Method 602 is an appropriate laboratory analytical method in the surface water column for TAH and Method 610 combined with Method 602 is appropriate to determine TAqH. DEC may accept alternate methods if the practicable quantitation limits are sufficiently low to determine compliance with the surface water quality standards at 18 AAC 70. For TAH and TAqH, DEC will consider alternative methods such as AK Method 101, Method 8021B, Method 8260B, Method 8270C or Method 8310. Refer to DEC Water Quality Standards at 18 AAC 70.020 (b) for more details.

## **CLEANUP ALTERNATIVES**

The following cleanup alternatives are applicable to petroleum contaminated sites in Alaska. Site-specific conditions will affect the technical feasibility and cost effectiveness of any particular alternative. The alternatives may be used alone or in combination with others depending on site conditions. DEC may also consider other alternatives or combinations of alternatives not described in this section. Cleanup operations should be conducted or supervised by a qualified person and meet with the requirements of 18 AAC 75.360.

### **Soil Treatment Technologies**

#### *Oversized Material*

For sites contaminated with gasoline or diesel type products, oversized material (greater than 2 inches in diameter) does not need to be treated or tested unless it has a potential to hold excessive amounts of contamination or contains visible petroleum product on the surface. Shale, schist, limestone, pumice or other porous types of rocks are examples of material that may hold excessive amounts of contamination.

Treatment of oversized material from spills of crude oil, waste oil, bunker C fuel oil, or other hazardous compounds is determined on a site-specific basis with the main goal of ensuring the protection of human health and the environment. Soil clumps greater than two inches must be treated. This includes silt and clay compounds, frozen tundra and peat material. Large non-rock material such as tree stumps should be treated or disposed of in a manner approved by DEC. All material must be disposed of in a non-wetland or non-environmentally sensitive area with sufficient separation to prevent leaching or migration of petroleum contaminants to the water table.

### *Asphalt recycling*

Cold or hot mix asphalt recycling involves blending petroleum-contaminated soil with sand and gravel aggregate for the manufacture of asphalt concrete or lower grade asphalt mixtures for road beds. Soil particle diameter and the amount of silt and clay in the contaminated soil are limiting factors for this option.

This technology is generally used only with soils contaminated by diesel, heating oils and heavier-chain petroleum hydrocarbon fuels. This treatment is *not* recommended for soils heavily contaminated with gasoline. Soils that exhibit free flowing product or the potential of free product are not acceptable for asphalt recycling. The asphalt produced by the cold asphalt recycling method is generally only suitable as a base coat and is not considered a finished product.

### *Bioremediation*

Bioremediation is a treatment method that decreases petroleum product concentrations in soil and groundwater through biological action. Bioremediation may be performed in-situ, in a specially designed treatment cell, or by landfarming. Different requirements may apply, depending on whether landfarming, in-situ, or cell bioremediation is used. If in-situ bioremediation or landfarming is used, the treatment design will require more detailed attention regarding site conditions. Cell bioremediation requires extensive construction, but fewer monitoring and testing requirements.

If cultured microbes are proposed, a detailed description of how the microbes were selected and cultured should be provided. It must be demonstrated that the cultured microbes are not pathogenic. Also, a determination of the nutrient requirements for the contaminant degrading microbes to achieve optimum growth should be provided. A complete description of the method used to determine microbe nutrient requirements should also be provided, as well as the identification of the electron acceptor and nutrient source.

### Cell bioremediation

Cell bioremediation employs specially designed treatment cells to contain contaminated soils and enhance biodegradation of hydrocarbons. Soil moisture, temperature, oxygen, and nutrients are controlled to optimize conditions for soil bacteria.

The major difference between in-situ bioremediation and cell bioremediation is how the contaminated soil is contained. In cell bioremediation, the contaminated soil is placed in a liner, tank, pad, or other structure designed to completely contain any leachate generated from the treatment process.

### In-situ bioremediation

In-situ bioremediation is most often accomplished in combination with vapor extraction and bioventing. This technology uses naturally occurring microorganisms that are stimulated to biodegrade contaminated soils in place. The most developed and most feasible bioremediation method for in-situ treatment relies on optimizing environmental conditions by providing an

oxygen source that is delivered to the subsurface through an injection well or infiltration system for the enhancement of microbial activity.

### Landfarming

Landfarming is an active, above-ground technology for soils that reduces concentrations of petroleum constituents through biodegradation. It involves spreading excavated contaminated soil in a thin layer (with or without a liner) over the ground surface and stimulating aerobic microbial activity with the soil using tilling for aeration and/or the addition of minerals, nutrients, and moisture. The enhanced microbial activity results in degradation of adsorbed petroleum constituents through microbial respiration. Landfarming requires periodic monitoring to determine if cleanup levels are met and can work well for gasoline and diesel and more slowly for heavier hydrocarbons.

### Landspreading

Landspreading is a passive above-ground method that can decrease petroleum constituent concentrations in soil through biological action and aeration. It involves spreading excavated contaminated soil in a thin layer (with or without a liner) over the ground surface and monitoring the natural degradation of petroleum constituents until cleanup levels are met. Depending on site conditions, landspreading may work on soils contaminated with gasoline or lightly contaminated with some types of diesel petroleum products. Landspreading operations should not be conducted on slopes greater than 5% and need to be designed to prevent surface water accumulation and to minimize runoff and erosion.

### *Bioventing*

Bioventing is an in-situ technology that enhances the activity of indigenous microorganisms by inducing air or oxygen flow into the unsaturated zone using either injection or extraction wells. In some cases, nutrients may be added. The microorganisms biodegrade organic constituents adsorbed to soils in the unsaturated zone; soils in the capillary fringe and the saturated zone are not affected. This technique can treat aerobically biodegradable constituents and is most often used at sites with mid-weight petroleum products such as diesel fuel and jet fuel (EPA, 1997a).

### *Soil Washing*

Soil washing is a technique that removes petroleum hydrocarbons from the soil by actively leaching the contaminants from the soil into a leaching medium. The extracted contaminants can then be removed from the washing fluid by conventional treatment methods. Soil washing with surfactants or solvents can achieve acceptable residual petroleum hydrocarbon levels for soil. However, the washing process can result in large amounts of wastewater that must be managed. It may be difficult to treat soils with a high percentage of silts and clays or organic matter and achieve corrective action goals.

### *Solidification and fixation*

Solidification and fixation are processes whereby additives are mixed into contaminated soil to immobilize the contaminants in the soil. The petroleum hydrocarbons become chemically and/or physically bound into the resulting mixture, limiting the solubility or leachability of a contaminant.

Solidification and fixation usually refers to the use of cementing agents that transform contaminated soil into freestanding, relatively impermeable blocks. It is important that the reuse of the treated material be for a *beneficial* purpose. If not, the treated material must be disposed of in accordance with 18 AAC 60. Examples of beneficial reuse include aggregate for concrete, road base course, building foundation fill, and parking lot base course. Beneficial reuse must occur in an area that is at least six feet above the seasonal high water table. Examples of use that are *not beneficial* include nonstructural fill, stockpiles, and wetlands fill.

#### *Thermal desorption*

This method is effective for treating most types of petroleum contaminants, although higher temperatures are needed to remove less volatile hydrocarbons from soil. Thermal desorption employs both permanent and mobile units. These technology uses a rotary kiln heated to 300° to 700° F to volatilize hydrocarbons from contaminated soil. Some petroleum hydrocarbons will remain in the soil depending on soil temperature, moisture content, texture, time in the unit, contaminant type and contaminant concentration. The emissions are oxidized in an afterburner to prevent discharge of large quantities of unburned hydrocarbons into the atmosphere.

Silty soil creates significant operational problems for thermal treatment systems because of dust generation and baghouse limitations. Large debris often cannot be processed in the thermal desorption unit and may need to be segregated and addressed separately.

#### *Vapor extraction systems*

Vacuum extraction is a remediation method that decreases petroleum product concentrations in soil by forcing airflow through contaminated soil. Contaminants move from the soil into the air stream. As the air exits the soil, it is either discharged to the atmosphere or treated to remove the contaminants before discharge.

Vacuum extraction works best with highly volatile contaminants in a uniform soil horizon with a low organic content. The method is not generally as effective for use with heavy fuels or long chain hydrocarbons. All vacuum extraction systems must have a system that monitors the explosive limit of vapor exiting the system. Whenever 20% of the lower explosive limit (LEL) is reached, the system must automatically shut down. All vacuum extraction systems must comply with local fire codes and city and borough regulations.

Vapor extraction involves the forced withdrawal or injection of air into subsurface soils to promote the volatilization of hydrocarbons. Contaminants move from the soil into the air stream. As the air exits the soil, it is either discharged directly to the atmosphere or treated to remove the contaminants before discharge. Vapor extraction works best for sites with petroleum products that have boiling points less than 300 degrees C. in a uniform soil horizon with low organic content. Vapor extraction can be performed in-situ or in a prepared cell.

#### In-situ vapor extraction

In-situ vapor extraction involves installing vertical or horizontal piping in the area of soil contamination. An air blower is then used to draw vapors out from the subsurface. In-situ vapor extraction should be used for volatile contaminants only in areas where soil permeability allows

easy vapor movement. Permeability will affect well spacing. The amount of soil organic matter and soil moisture will also affect the ease of stripping volatiles.

In-situ vapor extraction systems can be a series of wells, some type of French drain system buried in the contaminated area, or any other mechanical structure designed to push or pull air through the contaminated area.

Use of explosion proof equipment and automatic shutoff devices that will shut down the system is recommended if the atmosphere inside the treatment building exceeds 20 percent of the lower explosive limit (LEL).

#### Prepared cell vapor extraction

This technology is similar to in-situ vapor extraction. Prepared cell vapor extraction involves excavating the contaminated soil and placing it in treatment cells. Perforated pipes are placed within the treatment cells. The treatment cells are entirely enclosed by a liner and air is forced through the perforated pipes with blowers. Treatment cell venting can be effective for most of the year and can be done during periods of wet weather.

Like in-situ vapor extraction, prepared cell vapor extraction should be used for volatile contaminants. The amount of soil organic matter and soil moisture will also affect the ease of stripping volatiles.

### **Groundwater Technologies**

#### *Air sparging*

Air sparging involves the injection of air into the subsurface below the groundwater surface to volatilize hydrocarbon or other constituents dissolved in the groundwater and adsorbed to the soil. The volatilized hydrocarbon constituents are then removed from the vadose zone with vapor extraction wells. In addition to volatilizing petroleum contaminants, air sparging increases groundwater dissolved oxygen levels, which increases biological activity leading to in-situ destruction of contaminants.

This technology is optimized in homogenous soils with high permeability and should be used only for volatile contaminants. However, introducing oxygen enhances biodegradation of heavier chain compounds such as diesel.

It is essential that a detailed site characterization is completed and that it defines any preferential flow paths that might exist. Failure to properly characterize a site and design a treatment system could result in vapor migration to areas that can result in serious safety considerations (for example, basements or crawl spaces can collect vapors and present an explosion hazard). Special consideration should be given to areas without a significant vadose zone.

#### *Groundwater pump and treat*

Groundwater pump and treat is used when groundwater beneath a site is contaminated with petroleum. Contamination may be in the form of free product floating on the water table or petroleum constituents dissolved in the water. Any free product should be removed as soon as possible.

For dissolved phase contamination, groundwater is extracted, treated, and disposed. Several types of treatment could be used depending on the type and concentration of the contaminant and the site conditions. Some of the possible treatment technologies include oil/water separators, air strippers, activated carbon, and bioremediation or some combination (such as using an air stripper and activated carbon for volatile organic compounds and an oil/water separator for heavier end contaminants). Disposal options for extracted groundwater include discharging to surface water, groundwater (re-injection), a sewer system, and an industrial wastewater treatment facility. A permit may be required before discharge of any extracted water.

### *Monitored Natural Attenuation*

Natural attenuation is the reduction in the concentration and mass of hazardous substances due to naturally occurring physical, chemical and biological processes without human intervention. These processes include, but are not limited to, dispersion, diffusion, sorption, retardation, and degradation processes such as biodegradation. Other terms associated with natural attenuation in the literature include “intrinsic remediation”, “intrinsic bioremediation”, “passive bioremediation”, “natural recovery”, and “natural assimilation”.

Under appropriate field conditions, benzene, toluene, ethyl benzene, and xylenes (BTEX) may degrade through microbial activity and ultimately produce non-toxic products such as carbon dioxide and water. Where microbial activity is sufficiently rapid, the dissolved BTEX contaminant plume may stabilize (*i.e.*, stop expanding), and contaminant concentrations may eventually decrease to levels below regulatory cleanup levels.

Following degradation of a dissolved BTEX plume, a residue consisting of heavier petroleum hydrocarbons of relatively low solubility and volatility will typically be left behind in the original source (spill) area. Although this residual contamination may have a lower potential for further migration, it still may pose a threat to human health, safety, welfare or the environment either from direct contact with soils in the source area or by continuing to slowly leach contaminants to groundwater. For these reasons, monitored natural attenuation alone is generally not sufficient to cleanup a petroleum release site.

Source control measures usually need to be implemented in conjunction with natural attenuation processes. Other controls such as institutional controls may also be necessary to ensure protection of human health, safety, welfare and the environment.

Performance monitoring is a critical element for a natural attenuation strategy to evaluate cleanup effectiveness and to ensure protection of human health, safety, welfare and the environment. The monitoring program developed for each site should specify the location, frequency, and type of samples and measurements necessary to evaluate remedy performance and define the anticipated performance objectives of the remedy. Performance monitoring should continue as long as contamination remains above required cleanup levels.

Typically, monitoring is continued for a specified period (*e.g.*, one to three years) after cleanup levels have been achieved to ensure that concentration levels are stable and remain below cleanup levels. The mechanisms for maintaining the monitoring program should be clearly

established in the cleanup decision or other site documents, as appropriate. Details of the monitoring program should be provided to DEC as part of any proposed natural attenuation remedy. For more information, refer to the ADEC guidance "*Guidance on the Selection of Natural Attenuation as a Cleanup Alternative for the Restoration of Soil and Ground Water at Contaminated Sites*" (ADEC, 2000c). Another reference to consult is the EPA guidance "*Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks Sites*" (EPA, 1997b).

## REFERENCES

ADEC, 1992 Recommended Practices for Monitoring Well Design, Installation, and Decommissioning, Final, Alaska Department of Environmental Conservation, April 1992.

ADEC, 1998. Guidance on Fate and Transport Modeling, Alaska Department of Environmental Conservation, Contaminated Sites Remediation Program, June 1998.

ADEC, 1999. Guidance on Cleanup Levels Equations and Input Parameters, Alaska Department of Environmental Conservation, Contaminated Sites Remediation Program, July 1999.

ADEC, 2000a. Handbook for Conducting Cleanups of Contaminated Sites and Regulated Underground Storage Tanks under the Voluntary Cleanup Program, March 2000.

ADEC, 2000b. Risk Assessment Procedures Manual, Alaska Department of Environmental Conservation, Contaminated Sites Remediation Program, June 2000.

ADEC, 2000c. Guidance on the Selection of Natural Attenuation as a Cleanup Alternative for the Restoration of Soil and Ground Water at Contaminated Sites, January 2000.

API, 1996. A guide to the Assessment and Remediation of Underground Petroleum Releases, API Publication 1628 Third Edition, July 1996, American Petroleum Institute, 1220 L Street, Northwest, Washington, D.C. 20005-4070

EPA, 1995a. EPA/540/S-95/500 1995, Ground Water Issue: Light Nonaqueous Phase Liquids, Newell, C. J., S. D. Acree, R. R. Ross, and S. G. Huling, Office of Research and Development and Office of Solid Waste and Emergency Response, Washington DC 20460

EPA, 1995b. EPA/510-B-95-007 May 1995, How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites, A Guide for Corrective Action Plan Reviewers, Solid Waste and Emergency Response, Washington DC 20460

EPA, 1996a. EPA/540/R-95/128 May 1996, Soil Screening Guidance: Technical Background Document, Office of Emergency and Remedial Response, Washington DC 20460

EPA, 1996b. EPA/510-R-96-001 September 1996, How to Effectively Recover Free Product At Leaking Underground Storage Tank Sites, A Guide for State Regulators, Solid Waste and Emergency Response, Washington DC 20460

EPA, 1997a. EPA/510-B-97-001 March 1997, Expedited Site Assessment Tools For Underground Storage Tank Sites, A Guide for Regulators, Solid Waste and Emergency Response, Washington DC 20460

EPA, 1997b. EPA OSWER Directive 9200.4-17 November 1997, Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks Sites, Office of Solid Waste and Emergency Response, Washington DC 20460

TPHCWG, 1998a. Total Petroleum Hydrocarbon Criteria Working Group, 1998, Volume 3, Selection of Representative TPH Fractions Based on Fate and Transport Considerations, Amherst Scientific Publishers, Amherst, MA

TPHCWG, 1998b. Total Petroleum Hydrocarbon Criteria Working Group, 1998, Volume 4, Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH), Amherst Scientific Publishers, Amherst, MA



## APPENDIX A: Background information about method two

DEC established method two soil cleanup levels after reviewing guidance provided by the U.S. Environmental Protection Agency, the American Petroleum Institute, and other states. DEC also evaluated concepts such as the indicator/surrogate approach developed by the Total Petroleum Hydrocarbon (TPH) Criteria Working Group. The goal of the TPH Criteria Working Group was to develop scientifically defensible information for establishing soil cleanup levels that are protective of human health at petroleum contaminated sites.

### Indicators

The indicators are specific contaminants within petroleum that are evaluated individually. Laboratory analytical techniques can isolate these contaminants to measure their individual concentrations in environmental media. Available toxicological information for each indicator compound was used to determine cleanup levels. Indicator contaminants are listed in the following table:

**Table 5: Indicator Contaminants for Petroleum Contaminated Sites**

Indicator Contaminants	
<p><i>Volatiles (BTEX)</i></p> <ul style="list-style-type: none"> <li>benzene</li> <li>toluene</li> <li>ethylbenzene</li> <li>xylene</li> </ul> <p><i>Polynuclear Aromatic Hydrocarbons (PAHs)</i></p> <ul style="list-style-type: none"> <li>anthracene</li> <li>acenaphthene</li> <li>benzo(a)pyrene</li> <li>pyrene</li> <li>naphthalene</li> <li>chrysene</li> <li>indeno(1.,2,3,-cd)pyrene</li> <li>benzo(k)fluoranthene</li> <li>fluorene</li> <li>benzo(b)fluoranthene</li> <li>benzo(a)anthracene</li> <li>dibenzo(a, h)anthracene</li> </ul>	<p><i>Inorganic Compounds as required on a case by case basis</i></p> <ul style="list-style-type: none"> <li>arsenic</li> <li>barium</li> <li>cadmium</li> <li>chromium</li> <li>lead</li> <li>nickel</li> <li>vanadium</li> </ul> <p><i>Others as needed on a case by case basis</i></p> <ul style="list-style-type: none"> <li>ethylene dibromide (EDB)</li> <li>1,2 dichloroethane (EDC)</li> <li>methyl-1tert-butyl-ether(MTBE)</li> <li>chlorinated solvents</li> </ul>

### Surrogates

The surrogate approach refers to the risk analysis of “surrogate” factors, each presumed to represent potential noncarcinogenic toxic effects for a particular range or fraction of

hydrocarbons within petroleum. During laboratory analysis of petroleum, contaminated media, concentrations of distinct petroleum ranges (fractions) are measured. The cleanup level for each petroleum fraction is based on a value developed for the corresponding surrogate compound.

For the ingestion pathway, cleanup levels for petroleum fractions are derived using the fraction specific surrogate compound's reference dose. For the inhalation pathway, cleanup levels are derived using the fraction specific surrogate compound's reference concentration. A reference dose (RfD) is an estimate of daily exposure to the human population, including sensitive subgroups that is likely to be without appreciable risk of deleterious effects over the exposure period. A reference concentration (RfC) is an estimate of continuous inhalation exposure to the human population, including sensitive subgroups that is likely to be without appreciable risk of deleterious effects over the exposure period.

Based on fate and transport properties, the TPH Criteria Working Group recommended more than a dozen different surrogate fractions (TPHCWG, 1998a). As DEC had previously defined three hydrocarbon ranges for laboratory analytical protocols already used at numerous sites in Alaska, DEC elected to develop cleanup levels using the following three petroleum carbon ranges:

- C<sub>6</sub> - C<sub>10</sub> (gasoline range organics);
- C<sub>10</sub> - C<sub>25</sub> (diesel range organics); and
- C<sub>25</sub> - C<sub>36</sub> (residual range organics).

Gasoline range organics (GRO) includes light-range petroleum products such as gasoline, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of C<sub>6</sub> to the beginning of C<sub>10</sub> and a boiling point range between approximately 60° Centigrade and 170° Centigrade.

Diesel range organics (DRO) includes mid-range petroleum products such as diesel fuel, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of C<sub>10</sub> to the beginning of C<sub>25</sub> and a boiling point range between approximately 170° Centigrade and 400° Centigrade.

Residual range organics (RRO) includes heavy-range petroleum products such as lubricating oils, with petroleum hydrocarbon compounds corresponding to an alkane range from the beginning of C<sub>25</sub> to the beginning of C<sub>36</sub> and a boiling point range between approximately 400° Centigrade and 500° Centigrade.

These ranges are readily quantifiable by State of Alaska laboratory methods--the Alaska Series petroleum methods -- AK101, AK102, and AK103. Each GRO, DRO, and RRO carbon range was further subdivided into its aliphatic and aromatic components--for a total of six surrogate petroleum fractions.

Based on recommendations of the TPH Working Group series (TPHCWG, 1998b), DEC selected the following reference doses and reference concentrations to estimate the potential noncarcinogenic toxicity of each petroleum fraction.

**Table 6: Petroleum Hydrocarbon Toxicity and Surrogate Fractions**

<b>Petroleum Hydrocarbon Toxicity and Surrogate Fractions*</b>						
Fraction-Specific Oral Reference Doses (RfDs) and Inhalation Reference Concentrations (RfCs)						
<b>CARBON RANGE</b>	<b>Aromatic Oral RfD</b>  <b>mg/kg-day</b>	<b>Aromatic Inhalation RfC</b>  <b>mg/m<sup>3</sup></b>	<b>Critical Effect</b>	<b>Aliphatic Oral RfD</b>  <b>mg/kg-day</b>	<b>Aliphatic Inhalation RfC</b>  <b>mg/m<sup>3</sup></b>	<b>Critical Effect</b>
GRO C <sub>6</sub> – C <sub>10</sub>	0.20	0.4	Hepatotoxicity Nephrotoxicity	5.0	18.4	Neurotoxicity
DRO C <sub>10</sub> - C <sub>25</sub>	0.04	0.2	Decreased body weight	0.1	1.0	Hepatic & hematological changes
RRO C <sub>25</sub> - C <sub>36</sub>	0.03	NA	Nephrotoxicity	2.0	NA	Hepatic granuloma

\* Based on TPH Criteria Working Group recommendations listed in Table 1 of the *Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH)*, Volume IV in a series.

Physical and Chemical Properties of Petroleum Hydrocarbon Fractions  
The parameter values for the petroleum hydrocarbon fractions are shown below.

**Table 7: Chemical Specific Parameters for Petroleum Hydrocarbons**

<p><b>EQUIVALENT CARBON NUMBER (EC)</b> <math>EC = 4.12 + 0.02(BP) + 0.000065(BP)^2</math></p> <p><b>SOLUBILITY, S (mg/L)</b> <i>aliphatics</i> <math>\log_{10} S = [-0.21][EC] + 3.7</math> <i>aromatics</i> <math>\log_{10} S = [-0.55][EC] + 4.5</math></p> <p><b>HENRY'S LAW CONSTANT, H' (unitless)</b> <i>aliphatics</i> <math>\log_{10} H = [0.02][EC] + 1.6</math> <i>aromatics</i> <math>\log_{10} H = [-0.23][EC] + 1.7</math></p> <p><b>ORGANIC CARBON PARTITION COEFFICIENT, Koc (ml/g)</b> <i>aliphatics</i> <math>\log_{10} Koc = [0.45][EC] + 0.43</math> <i>aromatics</i> <math>\log_{10} Koc = [0.10][EC] + 2.3</math></p>					
<b>Hydrocarbon Range</b>	<b>Equivalent Carbon Number (range)</b>	<b>Solubility (range)</b>	<b>Unitless Henry's Law Constant (range)</b>	<b>Koc</b>	
C <sub>6</sub> -C <sub>10</sub> Aliphatics	8 (5.6 to 9.4)	1.3 (0.2 to 28)	57.5 (51.4 to 55.7)	10,715 (850 to 45,638)	
C <sub>6</sub> -C <sub>10</sub> Aromatics	8 (5.6 to 9.4)	105 (53 to 342)	0.7 (0.3 to 2.6)	1,259 (717 to 1,737)	
C <sub>10</sub> -C <sub>25</sub> Aliphatics	14 (9.4 to 22.5)	0.0006 (0.2 to 1.3E-8)	75.9 (61.4 to 112.3)	5.37 E+6 (4.6E+4 to 3.6E+10)	
C <sub>10</sub> -C <sub>25</sub> Aromatics	14 (9.4 to 22.5)	5.8 (0.09 to 53.2)	0.03 (0.0003 to 0.3)	5012 (1,737 to 35,645)	
C <sub>25</sub> -C <sub>36</sub> Aliphatics	30.5 (22.5 to 30.5)	5.3E-13 (1.3E-8 to 6.3 E-13)	162.2 (112.3 to 162.2)	n/a	
C <sub>25</sub> -C <sub>36</sub> Aromatics	30.5 (22.5 to 30.5)	0.002 (0.09 to 0.002)	4.8E-6 (3.3E-4 to 5.29E-6)	2.2 E+5 (3.6 E+4 to 2.2 E+5)	

n/a = Not applicable

*Equivalent Carbon Number (EC)*

The TPH Criteria Working Group developed use of the equivalent carbon number for the fractionation methodology (TPHCWG, 1998a). It is an empirically determined relationship based on the boiling point of a chemical normalized to the boiling point of the n-alkanes or its retention time in a boiling point gas chromatographic (GC) column. It is consistent with methods routinely used in the petroleum industry for separating complex mixtures and it is typically how analytical laboratories report carbon numbers for chemicals evaluated on a boiling point GC column.

Modeling of subsurface transport of chemicals is difficult for petroleum mixtures because they contain large numbers of individual compounds. To simplify modeling, the TPH Criteria Working Group grouped hydrocarbon compounds into fractions with similar transport properties. The following equation was used by the TPH Criteria Working Group to estimate the EC for thirteen fractions.

$$EC = 4.12 + 0.02(BP) + 0.000065(BP)^2$$

Where EC = Equivalent Carbon Number  
BP = Boiling Point in degrees Centigrade

The following thirteen hydrocarbon equivalent carbon fractions were developed and evaluated by the TPH Criteria Working Group.

<u>Aromatic EC Number Range</u>	<u>Aliphatic EC Number Range</u>
C <sub>5</sub> – C <sub>7</sub>	C <sub>5</sub> – C <sub>6</sub>
C <sub>7</sub> – C <sub>8</sub>	C <sub>6</sub> – C <sub>8</sub>
C <sub>8</sub> – C <sub>10</sub>	C <sub>8</sub> – C <sub>10</sub>
C <sub>10</sub> – C <sub>12</sub>	C <sub>10</sub> – C <sub>12</sub>
C <sub>12</sub> – C <sub>16</sub>	C <sub>12</sub> – C <sub>16</sub>
C <sub>16</sub> – C <sub>21</sub>	C <sub>16</sub> – C <sub>21</sub>
C <sub>21</sub> – C <sub>35</sub>	

Instead of the thirteen fractions recommended by the TPH Criteria Working Group, DEC grouped hydrocarbons into six fractions, three aromatic fractions and three aliphatic fractions. This was done as a practical matter to allow continued use of existing laboratory methods and to split the existing Alaska Method 101, 102, and 103 carbon ranges (GRO, DRO, and RRO) into aromatic and aliphatic components. DEC set cleanup levels for the following six hydrocarbon fractions, and set cleanup levels for the combined fractions.

<u>Aromatic fraction</u>	<u>Aliphatic fraction</u>	<u>Combined</u>
C <sub>6</sub> – C <sub>10</sub>	C <sub>6</sub> – C <sub>10</sub>	C <sub>6</sub> – C <sub>10</sub> GRO
C <sub>10</sub> – C <sub>25</sub>	C <sub>10</sub> – C <sub>25</sub>	C <sub>10</sub> – C <sub>25</sub> DRO
C <sub>25</sub> – C <sub>36</sub>	C <sub>25</sub> – C <sub>36</sub>	C <sub>25</sub> – C <sub>36</sub> RRO

DEC also defined the equivalent carbon number differently than the TPH Criteria Working Group. For the aliphatic and aromatic fractions in the C<sub>6</sub>-C<sub>10</sub> and C<sub>25</sub>-C<sub>36</sub> ranges, the equivalent carbon number was set at the average carbon number within the respective ranges. Because of the large range and variable transport properties of hydrocarbons in the C<sub>10</sub>-C<sub>25</sub> range, the equivalent carbon number was set at 14, weighted slightly towards the lighter, more mobile end of the carbon range.

#### *Henry's Law Constant*

The Henry's law constant, H, is an air-water partition coefficient measured as the ratio of a compound's concentration in air to its concentration in water at equilibrium. It is calculated by taking the ratio of vapor pressure to aqueous solubility. Henry's law applies to dilute solutions where the concentration of a chemical in water is less than the chemical's water solubility concentration. The relationship may not be valid when petroleum concentrations approach saturation levels in soil. Volatile emissions reach their maximum at C<sub>sat</sub> and will not increase above this level no matter how much more chemical is added to the soil (EPA, 1996a). C<sub>sat</sub> indicates a potential for nonaqueous phase liquid to be present in soil and a possible risk to ground water.

The dimensionless Henry's law constant was calculated as follows:

$$H = (VP \times MW) \div (S \times R \times T);$$

Where H	= Henry's law constant (dimensionless)
VP	= Vapor pressure
MW	= Molecular weight
S	= Solubility in water
R	= Universal gas constant (8.25 x 10 <sup>-5</sup> atm m <sup>3</sup> /mol)
T	= Temperature (K)

The TPH Criteria Working Group established fraction-specific values for various petroleum hydrocarbon ranges using the following equations.

$$\text{For aliphatics, } \log_{10} H = 0.02 (EC) + 1.56$$

$$\text{For aromatics, } \log_{10} H = -0.23 (EC) + 1.66$$

Where H	= Henry's Law Constant
EC	= Equivalent Carbon Number

#### *Organic Carbon Partition Coefficient (Koc)*

The organic carbon partition coefficient, Koc, measures the tendency of organic chemicals to be adsorbed to soil due to the organic carbon content of the soil. Generally, aliphatics sorb more strongly to organic carbon in soils than do aromatics. The following equations were used to set the Koc values for the aliphatic and aromatic C<sub>6</sub>-C<sub>10</sub>, C<sub>10</sub>-C<sub>25</sub> and C<sub>25</sub>-C<sub>36</sub> petroleum hydrocarbon ranges based on correlation's developed by the TPH Criteria Working Group.

$$\text{For aliphatics, } \log_{10} Koc = 0.45 (EC) + 0.43$$

For aromatics,  $\log_{10} K_{oc} = 0.10 (EC) + 2.3$

Where  $K_{oc}$  = Organic Carbon Partition Coefficient  
 EC = Equivalent Carbon Number

*Diffusivity in Air*

Diffusivity in air is a measure of the diffusion or movement under the influence of a concentration gradient in a gas phase. The TPH Criteria Working Group determined that an appropriate conservative value for diffusivity in air is 0.1 cm<sup>2</sup>/sec for all petroleum fractions.

*Diffusivity in Water*

Diffusivity in water is a measure of the diffusion or movement under the influence of a concentration gradient in a water phase. The TPH Criteria Working Group determined that an appropriate conservative value for diffusivity in water is 0.00001 cm<sup>2</sup>/sec for all petroleum fractions.

Total GRO, DRO, RRO versus Aromatic/Aliphatic fractions

Table B2 soil cleanup levels using petroleum hydrocarbons (GRO, DRO, and RRO) based on Methods AK 101, 102, and 103. The Table B2 GRO, DRO, and RRO levels were derived based on assumed default percentages of aromatic and aliphatic fractions within each carbon range. The Table B2 aliphatic/aromatic fractional cleanup levels were transformed into the GRO, DRO, and RRO levels by dividing the aromatic or aliphatic cleanup level by a corresponding aromatic or aliphatic default percentage.

DEC selected the default compositions of GRO, DRO, and RRO shown in the following table.

**Table 8: Petroleum Hydrocarbon Default Compositions**

CARBON RANGE	PERCENT ALIPHATIC*	PERCENT AROMATIC*
GRO - C <sub>6</sub> - C <sub>10</sub>	70	50
DRO - C <sub>10</sub> - C <sub>25</sub>	80	40
RRO - C <sub>25</sub> - C <sub>36</sub>	90	30

\* Note - Because fuel constituents vary considerably, the default composition of the percent aliphatic and percent aromatics was set at 120% of the total.

For example, the C<sub>10</sub>-C<sub>25</sub> DRO cleanup levels for the “Over 40 Inch Zone” in Table B2 were calculated by dividing the corresponding C<sub>10</sub>-C<sub>25</sub> aliphatic level by 0.80 and also dividing the corresponding C<sub>10</sub>-C<sub>25</sub> aromatic level by 0.40. The lowest result of these two calculations became the method two C<sub>10</sub>-C<sub>25</sub> DRO cleanup level.

### Maximum Allowable Concentrations

Under method two, DEC set maximum allowable concentrations for petroleum hydrocarbons as listed in Table B2 of 18 AAC 75.341. Several of the values listed in the ingestion, inhalation, or migration to groundwater columns in Table B2 are based on maximum allowable concentrations rather than calculations using equations from the *Guidance on Cleanup Levels Equations and Input Parameters* (ADEC, 1999). DEC established maximum allowable concentrations after reviewing information provided in the American Petroleum Institute publication, *A guide to the Assessment and Remediation of Underground Petroleum Releases* (API, 1996). The maximum allowable concentrations for DRO and RRO were developed based on estimates of soil saturation in a coarse to fine sandy silt soil type. Because GRO is more mobile than DRO or RRO, the maximum allowable concentrations for GRO were developed based on estimates of soil saturation in a coarse gravel soil type.