USER GUIDE
FOR
RISK ASSESSMENT OF
PETROLEUM RELEASES

Accompanying the
*WEST VIRGINIA VOLUNTARY REMEDIATION
AND REDEVELOPMENT ACT GUIDANCE MANUAL*

Version 1.0

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Prepared for
West Virginia Division of Environmental Protection
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by
Thomas Joy, P.E. and Christopher VanCantfort, Ph.D.
WPI, 2000 Kraft Drive, Blacksburg, Virginia 26040

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USER GUIDE FOR RISK ASSESSMENT OF PETROLEUM RELEASES

Accompanying the
West Virginia Voluntary Remediation and Redevelopment Act Guidance Manual

1 Introduction

1.1 Guidance Manual

The *West Virginia Voluntary Remediation and Redevelopment Act Guidance Manual* (Guidance Manual) has been produced by the West Virginia Division of Environmental Protection's Office of Environmental Remediation (WVDEP-OER). The manual gives guidance to the West Virginia Licensed Remediation Specialist (LRS) in most aspects of the risk-based procedures needed to successfully close a site under the State's Voluntary Remediation Program (VRP). The Guidance Manual not only is broad in scope, but also addresses a complex subject. Some of the information it presents may prove challenging to the LRS who lacks familiarity with the use of risk-based procedures for evaluating a site's need for remediation and its suitability for closure.

1.2 User Guide

It is anticipated that this User Guide will reduce the time needed for the LRS to understand human health risk assessment procedures described in the Guidance Manual. In addition, the User Guide will help ensure that the LRS can correctly apply risk assessment procedures to the type of site that will be most commonly encountered. The time and effort saved when these goals are realized should decrease the cost of risk evaluation and help bring uncontrolled site risks under control in a timely fashion.

It is anticipated that simple sites with historical soil and groundwater contamination by a variety of petroleum products will be the most common candidates for the VRP. The User Guide focuses on a hypothetical abandoned service station as an example of such a site. In keeping with this focus, the User Guide provides information specific to petroleum products that is not found in the Guidance Manual. The User Guide also focuses on human health risk assessment. Ecological risk evaluation (UG 6.3) is not treated in detail in the User Guide because it is not likely to be required at the typical abandoned service station site. The human health risk assessment procedures explained in the User Guide and the contaminant-specific data that are provided apply to a wide range of petroleum-contaminated sites besides abandoned service stations. The process of site characterization is not covered in the User Guide although it is treated extensively in the Guidance Manual.

1.3 Relationship of the User Guide to the Guidance Manual

The User Guide is based on procedures explained in the Guidance Manual. Each procedural step in the User Guide is referenced to the appropriate section, table, figure, or equation of the Guidance Manual. All references to the Guidance Manual are shown in the User Guide preceded by the letters "GM" (e.g., GM 1.1). Internal references to User Guide material are preceded by the letters "UG" (e.g., UG 1.3).

1.4 User Guide Organization

The User Guide addresses the following topics:
• Contaminants of Concern (UG 2)
• Free Product (UG 3)
• Abandoned Service Station Characterization (UG 4)
• Conceptual Site Model (UG 5)
• Risk Assessment Overview (UG 6)
• Example Risk Calculations (UG 7)

2 Contaminants of Concern (GM 2.6)

Individual contaminants for which risk must be assessed are known as contaminants of concern (COCs). COCs must be determined on a site-by-site basis. COCs are selected from a list of chemicals of potential concern (COPCs) at a site as described in following sections. Data on groups of chemicals (e.g., total petroleum hydrocarbons [TPHs]) are not generally useful in the risk assessment process because available toxicity information used to estimate risk is most often restricted to individual compounds. The estimation of risk associated with exposure to compounds that are characterized as a group can be highly inaccurate or impossible and as a result is not recommended by WVDEP (GM 2.6.7.2). Although risk assessment methods based on TPH data are under development for sites where contamination by crude oil or multiple fuels is a concern, WVDEP will decide on the applicability of such methods to VRP sites on a case-by-case basis.

2.1 COC Selection

COC selection is a two-step process:
- Step 1: Identify COPCs by listing all chemicals known or suspected to have been used or stored on the site, their breakdown products, and all chemicals detected in any sample, even if detected at a level below the practical quantitation limit (PQL) for the analytical method used.
- Step 2: Screen the COPCs to determine whether any of them can be eliminated. The contaminants that remain after this evaluation are the COCs.

2.2 Eliminating COPCs

Acceptable reasons for eliminating a COPC are listed and explained in the Guidance Manual. They include
- field or laboratory contaminants (GM 2.6.1),
- low concentrations (GM 2.6.2.1),
- low frequency of detection (GM 2.6.2.2),
- unusually high sample quantitation limits (GM 2.6.3),
- comparison to background (GM 2.6.4), and
- substances that are evaluated as essential nutrients (GM 2.6.5).

COPCs may be eliminated for other reasons upon approval of WVDEP.

2.3 Documenting the COC Selection Process

The risk assessment section of the final report should
- list all COPCs identified,
- document the process of identifying the COPCs,
- describe how the elimination of any COPC was justified by the acceptable reasons or any combination of the acceptable reasons listed in UG 2.2, and
- list all COCs.

2.4 Occurrence of COCs in Fuels, Motor Oil, and Antifreeze

Individual petroleum products generally consist of numerous COPCs, sometimes exceeding 100 in number. Most of these chemical substances occur naturally in refined petroleum, but some are added (e.g., methyl tert-butyl ether and tetraethyl lead) to enhance product performance. While many of these are present at release sites, not all are considered COCs. In addition to reasons outlined in UG 2.2, COPCs may be excluded from COC listing because
- they are not detected by standard site characterization methods,
- their toxicity is considered minor in comparison to other COPCs,
- their toxicity is unknown, or
- their chemical or physical properties are not understood well enough to permit their inclusion in a risk assessment.

The User Guide discusses all contaminants as though they have been determined to be COCs. Table 2-1 lists the COCs usually associated with petroleum and antifreeze releases. They include volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), wear metals, and additives. Used antifreeze generally contains ethylene glycol as well as metals originating from engine cooling systems.

The following discussion identifies the COCs for petroleum sites based on current knowledge or information. *The LRS should confirm that additional chemicals have not become appropriate as COCs at the time a site undergoes assessment.*

2.4.1 COCs in Diesel, Kerosene, and Gasoline
COCs in diesel, kerosene, and gasoline (leaded and/or unleaded) include the following:
• Benzene (a carcinogen), toluene, ethylbenzene, and xylenes: VOCs collectively known as BTEX.
• MTBE: VOC used as an additive to gasoline. (See UG Discussion 2-3)
• Lead: This metal will not be present as a result of releases of gasoline manufactured after 1989 but may be present at sites contaminated with gasoline manufactured prior to that date, such as abandoned service stations. (See UG Discussion 2-4)
• SVOCs: Polycyclic aromatic hydrocarbons (PAHs) occur in diesel and kerosene, and in lesser amounts in gasoline. (See UG Discussion 2-1) Some [e.g., benzo(a)pyrene] are carcinogenic.

2.4.2 COCs in Used Motor Oil
COCs in used motor oil include the following:
• PAHs: Found at much higher concentrations in motor oil than in fuels. (See UG Discussion 2-1)
• Lead, cadmium, other metals: These wear metals abrade from the motor's moving parts.

2.4.3 COCs in Antifreeze
COCs in antifreeze include the following:
• Ethylene glycol: This compound is an SVOC. It is not a naturally occurring petroleum constituent. (See UG Discussion 2-2)
• Metals: Cooling system operation and corrosion can introduce metals into used antifreeze. (See UG Discussion 2-2)

2.4.4 COCs Likely to Be Encountered at a Typical Abandoned Service Station
The COCs most likely to be encountered at a typical site due to releases of petroleum products and antifreeze are listed in UG Table 2-1. Table 2-1 should be used with caution. As stated in UG 2, COCs must be determined on a site-by-site basis.

In addition to the COCs listed in UG Table 2-1, nonpetroleum-based COPCs originating from products such as parts-cleaner solvent, paint stripper, and paints may be encountered at abandoned service station sites. The Guidance Manual provides instruction on how to evaluate the risk posed by all types of COCs.

Table 2-1. COCs Likely to Be Encountered Due to Petroleum and Antifreeze Releases

VOCs	SVOCs		Metals[a]
	PAHs	**Non-PAHs**	
Benzene[b]	Acenaphthene	Ethylene glycol	Cadmium
Ethylbenzene	Acenaphthylene		Chromium(III)
Toluene[b]	Anthracene		Chromium(VI)
m-Xylene	Benzo(a)anthracene		Lead
o-Xylene	Benzo(a)pyrene[b]		
p-Xylene	Benzo(b)fluoranthene		
Methyl tert-butyl ether	Benzo(g,h,i)perylene		
	Benzo(k)fluoranthene		
	Chrysene		
	Dibenzo(a,h)anthracene		
	Fluoranthene		
	Fluorene		
	Indeno(1,2,3-c,d)pyrene		
	Naphthalene[b]		
	Phenanthrene		
	Pyrene		

[a]Various metals have been detected in used motor oil (Toxicological Profile for Mineral-Based Crankcase Oil, Agency for Toxic Substances and Disease Registry, September 1997). The ones listed here occur most commonly and have toxicity that is of greatest concern (Environmental Regulations and Technology: Managing Used Motor Oil, USEPA, EPA/625/R-94/010, December 1994). The LRS should characterize all metals associated with a used oil release and, using the procedures described in UG 2.2, determine whether individual metals should be excluded as COCs at a site.

[b]COC used as example for risk assessment (UG 7).

2.5 Typical Distribution of Petroleum Products and Their COCs in Environmental Media

Risk evaluation requires the identification of routes by which COCs might move through environmental media to reach receptors. For several reasons, not all exposure routes are probable for all contaminants. Not only are fuels and used motor oils typically stored differently; their COC compositions are different, and their constituent COCs have differing physical properties. These factors largely determine the media in which the COCs of a particular petroleum product are most likely to occur at a typical abandoned service station site and thus their significant and potentially significant exposure routes. This User Guide considers the occurrence of COCs from fuels and used motor oil in the following media:

• Surface soils
• Subsurface soils
• Groundwater
• Ambient air
• Indoor air

Because surface water and sediment are not likely to be present at a typical abandoned service station site, the occurrence of fuel and used motor oil COCs in these media is not considered in the User Guide. The LRS should determine whether exceptional circumstances (e.g., extremely porous surface soil or karst) exist at a site that might override or alter the generalizations concerning the environmental distribution of petroleum products and COCs described below.

2.5.1 Used Motor Oil Contamination in Surface Soils

At a typical abandoned service station site, significant petroleum contamination found in surface soils (defined as the upper 2 feet of soil) is likely to be the result of releases of used motor oil, rather than releases of gasoline, diesel, or kerosene. This is true for several reasons. Used motor oil is generally (but not always) stored in aboveground containers. Therefore, most used motor oil contamination results from surface releases. Once released on the surface, motor oil is unable to penetrate most soils to any appreciable depth due chiefly to its high viscosity. Its constituent metals and most of its constituent PAHs (with the exception of naphthalene [See UG Discussion 2-1]) have low volatility, low solubility, and a strong affinity for soil particles. They tend to remain in surface soils rather than volatilize into the atmosphere or dissolve into water infiltrating downward from the surface.

Discussion 2-1. Naphthalene and PAHs: Physical Properties and Occurrence

PAHs are a class of compounds that are found in varying amounts in petroleum products. They are present in low amounts in gasoline and somewhat higher amounts in diesel and kerosene and are a significant component of oils. There may be upwards of 100 different PAHs in petroleum products, but, depending on the analytical method used, only 16 to 21 are measured in site characterization samples. PAHs are substances with multiple rings in their chemical structures. The environmental fate and transport of an individual PAH is related to the number of rings in its structure. The majority of PAHs have four or more rings. Five of the commonly measured PAHs have three rings (i.e., acenapthene, acenapthylene, anthracene, fluorene, and phenanthrene). One PAH (naphthalene) has two rings. Other two-ring PAHs (e.g., methylnaphthalenes) are present in petroleum products but are not detected individually by standard site-characterization analytical methods.

PAHs with four or more rings have very low water solubility and very low volatility, are strongly sorbed to soil, and resist chemical and biological degradation. Unless mobilized in free product, PAHs with four or more rings tend not to move from their point of release in soil. Three-ring PAHs are somewhat more mobile in soil than higher-ring-number PAHs but are still relatively resistant to movement in soil in comparison to VOCs like BTEX and chlorinated hydrocarbon solvents.

Naphthalene, with only two rings, has appreciable water solubility and volatility and is only moderately sorbed to soil. These properties indicate that naphthalene has a potential to move through soil and to contaminate groundwater more like a VOC than other PAHs. Thus, more than with other PAHs typically encountered at petroleum (oil or fuel) release sites, particular attention often needs to be paid to naphthalene's potential to contaminate groundwater and to the potential risks associated with such contamination. The User Guide highlights these potential concerns where appropriate. The LRS should carefully evaluate naphthalene contamination when PAHs are known or suspected to be present at a site.

As a general rule, risk assessments for used motor oil constituents in surface soils would consider only potential exposure pathways that include the ingestion of COCs present in surface soils, the inhalation of COCs sorbed to airborne dust particles originating from surface soils, and dermal exposure arising from contact of contaminated surface soil with skin. Where a large, recent release has occurred, naphthalene volatilization to ambient air should also be considered. If large or very prolonged surface releases of used motor oil have occurred, it may be appropriate to investigate the potential for the oil to have moved below the top 2 feet of soil and to consider whether oil COCs (particularly naphthalene) may have migrated to groundwater.

2.5.2 Antifreeze Contamination in Surface Soils

Antifreeze contamination generally results from surface releases due to spills and overfills or leaks of used antifreeze from surface storage containers. Because of its low viscosity, antifreeze has much greater ability to penetrate surface soils than does motor oil. Sufficiently large releases may penetrate to the subsurface and reach groundwater. Ethylene glycol, antifreeze's most important constituent COC does not sorb readily to soil particles, and it biodegrades rapidly, making it unlikely to be found in surface soils at the typical abandoned service station. Metals originating from cooling system components may be

encountered where used antifreeze has been released. See UG Discussion 2-2 for additional information on ethylene glycol.

Discussion 2-2. Ethylene Glycol: Physical Properties and Occurrence

Ethylene glycol has historically been the primary ingredient in antifreeze. While other ingredients (e.g., propylene glycol) have recently been introduced as supplements to or replacements for ethylene glycol, it remains the organic chemical of greatest concern with respect to releases of antifreeze to the environment. Used antifreeze may also be contaminated by metals from cooling system components. The amount of metals that may be present in used antifreeze can range from enough to qualify it as hazardous waste to virtually none and is highly dependent on a given batch's use and history.

Ethylene glycol is miscible with water, has very low soil organic matter (K_{oc}) and octanol/water (K_{ow}) partition coefficients, and low vapor pressure (low volatility). These physical properties suggest that ethylene glycol will not sorb strongly to soil and has the potential to contaminate groundwater. However, this potential is mitigated by the fact that ethylene glycol is very rapidly biograded in soil. Ethylene glycol would not be expected to be found in surface soils as a result of historical releases. The potential for ethylene glycol to be present in subsurface soil and groundwater will depend on the age and magnitude of a given release.

There is currently no drinking water standard (Maximum Contaminant Level [MCL] or Maximum Contaminant Level Goal [MCLG]) for ethylene glycol. The U.S. Environmental Protection Agency (USEPA) has not formally classified the carcinogenicity status of ethylene glycol, but studies to date suggest that it is not carcinogenic. USEPA's Integrated Risk Information System (IRIS) database does not list a cancer slope factor but does contain an oral reference dose value. This value (UG Table 6-5) can be used to evaluate ingestion exposure risks using either Uniform or Site-Specific risk-based equations as outlined for noncarinogenic SVOCs in UG 7.

Reference
Agency for Toxic Substances and Disease Registry. 1997. *Toxicological Profile for Ethylene Glycol and Propylene Glycol.*

2.5.3 Fuel Contamination in Surface Soils

Although gasoline, diesel, and kerosene are generally stored in USTs, they can contaminate surface soils when spills or overfills occur. Typically, such releases are small, but they may occur intermittently over long periods of time. The VOCs found in these fuels (i.e., BTEX and MTBE [See UG Discussion 2-3 for specific information on MTBE]) are rarely encountered in surface soils at the typical abandoned service station site. BTEX and MTBE are rapidly removed from surface soils by volatilization and biodegradation and by dissolution into water percolating downward from the surface. PAHs may be present in surface soils as a result of fuel spills and overfills, but unless there has been an extremely large or continuous release, they rarely occur in environmentally significant concentrations and are not generally considered in risk evaluations. Naphthalene in surface soils is likely to be removed by the same mechanisms that remove VOCs.

Discussion 2-3. MTBE: Physical Properties and Occurrence

MTBE is a chemical that is often added to gasoline to improve combustion efficiency and reduce engine emissions. It is the most commonly used member of a family of gasoline additives known as "oxygenates" and is the oxygenate most likely to be encountered at gasoline release sites. MTBE use in gasoline in the United States has increased greatly since its introduction in the 1980s. It is estimated that 60–70% of all gasoline sold in the United States today contains some MTBE. MTBE is often the individual chemical substance present in the greatest amount in gasoline, with some blends having as much as 15% MTBE.

MTBE's properties make it unlikely that it will be found in surface soils at the typical abandoned service station site. These properties include the following:
- Very high water solubility compared to benzene, the most water-soluble petroleum component in gasoline.
- Low affinity for soil organic carbon resulting in low soil sorption, a high potential to leach from soil to groundwater, and low retardation when moving in groundwater through soil.
- Low Henry's Law Constant compared to gasoline VOCs, resulting in very little volatilization from surface water or groundwater.
- High vapor pressure compared to gasoline VOCs, resulting in volatilization from surface and vadose zone soil to ambient and indoor air.
- High resistance to subsurface biodegradation.

MTBE's high vapor pressure could allow it to volatilize from surface or subsurface soil to ambient or indoor air, where it could pose an inhalation risk. However, MTBE volatilization is not likely to be a significant exposure pathway at the typical abandoned service station site unless free product is present. MTBE's high solubility and low affinity for soil materials usually cause it to leach rapidly to groundwater from both surface and subsurface soils.

Once in groundwater, MTBE's low Henry's Law Constant indicates that it will not volatilize from in situ groundwater. Thus, it would not be expected to migrate upward through overlying soil to ambient air to pose an inhalation risk. However, its high solubility, low soil sorption potential, and resistance to biodegradation allow it to move farther and faster and to persist in groundwater much longer than the petroleum VOCs (i.e., BTEX) that are often the focus of concern. It is not uncommon for MTBE to be found in advance of a BTEX plume. It is possible for receptors to be exposed to MTBE before being exposed to BTEX. When MTBE-contaminated groundwater is used as tapwater, receptors may be at risk due to ingestion, dermal absorption, and inhalation.

References

U.S. Environmental Protection Agency. 1999. *Achieving Clean Air and Clean Water: The Report of the Blue Ribbon Panel on Oxygenates in Gasoline.* EPA 420-R-99-021.

Anonymous. 1998. *Health and Environmental Assessment of MTBE.* Report to the Governor and Legislature of the State of California.

For the reasons stated above, the exposure pathways that include ingestion, dermal contact, or dust inhalation of fuel-contaminated surface soils generally do not have to be considered in assessing risk at the typical abandoned service station site. However, the ingestion and dust inhalation exposure pathways must be considered for lead if it is found in surface soils due to historical spills or overfills of leaded gasoline. (See UG Discussion 2-4)

Discussion 2-4. Lead (Pb): Occurrence in Petroleum Products and Environmental Media

Lead may be present at service station sites primarily from two sources. Used motor oil may be contaminated with inorganic lead from engine wear. Lead may also be present as a result of its historical use in gasoline. Until the late 1980s organic lead compounds known as tetraalkyl lead (TAL) were added to gasoline to reduce engine knock. Several TAL compounds were used as antiknock agents, but by far the most extensively used TAL was tetraethyl lead. Leaded gasoline production diminished dramatically during the 1980s, and after 1989 leaded gasoline production ceased. Therefore, releases of gasoline after 1989 will not represent a source of lead at service stations. Only releases that predate the mid- to late-1980s are likely to represent a significant source of lead from gasoline.

Lead's fate and transport in the environment is heavily dependent on its chemical form. Inorganic lead, which is the form of lead in used oil, is very strongly sorbed to soil and is virtually immobilized upon contact with it. Surface releases of inorganic lead seldom move beyond the top few inches of soil, where they pose a potential threat due to ingestion or to inhalation of lead sorbed to airborne particulates.

The environmental fate and transport of TAL compounds is currently poorly understood. They appear to strongly sorb to soil and be fairly immobile; however, their mobility is enhanced by the presence of petroleum, and, as a result, TAL compounds may contaminate groundwater by comigration with petroleum products. TAL compounds also undergo chemical and biological degradation to tri- and dialkyl lead compounds that are much more mobile in the subsurface than their parent compounds. Ultimately, organic lead compounds are converted to inorganic lead in the environment, but this is believed to occur slowly in soils.

TAL compounds and their organic degradation products are not target analytes in methods commonly used to characterize sites, and their concentrations in environmental media are not routinely measured. Their presence at a site should be suspected if lead levels above background (UG 6.9) are detected in soils or groundwater in the vicinity of gasoline releases that are believed to predate the mid-1980s. (See UG Discussion 6-2 for guidance on how to proceed with TAL risk assessment.)

It is possible, though unlikely, that inorganic lead may contaminate groundwater. In the event that lead-contaminated groundwater occurs at a site, the West Virginia groundwater standard for lead of 0.015 mg/L (15 parts per billion [ppb]) applies (GM 3.3, GM Table C-1).

2.5.4 Used Motor Oil Contamination in Subsurface Soils

Although used motor oil contamination may usually be confined to surface soils, motor oil also has the potential to reach the subsurface under certain circumstances. Motor oil, particularly when large surface releases occur, may penetrate to the subsurface through fissures or loose soils. In some cases, used motor oil may be released from underground storage tanks. As indicated in UG 2.5.1, most of used motor oil's constituent COCs (with the exception of naphthalene) are relatively immobile in the environment. In addition, subsurface soils are generally not available for ingestion and dermal contact. Therefore, naphthalene migration to groundwater and its volatilization to ambient air are usually the only exposure pathways that need to be considered for used motor oil contamination in the subsurface.

2.5.5 Antifreeze Contamination in Subsurface Soils

Antifreeze has much greater potential than motor oil to penetrate soils because of its lower viscosity. However, it is likely that a large release would be required for significant amounts of its constituents to reach the subsurface. Ethylene glycol (an SVOC) is the most significant organic component of antifreeze. It biodegrades rapidly but may be encountered if a release has occurred relatively recently. Used antifreeze may contain metals originating from engine cooling system components. (See UG Discussion 2-2)

2.5.6 Fuel Contamination in Subsurface Soils

At a typical abandoned service station site, most gasoline, diesel, and kerosene contamination results from leaking fuel storage and delivery systems (i.e., USTs and underground piping). Released fuels may exist in the unsaturated soils of the vadose zone as small, immobile globules and ganglia trapped in soil

pores by capillary forces (i.e., residual contamination) or as a discreet liquid mass that is capable of movement in the subsurface (i.e., free product). Their constituent COCs (i.e., VOCs, PAHs, and metals) typically may

• volatilize into the soil gas (VOCs and naphthalene),
• sorb to soil particles (all constituent COCs),
• dissolve into precipitation that percolates downward through the vadose zone (VOCs and naphthalene), or
• dissolve directly into the groundwater if free product reaches the water table (VOCs and naphthalene).

The exposure pathways that must be considered for fuel's constituent COCs in subsurface soils involve volatilization or dissolution from residual contamination and include movement of volatilized COCs to ambient and indoor air and migration of dissolved COCs to groundwater. *The risk assessment procedures presented in the Guidance Manual are not applicable to free product. The LRS should refer to UG 3 for a discussion of what to do if free product is encountered at a site.*

2.5.7   Direct Exposure to Subsurface Soils
If the subsurface is invaded or disturbed during site investigation or if it may potentially be disturbed during future site development activities, new exposure routes will be created. See UG Discussion 6-1 for guidance.

2.5.8   Contamination in Groundwater
Fuel constituents can reach groundwater via
• direct dissolution of free product at the water table,
• direct dissolution of residual contamination in a smear zone, and
• dissolution into water infiltrating from the surface and subsequent transport to groundwater.
Ethylene glycol may also reach groundwater through similar mechanisms if a large, relatively recent release of antifreeze has occurred (UG 2.5.2 and 2.5.5).

BTEX, MTBE, and naphthalene are the COCs most likely to be found in groundwater as a result of fuel contamination. They tend to migrate with the groundwater, although at a slower speed, and may form large contaminant plumes that can extend off site. The exposure routes that must be considered for BTEX and MTBE in groundwater are volatilization from in situ groundwater to ambient and indoor air and volatilization into indoor air and dermal exposure at the point of use (e.g., showering or washing). BTEX, MTBE, naphthalene, and ethylene glycol must be considered for the groundwater ingestion exposure route.

2.5.9   Occurrence of COCs in Air
VOCs can volatilize from contaminated soils or groundwater to ambient or indoor air. SVOCs and metals can adsorb to particles of surface soil and be blown as dust into the ambient air. In each case, inhalation is the exposure route of concern. (Note: Other exposure routes for vapors and/or particulates are possible [e.g., dermal and ingestion] but are considered to pose minimal risk.)

3 Free Product

3.1 What Is Free Product?

Free product is defined as "liquid phase hydrocarbon existing in the subsurface with a positive pressure such that it can flow into a well." (USEPA 1996) It is that portion of a petroleum release that exists as a phase separate from water, soil, and air and that is capable of flowing downward and/or laterally. It generally exists as a pool or mound floating on the water table or resting on an impermeable soil layer. Free product is not to be confused with the immobile (residual) petroleum phase that is also present at petroleum release sites. It is free product that is the subject of special regulatory attention described below.

3.2 What to Do If Free Product Is Encountered

Free product presents an imminent danger to public health that must be addressed without undue delay. *If free product is discovered at a site, the LRS must notify WVDEP within 24 hours and present a suggested recovery plan.* If free product is not thought to be present at a site, the LRS should clearly describe the basis for that conclusion in the application.

The West Virginia Code of State Regulations (33 CSR 30-2) incorporates elements of the federal underground storage tank corrective action requirements, including Title 40 Code of Federal Regulations (CFR) Part 280.64 which requires that free product be remediated and recovered to the extent practicable. The document *How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites—Guide for State Regulators* (USEPA 1996) provides guidance on free product recovery.

3.3 Detecting the Presence of Free Product

The presence of free product should be suspected if information gathered during the site characterization indicates that a single large release or a long and continuous release of any size may have occurred at the site. Free product is most often detected as discreet phases, globules or sheens in water from wells, in excavations, in runoff, or on cuttings or soil samples from excavations or boreholes. Screening monitoring wells across the water table may facilitate the detection of free product. Guidance is available for developing the design of a free product investigation (USEPA 1996).

The concept of soil saturation is also relevant to determining whether free product may be present at a site. Soil saturation (sat) corresponds to the contaminant concentration in soil at which the adsorptive limits of the soil particles and the solubility limits of the available soil moisture have been reached. Contamination above this value suggests that free product is present in the soil. UG 7.2.1 illustrates how soil saturation can be applied to a free product determination.

3.4 References

Cohen, R.M., A.P. Bryda, S.T. Shaw, and C.P. Spalding. 1992. Evaluation of Visual Methods to Detect NAPL in Soil and Water. *Ground Water Monitoring Review*, 12(4), 132–141.

Newell, C.J., S.D. Acree, R.R. Ross, and S.G. Hulling. 1995. *Light Nonaqueous Phase Liquids.* EPA/540/S-95/500.

United States Environmental Protection Agency (USEPA). 1996. *How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites—Guide for State Regulators.* EPA 510-R-96-001.

4 Abandoned Service Station Site Characterization

A hypothetical abandoned service station, its adjoining properties, and the contamination resulting from historical releases of petroleum products at the station are the example upon which this User Guide is based. The layout of the hypothetical site and its immediate vicinity are shown in UG Figures 4-1 and 4-2.

4.1 Description of Site and Adjoining Properties

The site description below is based on the assumptions that the characterization objectives have been attained for the hypothetical site (GM 2.1) and that an investigation based on an adequate sampling and analysis plan (GM 2.3) has determined the distribution and concentrations of the COPCs in surface and subsurface soils and groundwater.

Site Description of Hypothetical Abandoned Service Station

Site Features (UG Figure 4-1)
- Size: 80 x 110 foot (1/5-acre) corner lot
- Surface: Gravel-surfaced
- Surface water: None present
- Existing structures: 25 x 45 foot abandoned building
- Existing underground storage tanks (USTs):
  - ▼ One 2,000-gallon UST (empty)—Formerly contained leaded gasoline
  - ▼ One 1,000-gallon UST (empty)—Formerly contained diesel
- Visible evidence of contamination: Stained soil observed in vicinity of two 55-gallon drums containing used motor oil residue
- Water supply: Supplied by city

Site History
On-site building formerly used as a service station, then briefly as a convenience store. Fuel pumps and piping removed when station closed.

Land Use
- Current: Industrial
- Future: Industrial
- Adjoining: Site bordered to east and south by city streets and to west, by vacant lot separated from site by an alley. Other adjoining land uses include machine shop and private residence with drinking water well north of site (UG Figure 4-1).

Subsurface Characteristics (UG Figure 4-3)
- Soils: Alluvial sediments consisting of interlayered sands and silts
- Aquifer: Unconfined
- Water table: 20 feet below ground surface (bgs)
- Groundwater flow direction: Northeastward (toward machine shop and private residence)
- Bedrock: 40 feet bgs

Site Contamination
- Surface soils (defined as the upper 2 feet of soil): Used motor oil in vicinity of two 55-gallon drums on north side of building (UG Figure 4-1).
- Subsurface soil: Gasoline and diesel contamination originating from the in-place USTs extends from below USTs to water table (UG Figures 4-1 and 4-2). No free product detected.
- Groundwater contamination: Plume of dissolved contaminants originating from contaminated soil beneath USTs extends from site to beneath adjoining residence and machine shop (UG Figure 4-2) . Plume extends approximately 10 feet below water table. Does not reach bedrock (UG Figure 4-3).

Figure 4-1. Site Layout
Showing Surface and
Subsurface Soil
Contamination

Residence

Machine
Shop

Vacant Lot

Alley

A Avenue

55-gallon
drums

Underground
Storage Tanks

A

A'

Abandoned
Service
Station

Surface Soil Contamination:
Used Motor Oil (PAHs, metals)

Subsurface
Soil Contamination: Gasoline and Diesel (BTEX)

B Street   *Not to scale*

Residence

Machine
Shop

Vacant Lot

A

A'

Abandoned
Service
Station
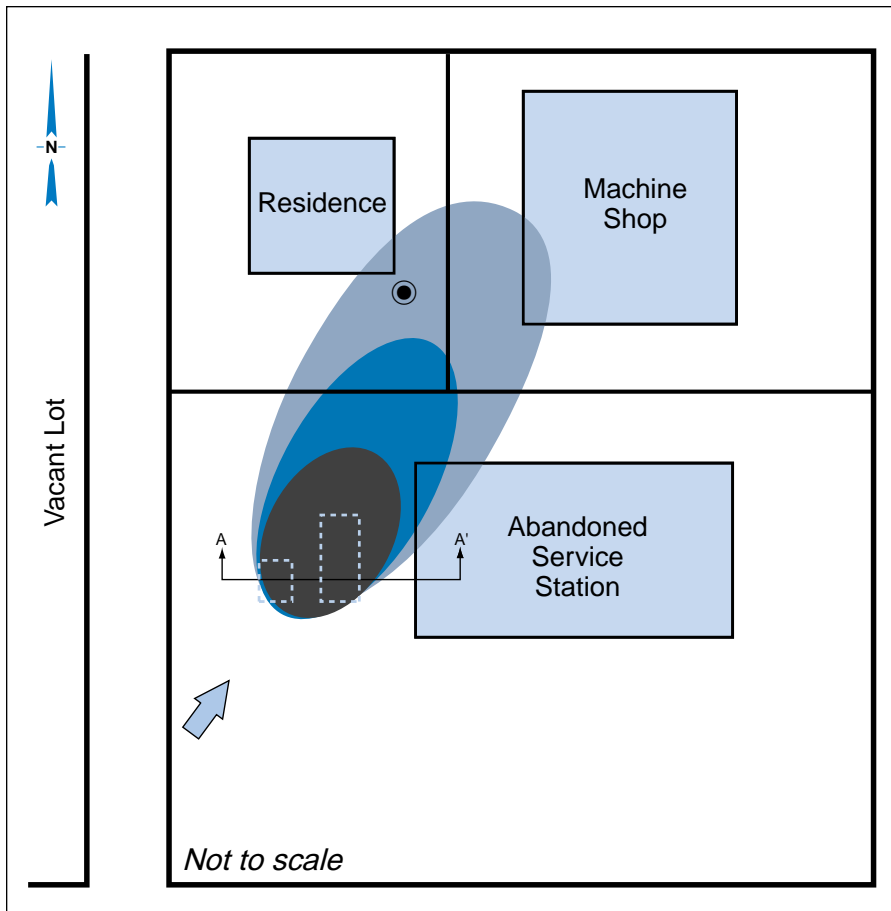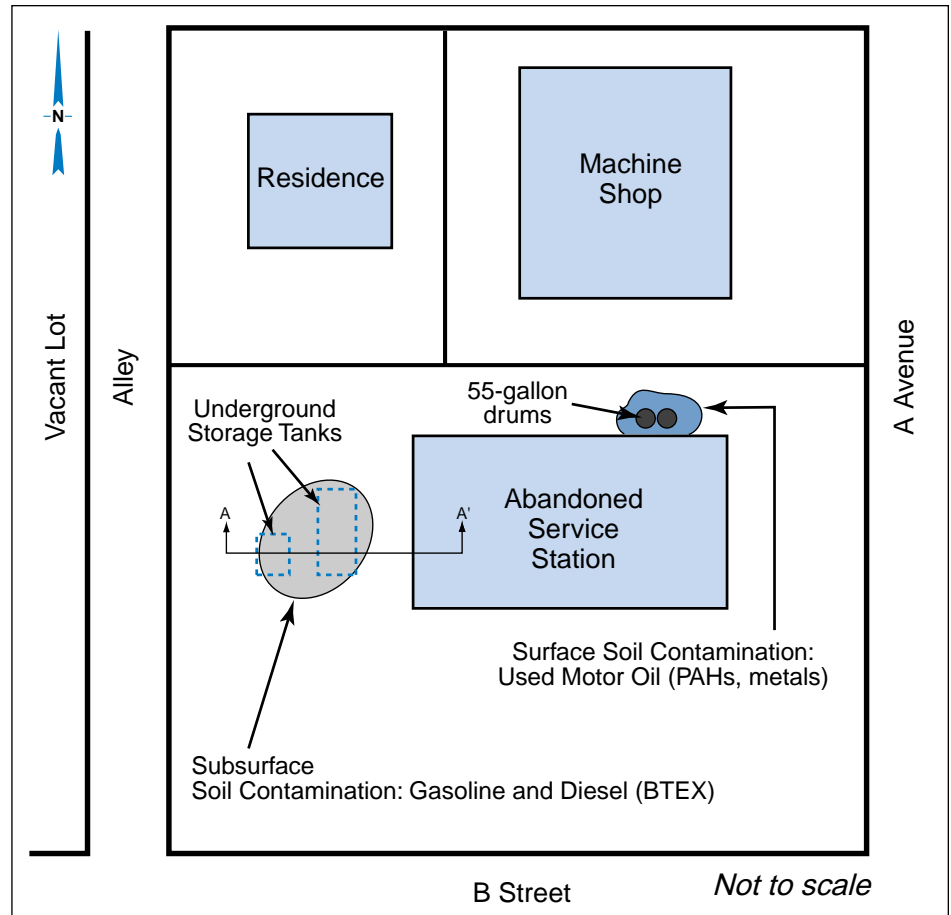
Figure 4-2. Site Layout
Showing Estimated Limits
of Benzene Contamination
in Groundwater and the
Direction of Groundwater
Migration

Direction of groundwater migration

Benzene concentrations

■ ≤100 mg/L
■ ≤10 mg/L
■ ≤1 mg/L

◉ Drinking water well

Not to scale

12
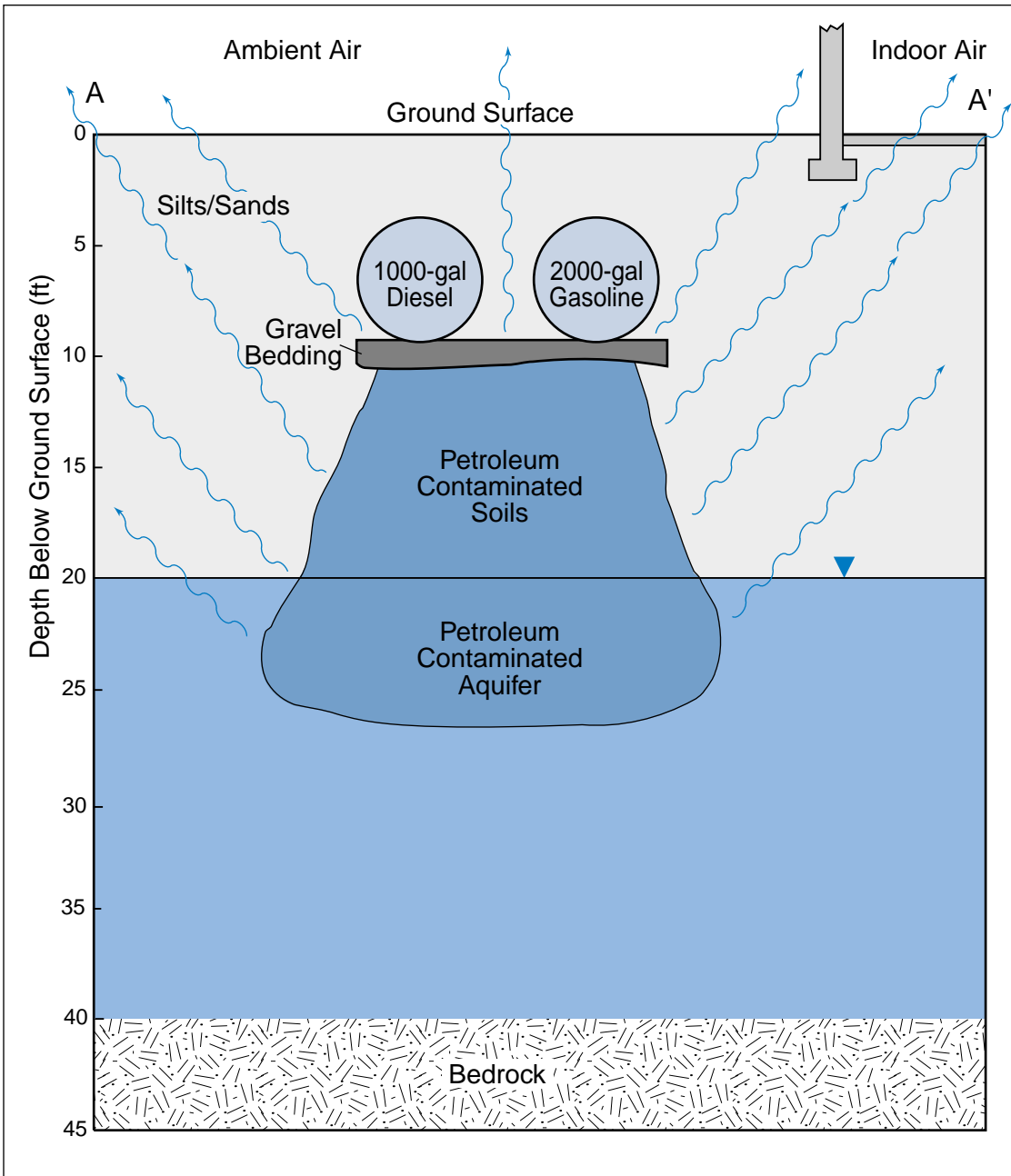
Figure 4-3. Cross Section of Petroleum Contamination Beneath Existing USTs at Hypothetical Abandoned Service Station

4.2 COC Concentrations in Samples

Soil and groundwater samples were collected in on-site and off-site areas affected by contamination origi-nating from the site. Laboratory analyses provided the sample concentrations of individual COCs that were used as the bases for subsequent Uniform and Site-Specific risk evaluations. Both risk evaluations employed either the 95% upper confidence limit (UCL) of the arithmetic mean of a COC's sample con-centrations or the COC's highest concentration value among all samples in which the COC occurred. UG Table 4-1 presents the concentration values of COCs selected for use in the example risk calculations illustrated in UG 7.

Table 4-1. Concentration Values Used for Risk Assessment of Selected COCs

	95% UCL of Sample Mean		
VOCs	**Surface Soil**	**Subsurface Soil**	**Groundwater**
	mg/kg	**mg/kg**	**mg/L**
Benzene		550	0.001
Toluene		8050	1.00
SVOCs (PAHs)			
Benzo(a)pyrene	10.00		
Naphthalene	4300		

Section 5 Conceptual Site Model

5.1 Definition and Use of the Conceptual Site Model

The conceptual site model (CSM) is a representation of the transport of contaminants from sources through environmental media to receptors. Receptors are humans potentially exposed to contaminants released at the site (Refer to UG 1.2. Ecological risk is discussed briefly in UG 6.3.) Since contaminants may move off site, both on-site and off-site receptors must be considered in the CSM. There are many ways that a CSM may be expressed. This is reflected in the fact that there is no nationally accepted format for a CSM. While the term "model" sometimes connotes the output of computer programs and/or algorithms, CSMs are usually simple, qualitative descriptions of site conditions.

The CSM is used for several purposes, including support of site characterization, risk evaluation, and remedial design. (GM 2.2.4) In this User Guide, the emphasis is on the use of the CSM in the risk assessment step. The model helps identify, and provide a visual representation of the following:
• Anticipated contaminants (e.g. volatile organics, metals, pesticides, explosives, petroleum)
• Source areas (e.g., residual chemicals in abandoned tanks, lagoons, sumps, contaminated soils)
• Release mechanisms (e.g., leaking tanks, spills, leaching from contaminated soils)
• Media of concern (e.g., soil, groundwater, surface water, sediments, air)
• Migration pathways (e.g., groundwater movement, windblown dust, volatilization to air)
• Exposure routes (e.g., ingestion, inhalation, dermal contact)
• Potential receptors (e.g., on-site workers, off-site residents, site visitors)

5.2 CSM Inclusions and Refinement

It is important to recognize that the CSM is a dynamic representation whose content and form evolves as knowledge of the site increases. Initially, the model should include all sources, media, and exposure pathways that are (or will be) of reasonable, or even merely plausible, concern. The LRS generally can develop a reasonable model after researching the property's history and geology and conducting a site reconnaissance. As the site investigation proceeds and additional data are generated, the CSM is refined. Based on this additional knowledge, certain initially suspected source areas and pathways may be excluded from the model. *It is essential that when such exclusions are made that their rationale is documented in the text of the CSM.*

5.3 Checklist for CSM Development

A preliminary identification of potential human receptors must be performed at the outset of CSM development to permit evaluation of the risks that may be posed by the site under existing and/or future use scenarios (GM 2.2.3). A "Checklist for Conceptual Site Model Development" (GM Appendix A) guides the LRS in identifying receptors. The checklist must be completed and submitted to WVDEP. Both land and groundwater use must be considered for potential exposure pathways that are evaluated in the course of identifying on-site or off-site receptors.

5.3.1 Land Use
Current and future land uses of the site and surrounding properties are important considerations for the development of a CSM. The Guidance Manual describes two categories of land use—residential and industrial. Residential land use includes homes, schools, nursing homes, and recreation areas. Industrial land use includes commercial establishments involved in the manufacture or distribution of goods and services (GM 1.1.3). Given the typical setting of service stations, most such sites will have a current and future use that is industrial, and on-site soil contamination will be evaluated as industrial. In the uncommon event that soil contamination extends off site, potential risk posed to off-site receptors should be evaluated in accordance with the off-site land use.

5.3.2 Groundwater Use
Groundwater use must be considered to identify certain potential exposure pathways in the CSM. Groundwater use considerations focus on the fact that potable water is likely to be used as tapwater for drinking, showering, and bathing, whereas nonpotable water is not. Groundwater that is currently used as tapwater, is expected to be used as tapwater in the future, or is contained in an aquifer that is hydrogeologically connected to an aquifer used for drinking water should undergo risk assessment for the exposure routes associated with domestic use (UG 2.5.8). Groundwater with a dissolved solids content greater than 2500 milligrams per liter (mg/L) is generally considered to be not potable and is unlikely to be a suitable source of tapwater (GM 3.3.1 and 3.4.2.1). Because such waters are considered unlikely to be used for ingestion, showering, or bathing, it is not necessary to evaluate the risks posed by their use for these activities. *Although the human health risk is eliminated, other laws and regulations identified in the Voluntary Remediation Agreement for the site may have applicable requirements, which the LRS should evaluate.*

5.3.3 Example Checklist for Hypothetical Abandoned Service Station
User Guide Appendix B shows the "Checklist for Conceptual Site Model Development" (UG Figure B-1) filled out for the hypothetical abandoned service station described in UG 4. This example checklist is not intended to represent any actual site. It is supplied for illustration purposes only. *The LRS must fill out and submit a checklist that describes the situation at the applicant's site.*

5.4 Generic CSM Pathway Analysis Diagram

The Pathway Analysis Diagram, depicting the pathway(s) of contaminants from sources to receptors, is a key element in the CSM. The Pathway Analysis Diagram, along with site maps, hydrogeologic cross sections, and a narrative which discusses the rationale for including and excluding exposure pathways for consideration often constitutes an acceptable CSM.

Pathway Analysis Diagrams may have varying levels of complexity. Figure A-1 (UG Appendix A) is a detailed CSM Pathway Analysis Diagram that is suitable for most contaminated sites, including petroleum sites. GM Figures 2-2 and 2-3 are less complex variations on UG Figure A-1.

5.4.1 Use of the Generic CSM Pathway Analysis Diagram
The generic CSM Pathway Analysis Diagram of UG Figure A-1 is designed to promote the consideration and identification of every reasonably potential exposure scenario arising from the release and movement of COCs from sources through environmental media to receptors. Completion of the diagram will document and help make clear the identification of those receptors and exposure scenarios that require risk assessment. *A completed CSM must be submitted to WVDEP.* It is recommended that a completed generic CSM Pathway Analysis Diagram be part of that submission.

The Pathway Analysis Diagram (UG Figure A-1) is easy to use:
- First, all known or suspected sources of COCs are marked with a check on the diagram. This results in the identification of contaminants with a source(s) by a number. For example, semivolatile organic chemicals (COC type "b") and engine wear metals (COC type "c") from a spill of used oil from a drum would be represented as "1b" and "1c," respectively. A leak of unleaded gasoline from a belowground storage tank would be denoted by the identifier "2b."
- These identifiers are then carried across the diagram and entered into each applicable release, medium, and exposure box (or boxes) corresponding to the COCs' known or suspected movement towards a receptor.
- Next, the exposure routes are evaluated to determine whether the COCs affect on-site or off-site receptors (or both).
- Once this determination is made, the source-COC identifier is finally placed into the on-site or off-site row under the appropriate land use column (residential or industrial).

The diagram makes clear which exposure pathways have been excluded from risk assessment. *A narrative discussion of the diagram inputs (sources and COCs) along with site-specific release, media, and exposure circumstances should accompany the diagram to support the exclusion of any pathway.*

5.4.2 Pathway Analysis Diagram and Risk Assessment Equations

Those pathways requiring risk assessment (denoted by identifiers in the residential and industrial columns) are subjected to risk assessment as described in UG 6. Risk assessment is carried out using risk-based equations provided in the Guidance Manual. The Guidance Manual equations do not apply to every possible exposure pathway. The availability of risk-based equations for the two types of standards (Uniform and Site-Specific) described in UG 6 is summarized in UG Table 5-1. (Additional risk-based equations will be available in subsequent versions of the Guidance Manual.) The Generic CSM Pathway Analysis Diagram indicates whether or not an equation is available, and directs the user to the available equation or equations appropriate for each exposure route. De Minimis Standards, although not generally applicable to service station sites (UG 6.5), are cited in UG Figure A-1 to make the generic CSM Pathway Analysis Diagram applicable to a broad range of sites.

Table 5-1. Summary of the Currently Available Standard Equations in Guidance Manual (Version 1.1)

Surface Soil	Uniform	Site-Specific
Ingestion	Yes	Yes
Dermal	No	Yes
Inhalation (ambient)	Yes	No
Inhalation (indoor)	No	No[a]
Subsurface Soil		
Ingestion	No	Yes
Dermal	No	Yes
Inhalation (ambient)	Yes	No[a]
Inhalation (indoor)	No	No[a]
Leaching to groundwater	Yes	No
Ground Water		
Inhalation (ambient)	No	No[a]
Inhalation (indoor)	No	No[a]
Tap Water		
Ingestion	Yes	Yes
Dermal	No	Yes
Inhalation (indoor)	Yes	No[a]
Surface Water		
Ingestion	No	Yes
Dermal	No	Yes
Inhalation	No	No[a]
Sediments		
Ingestion	No	No
Dermal	No	No
Inhalation	No	No[a]

[a] A Site-Specific inhalation risk equation is listed in the Guidance Manual; however, as discussed in UG 7, the equation is not readily applied to most sites.

5.5 Example Pathway Analysis Diagram for Hypothetical Abandoned Service Station

Figure A-2 (UG Appendix A) illustrates the application of the Generic CSM Pathway Analysis Diagram to the abandoned service station site described in UG 4. UG Figure A-2 is for illustration purposes only. It is not intended to represent any actual petroleum release site. *The LRS must develop and submit to WVDEP a CSM that represents the applicant's site.*

Surface soil contamination: At the site described in UG 4, used motor oil has been released from drums (UG Figure 4-1) located on the surface of the site. The COCs in used motor oil are SVOCs and metals (COC types "b" and "c," respectively, on UG Figure A-2) (UG 2.4.2). The site investigation revealed that the oil contamination is confined to the on-site surface soil. Humans may be exposed to contaminated surface soil by the inhalation of wind-blown dust, inadvertent ingestion of soil, or direct contact of the soil with skin. It is also known that site land use has been, and will continue to be, industrial. Therefore, the release identifiers "1b" and "1c" are placed in the boxes corresponding to on-site, industrial surface soil inhalation, ingestion, and dermal exposure. Subsurface soil and groundwater have not been contaminated by the used motor oil COCs, and there are no surface water or sediments at the site.

Subsurface soil contamination: The site investigation revealed that on-site subsurface soil is contaminated by fuels (gasoline and diesel) that have leaked from underground storage tanks (UG Figure 4-1). The COCs in gasoline and diesel (UG 2.4.1) are VOCs (COC type a) and SVOCs (COC type b). The future industrial use of the site is not expected to result in humans coming in contact with contaminated on-site soil that is at a depth of more than 4 feet; therefore, subsurface soil ingestion and dermal exposure are excluded from consideration in the CSM, and no identifiers are put in those boxes. The rationale for this exclusion would be documented for WVDEP in a written discussion accompanying the Pathway Analysis Diagram. The subsurface soil VOC contaminants might volatilize to ambient air or, through on-site building foundations, to indoor air (UG 2.5.6 and UG Figure 4-3). The identifier "2a" is put in the on-site, industrial ambient, and indoor air boxes. The subsurface soil SVOC identifier "b" is not added to those boxes, because SVOCs do not volatilize significantly under typical site conditions.

Contaminants in subsurface soil may migrate to groundwater (GM 3.3.2; UG Figure 4-3). The Guidance Manual (GM Appendix D.4.5) provides equations for evaluating the risk posed by the migration of contaminants to groundwater from subsurface soil. The use of these equations is illustrated in UG 7.2.3.4. The evaluation is independent of site land use (residential or industrial). Because both VOCs and SVOCs (particularly naphthalene) may be involved, the identifier "2ab" is put in the on-site migration to groundwater box.

Groundwater and air contamination: The site investigation revealed that on-site and off-site groundwater is contaminated (UG Figure 4-2) by fuels that have leaked from underground storage tanks. The contaminants include VOCs and naphthalene. Only the VOCs in groundwater have the potential to volatilize to ambient and indoor air above the contaminant plume (UG 2.5.7) as illustrated in UG Figure 4-3. Because contaminated groundwater exists under on-site buildings and an off-site residence, the boxes for on-site industrial indoor air and off-site residential indoor air contain the "2a" identifier. Similarly, on-site industrial and off-site residential ambient air must be evaluated.

There is the potential that occupants of the adjacent residence, where a well is situated in the contaminated groundwater plume, may ingest contaminated drinking water and experience dermal exposure to BTEX, MTBE, and naphthalene through bathing, washing, or while using contaminated groundwater for other domestic activities. Therefore, the identifier "2ab" is put in the off-site residential boxes for tapwater ingestion, and dermal exposure. VOCs and naphthalene may volatilize (and be inhaled) from tapwater that is used off site for showering and other domestic activities. Therefore, the identifier "2ab" is put in the box for volatilization> indoor air> inhalation exposure pathway and the associated off-site residential receptor box. Current and future industrial use of the site does not involve use of the groundwater; therefore, the on-site groundwater ingestion and dermal absorption exposure routes are excluded from evaluation, and their associated boxes are not marked. *A written narrative should be presented to WVDEP that documents the reasons for including or excluding all of the exposure pathways shown on the CSM Pathway Analysis Diagram.*

Surface water and sediments: Finally, the contaminated groundwater does not discharge to surface water. Furthermore, no surface water and sediments are on site or nearby that could have been contaminated by an on-site release or runoff from the site. As a result, the surface water and sediments pathways are excluded from consideration, and *this exclusion would be documented in a discussion accompanying the Pathway Analysis Diagram.*

Section 6 Risk Assessment Overview

6.1 General (GM 1.1.2, 1.1.3, 3.1)

Risks to both human health and the environment must be evaluated and addressed to restore contaminated sites to productive use. The development of human health and ecological risk-based standards is a key step in the site risk assessment process. Risk-based standards are used to
- determine whether a remedial response action is necessary,
- identify target cleanup levels in the event that a remedial action is required, and
- document that a level protective of human health and the environment exists or has been achieved at a site.

6.2 Alternative Technical Approaches

WVDEP recognizes that the technical approaches outlined in the Guidance Manual and this User Guide are not the only valid risk assessment methods. If the LRS believes other risk assessment methodology is appropriate, such methods should be presented to WVDEP for review and approval prior to their use. Proposed risk assessment alternatives should be supported with as much documentation as possible to facilitate WVDEP's determination of acceptability.

6.3. Ecological Risk (GM 4.0, Appendix C-2)

All sites must be evaluated for potential harm to the environment. The Guidance Manual provides an ecological screening process for determining the extent to which a site must undergo ecological assessment. A "Checklist to Determine the Applicable Ecological Standard" (GM Appendix C-2) must be filled out and submitted to WVDEP for all sites. Given that service station sites often are small and lack sensitive habitat and potential ecological receptors of concern, it is likely that most will not require extensive ecological evaluation. However, *a limited ecological evaluation should not be assumed by the LRS but should be documented through the checklist process.* Since detailed ecological risk assessment will not be warranted at most sites, it will not be discussed further here. The Guidance Manual provides extensive guidance and references for performing detailed ecological assessments.

6.4 Human Health Risk Assessment Overview (GM 3.1)

Human health risk assessment is undertaken once the CSM has been developed. It is carried out for each individual COC and exposure pathway identified in the CSM. Risks associated with contaminated sites are determined by considering the toxicity of contaminants present at the site and the extent to which individuals are exposed to the contaminants (GM 3.4.1.3). To carry out an evaluation of the human health risks that exist at a site, the proper human health standard must first be selected. Human health standards are discussed in general terms in this section of the User Guide. In UG 7, the development of human health standards will be illustrated for the User Guide's hypothetical abandoned service station.

6.4.1 Available Human Health Standards and Standard Selection

The Guidance Manual describes three types of risk-based human health standards: De Minimis, Uniform, and Site-Specific (GM 1.1.3). For reasons discussed in UG 6.5, only the latter two apply at most petroleum sites. Different standards may be applied to the same site if discrete areas of contamination exist on the site. Appendix C-1 of the Guidance Manual contains the checklist *Determination of the Applicable Human Health Standard* that is intended to help the LRS determine which human health standard is appropriate for a particular site. *The LRS should submit the completed checklist to WVDEP for review.* (GM 1.1.3.1).

The Guidance Manual recommends (GM Figure 3-1 and GM Appendix D) evaluating a site using the simpler, less resource-intensive Uniform Standards process before undertaking the more time-consuming and complex Site-Specific Standards process. If the site does not exceed the Uniform Standard, or the applicant chooses to apply the Uniform Standard as a cleanup objective at the site, then a Site-Specific assessment would not be necessary. However, if the applicant has reason to believe that a site is best evaluated

by a Site-Specific Standard assessment, it is acceptable to proceed directly with such an assessment without carrying out a Uniform Standard assessment (GM Appendix D).

6.4.2 Selection of the Appropriate Risk-Based Equation

After the appropriate human health standard has been selected, the risk-based equation that will be used to implement it must also be chosen. UG Table 5-1 summarizes the risk-based equations that are currently available to develop Uniform and Site-Specific risk assessments. The GCSM Pathway Analysis Diagram (UG Figure A-2) directs the user to the proper equations for calculating Uniform standards and the proper Site-Specific intake and risk equations for calculating site-specific risk levels for each combination of environmental medium, exposure route, and residential or industrial land use that will be encountered at a site.

6.4.2.1 Carcinogenic and Noncarcinogenic COCs

The determination as to whether a COC is a carcinogen or a noncarcinogen (i.e., a systemic toxicant) is the final decision that must be made to select either the appropriate Uniform risk-based equation that will be used to calculate the Uniform standard for the COC or the proper input factors to use for calculating a site-specific risk level for the COC that will be compared to the Site-Specific standard. Carcinogenicity information is presented in UG Table 6-5 for COCs likely to be present at a typical abandoned service station site. If a COC exhibits both carcinogenic and noncarcinogenic effects, then both its carcinogenic and noncarcinogenic risk-based Uniform standards or Site-Specific risk levels must be calculated. For the Uniform standards, the more conservative result (i.e., the lower of the two values) is then used as the Uniform remediation standard (GM 3.3.3). The Site-Specific values are incorporated into the cumulative carcinogenic and noncarcinogenic risk estimates.

6.4.3 How Risk Is Expressed

It is necessary to understand how risk is expressed to understand risk-based standards. Carcinogenic risk is expressed as an excess upper bound lifetime risk of cancer and is represented as a risk ratio [e.g., one in ten thousand (1×10^{-4})]. Noncarcinogenic risk is expressed as the ratio of the level of exposure to the level of a dose that is without appreciable risk of deleterious effect. This ratio is called the Hazard Quotient (HQ) (e.g., HQ = 0.8).

6.5 De Minimis Standards (GM 3.2 and Appendix C-1)

The use of De Minimis standards is limited to situations in which ingestion of soil and of groundwater are the only exposure pathways. De Minimis standards cannot be applied where volatilization or dust inhalation exposure pathways are present or where contaminants may leach to groundwater. Thus, they are normally inapplicable to abandoned service station sites, where dust-borne PAHs and metals (UG 2.5.1) or volatile and leachable BTEX constituents and MTBE (UG 2.5.6) may be present. De Minimis standards are not considered further in this User Guide.

6.6 Uniform Standards (GM 3.3 and Appendix D)

Uniform standards are COC-specific, calculated concentrations that represent cleanup levels for individual COCs corresponding to a default risk level (UG 6.10 and UG 6.10.4) considered protective of human health. As discussed in UG 6.4.2, they are calculated by means of Uniform risk-based equations. Separate equations exist for various combinations of environmental medium, exposure route, land use, and carcinogenicity. For example, Appendix D of the Guidance Manual contains Uniform risk-based equations for the combined inhalation and ingestion exposure pathways for (1) carcinogenic contaminants in residential soil, (2) noncarcinogenic contaminants in residential soil, (3) carcinogenic contaminants in industrial soil, and (4) noncarcinogenic contaminants in industrial soil.

As summarized in UG Table 5-1, the exposure routes for which Uniform standards can be calculated by the risk equations in Version 1.1 of the Guidance Manual are limited to (1) surface soil ingestion, (2) inhalation of suspended ambient surface particulate matter (dust), (3) inhalation of ambient vapors from contaminated surface or subsurface soil, (4) household exposure to groundwater (including both ingestion of tapwater and inhalation of tapwater vapors during showering, laundering, and dish washing), and (5) migration of contaminants from soil to groundwater.

Exposure routes not covered by the Uniform risk-based equations in Version 1.1 of the Guidance Manual include (1) dermal exposure to any environmental medium, (2) inhalation of particulate matter in indoor air arising from contaminated surface soil, (3) inhalation of vapors in indoor air arising from contaminated subsurface soil, (4) inhalation of vapors in indoor air arising from contaminated groundwater, and (5) any exposure (ingestion, inhalation, dermal) to either surface water or sediments. If any of these pathways are applicable at a site, a Site-Specific assessment of human health risks may be appropriate.

The Uniform standard equations in GM Appendix D are not appropriate for lead. Lead in drinking water must meet the WV groundwater standard (UG Discussion 2-4). Lead in soils must meet the De Minimis standards or a cleanup value derived by using the method presented in GM Appendix F (GM 3.3).

6.7 Site-Specific Standard (GM 3.4 and Appendix H)

The term "Site-Specific standard," as it is employed in the User Guide for carcinogens, refers to a range of carcinogenic risk levels between one in ten thousand (1×10^{-4}) and one in one million (1×10^{-6}). In reference to noncarcinogenic risk, the term "Site-Specific standard" refers to an HQ of 1.0 or less.

As described in UG 6.12.2.2, in the case of a Site-Specific baseline risk assessment, risk quantification is the basis for assessing the need for remediation. The Guidance Manual contains Site-Specific intake equations (GM Appendix H) and site-specific risk equations (GM 3.4.1.3) that are used to calculate Site-Specific risk levels. The calculated Site-Specific risk level, which, in the case of a Site-specific risk assessment is generally a cumulative risk (UG 6.11), is compared to the appropriate Site-Specific standard (i.e., a risk range of 1×10^{-6} to 1×10^{-4} for carcinogens, or a Hazard Index (HI) of 1.0 or less for noncarcinogens) to determine if remediation is necessary. *If the calculated risk level exceeds the risk range, Site-Specific remediation standards (i.e., cleanup levels) that incorporate the considerations documented in the Guidance Manual (GM 3.4.2.1, 3.4.2.2, 3.4.2.3) must be established in consultation with WVDEP.*

UG Table 5-1 indicates that, in Guidance Manual Version 1.1, equations are available for determining Site-Specific risk levels for (1) ingestion of either groundwater or surface water, (2) ingestion of surface or subsurface soil, (3) dermal exposure to either groundwater or surface water, (4) dermal exposure to surface or subsurface soil, (5) exposure to airborne chemicals, and (6) ingestion of contaminants in fish. The latter two pathways are not likely to be applicable at most petroleum sites. The airborne inhalation assessment requires a reliably measured or modeled contaminant concentration in air, something that is unlikely to be available at most sites. Contaminated fish ingestion will be a very uncommon concern.

Among the ways in which a Site-Specific risk evaluation differs from a Uniform risk evaluation is that land use and carcinogenicity are characterized and incorporated into the Site-Specific process by means of input factors, rather than by the use of separate equations.

For the industrial land use that will most often apply to service station sites, the Guidance Manual provides (GM 3.4.1) that Site-Specific risk levels for lead be evaluated using USEPA's adult lead exposure model. GM Appendix F details the model, and additional information is presented in UG Discussion 6-2.

6.8 What to Do When Uniform or Site-Specific Risk-Based Equations Are Not Available

It is evident from UG Table 5-1 and the GCSM Pathway Analysis Diagram (UG Figure A-1) that in Version 1.1 of the Guidance Manual, Uniform and Site-Specific risk-based equations are unavailable for a number of media and exposure routes. Furthermore, in the course of applying the available equations, the LRS may find that because of site-specific circumstances or the lack of key input data, some of them are inapplicable for pathways that the CSM Pathway Analysis Diagram indicates are of concern. *If either circumstance occurs (unavailability or inapplicability of equations), the LRS should contact WVDEP for guidance on how to proceed. It is not acceptable to simply ignore such pathways.*

6.9 Establishing Background for Uniform and Site-Specific Standards (GM 2.5 and Appendix B)

Neither the Uniform standard nor Site-Specific remediation standards are required to be set at levels below natural or anthropogenic background levels. Natural background refers to the concentrations of substances that occur naturally in the earth, without any human interference. Anthropogenic background refers to concentrations of substances that occur over a wide area as a result of human activities. The potential relevance of background concentrations and the method of establishing them varies with the environmental medium and the COC under consideration. At the typical abandoned service station site, the environmental media will consist of soil and groundwater, and COCs will be VOCs, PAHs, and metals.

6.9.1 Background Concentrations in Soil

Some metals and PAHs are natural components of soil, and the concentrations at which they occur constitute natural background levels. Anthropogenic background levels of environmentally persistent metals and PAHs are generated by many widespread and common human activities (e.g., internal combustion engines, power generating stations, and smelters). On the other hand, the concept of widespread, environmentally persistent background levels is not applicable to VOCs in soils because (1) VOCs do not arise from natural sources (widespread or otherwise), (2) their anthropogenic releases are generally local in nature (spills, overfills, leaks), and (3) they tend not to persist in soils (UG 2.5.3).

6.9.2 Background Concentrations in Groundwater

The question as to whether the concentration of any COC in groundwater is due to background is generally determined by comparing the COC's on-site concentration to its concentration in an upgradient well that is believed to be free of the effects of on-site contamination (GM B.1.3). Metals and PAHs may occur naturally in groundwater, and their upgradient well concentrations can be used as background. VOCs do not occur naturally in groundwater, and their presence cannot be attributed to background. VOCs in groundwater are present as a result of either an on-site or off-site release. An investigation may be undertaken to identify upgradient, possibly off-site, sources of VOCs in groundwater, but upgradient VOC levels are not to be considered as background.

6.9.3 Determining Background Concentrations

The Guidance Manual provides a detailed description of various approaches to determining site-specific background levels (GM Appendix B). In addition, GM Table 2-3 lists natural background levels of several inorganics in soil in West Virginia and surrounding areas. Determining background levels by use of site-specific information is recommended in preference to reliance on GM Table 2-3 values. (GM 2.5.1.2). *If a background determination of metals or PAHs is undertaken at a site, the applicant should suggest an approach to be reviewed by WVDEP in advance of its use.*

6.10 Risk-Based Equation Approaches to Risk Determination

It is important to recognize that Uniform risk-based equations and Site-Specific risk-based equations represent different approaches to risk determination. Uniform risk-based equations proceed from a default target risk level to produce, for a given COC, a corresponding contaminant concentration level that is the Uniform standard to which actual concentrations of the COC determined from sampling data can be compared (UG 6.6). Site-Specific risk-based equations, on the other hand, proceed from a COC-specific on-site concentration level and allow the calculation of the Site-Specific risk posed by that COC. The risk is then compared to the appropriate risk range and, if necessary, a Site-Specific remediation standard is established as described in UG 6.7. UG Figure 6-2 illustrates these approaches in general terms. They are discussed further in following sections.

Uniform risk-based equation

default target risk level $\longrightarrow$ contaminant concentration level
(input)   (Uniform standard)

Site-Specific risk-based intake equation*

contaminant concentration level $\longrightarrow$ contaminant risk level
(input)   (for comparison to appropriate risk range)
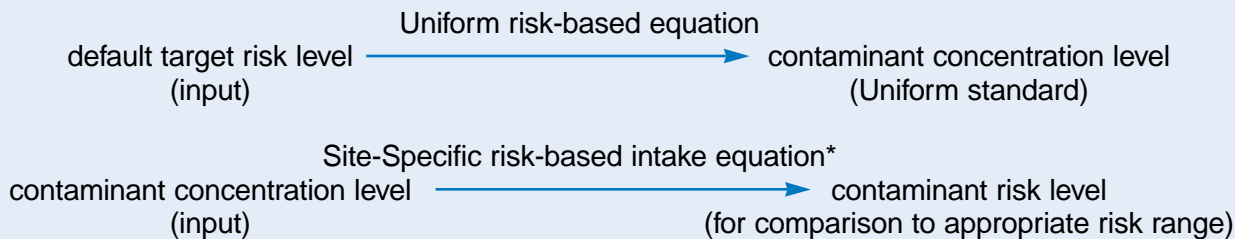
* The exposure (intake) value that is the output of the Site-Specific intake equation is multiplied by either a carcinogenic or noncarcinogenic toxicity factor to yield a risk level as described in GM 3.4.1.2.

Figure 6-2. Input and Output of Uniform and Site-Specific Risk-Based Equations

6.10.1 Default Target Risk Levels as Input to Uniform Risk-Based Equations
The Guidance Manual (Appendix D) specifies that the following default target risk levels be used in the Uniform risk-based equations:
• Carcinogens
   ▼ Residential exposure default target risk: one in one million (1×10^{-6})
   ▼ Industrial exposure default target risk: one in one hundred thousand (1×10^{-5})
• Noncarcinogens
   ▼ Both residential and industrial exposure default target risk: Hazard Quotient of 1.0

6.10.2 Contaminant Concentration Values as Input to Site-Specific Risk-Based Intake Equations
The contaminant concentration at the point of exposure is a key input to a Site-Specific risk-based intake equation and can be determined by either measurement or modeling. The Guidance Manual (GM Appendix H.2) recommends that where measured contaminant levels are utilized in the Site-Specific risk-based intake equations that the 95% UCL on the arithmetic mean be used. Refer to the Guidance Manual for considerations involved in calculating the 95% UCL (GM page H-8).

The Guidance Manual provides an extensive discussion of how modeling may be used to estimate contaminant concentrations at the point of exposure (GM 2.4.13). As the Guidance Manual makes clear, modeling introduces into the risk assessment numerous complications and uncertainties. Guidance for model selection can be found in the document titled *RBCA Fate and Transport Models: Compendium and Selection Guidance*. This document is available at the USEPA's Web site at http://www.epa.gov/swerust1/oustnews.htm. *Applicants considering the use of models should consult with WVDEP before proceeding (GM 2.4.13.4). Any use of a model must be accompanied by a discussion of the uncertainties that its use introduces to the risk evaluation.*

6.10.3 Additional Inputs for Uniform and Site-Specific Risk-Based Equations
In addition to the inputs shown in UG Figure 6-2, the Uniform and Site-Specific risk-based equations require several other parameters or factors as input. Both require (1) pathway-specific exposure factors, (2) COC-specific physical property data, and (3) COC-specific toxicity data. Furthermore, some Uniform risk-based equations utilize medium-specific input data such as the physical properties of the soils and aquifer.

The Guidance Manual provides default values for exposure factors and medium-specific physical property data, and it recommends sources for COC-specific toxicity values. No values are provided, nor sources recommended, for COC-specific physical property data. Values for a number of parameters are provided in the tables below to facilitate use of the risk-based equations. The Guidance Manual recommends carrying out the Uniform and Site-Specific risk evaluations using default input parameter values to the extent possible (GM 3.3, Appendix D.3, and Appendix H.2). Default parameter values can be replaced with values based on site-specific information and circumstances when documented justification is provided to WVDEP.

6.10.3.1 Default Pathway-Specific Exposure Factors (GM Appendix D.3)
Exposure factors incorporate assumptions for exposure duration, exposure frequency, and exposure intensity for the adult or child in a residential or industrial setting. Because exposure factors reflect the settings and individuals of concern as determined by the CSM, the resulting calculated Uniform standards and Site-Specific risk levels reflect the land and water use circumstances at the site.

Default exposure factors for use with Uniform and Site-Specific risk-based equations are available in GM Table D-2. The default exposure factors are reproduced below in UG Table 6-1.

Table 6-1. Default Exposure Factors for Uniform Equations[a]

Symbol	Definition	Default Value	Units
ATc	Averaging time, carcinogens	25,550	days
ATn	Averaging time, noncarcinogens	ED x 365	days
BWa	Body weight, adult	70	kg
BWc	Body weight, child	15	kg
EDc	Exposure duration, child	6	years
EDo	Exposure duration, occupational	25	years
EDr	Exposure duration, residential	30	years
EFo	Exposure frequency, occupational	250	days/year
EFr	Exposure frequency, residential	350	days/year
IFSadj	Ingestion factor, soils	114	mg-yr/kg-d
IFWadj	Ingestion factor, water	1.1	L-yr/kg-d
InhFadj	Inhalation factor	11	m^3-yr/kg-d
IRAa	Inhalation rate, adult	20	m^3/day
IRAc	Inhalation rate, child	10	m^3/day
IRSa	Soil ingestion, adult	50	mg/day
IRSc	Soil ingestion, child	100	mg/day
IRSo	Soil ingestion, occupational	50	mg/day
IRWa	Drinking water ingestion, adult	2	L/day
IRWc	Drinking water ingestion, child	1	L/day
T[b]	Exposure interval	950,000,000	seconds
THQ	Target hazard quotient	1	Unitless
TRI	Target cancer risk, industrial	10^{-5}	Unitless
TRR	Target cancer risk, residential	10^{-6}	Unitless
VFw	Volatilization factor, water	0.5	L/m^3

[a]Values in this table are taken from Table D-2 of the Guidance Manual. GM Table D-2 also lists the references from which the values were obtained.
[b]Value for T was taken from the table accompanying GM Equation D-7.

Tables H-1 and H-2 of the Guidance Manual contain exposure factors that may be required for use with Site-Specific risk-based equations. The site-specific default exposure factors are reproduced below in UG Tables 6-2 and 6-3. *The Guidance Manual should be consulted for details and special considerations for the use and application of the default exposure factors. The Guidance Manual cites source documents that provide justification for the values of the factors.* Default exposure factors are not available for the case in which direct exposure to subsurface contamination may be a potential exposure pathway. Refer to UG Discussion 6-1 for guidance on how to proceed in this event.

Table 6-2. Site-Specific Reasonable Maximum Exposure Parameter Values Recommended by USEPA[a]

Symbol	Parameter	Application	Value	Units
AF	Soil-to-skin adherence factor	All ages	1.45	mg/cm^2
AT[b]	Averaging time	Carcinogens	25550	days
		Noncarcinogens	10950	days
BW	Body weight	Adult	70	kg
		Child, 1–6 yr	16	kg
ED	Exposure duration	Lifetime	70	years
		90th percentile, one location	30	years
		Median, one location	9	years
		Construction worker[c]	25	years
ET	Exposure time	Showering, average duration	8 (0.13)	minutes (hours)
		Showering, 90th percentile duration	12 (0.20)	minutes (hours)
		Bath duration, all ages	20 (0.33)	minutes (hours)
EF	Exposure frequency	Default value[c]	350	days/year
		Construction worker, default[c]	250	days/year
FI	Contaminated soil ingestion	Fraction from contaminated source	d	Unitless
IRW	Ingestion rate, water	Adult, 90th percentile	2.32	L/day
		Adult, average	1.4	L/day
		Child, 1–10 yr, 90th percentile	1.3	L/day
		Child, 1–10 yr, average	0.74	L/day
IRS	Ingestion rate, soil	Child, 1–6 yr, upper bound value	200	mg/day
		Adult, upper bound value	100	mg/day
SA	Skin surface area	See UG Table 6-3		

[a]Values in this table are taken from Table H-1 of the Guidance Manual. Table H-1 also lists the references from which the values were obtained. The USEPA recommends that when calculating the Reasonable Maximum Exposure (RME) value, the 90th or 95th percentile values specified in this table should be used (GM H-7).

[b]Value from AT definition (GM p.3-13).

[c]Value can also be pathway-dependent, depending on the nature of the exposure scenario.

[d]The fraction of ingested soil originating from the contaminated site is exposure and pathway scenario specific. The LRS should develop and justify a site-specific fraction ingested value for WVDEP review and approval.

Table 6-3. 50th Percentile Body Surface Area[a]

Total Body Surface Area (cm^2): 50th Percentile		
Age (years)	Male	Female
3< 6	7,280	7,110
6< 9	9,310	9,190
9< 12	11,600	11,600
12< 15	14,900	14,800
15< 18	17,500	16,000
Adult	19,400	16,900

Body-Part Specific Surface Area (cm^2): 50th Percentile			
Age (years)	Arms	Hands	Legs
3< 4	960	400	1800
6< 7	1100	410	2400
9< 10	1300	570	3100
Adult	2300	820	5500

[a]Values in this table are taken from Table H-2 of the Guidance Manual. They have been converted from the m^2 units of the original table for use with GM Equations H.1.2 and H.1.4. The reference from which the values were obtained is also listed in the Guidance Manual.

Discussion 6-1. Direct Exposure to Subsurface Contamination

Subsurface releases at service stations will typically occur at a depth (4–8 feet below the surface). This fact reduces the likelihood of direct exposure or contact with the releases in the course of normal site activities. However, contamination at depth may occasionally be uncovered or made available for direct contact. For example, construction or demolition activities at a site may necessitate excavation to depths where soil or groundwater contamination is present. Such activities could create an exposure pathway not addressed in the CSM. Because the activities giving rise to this new exposure pathway are very activity- and site-specific, it is not possible to specify default exposure factors to permit estimation of exposure or intake. Examples of exposure factors that may be activity- and site-specific include, but are not limited to the following:
- Exposure frequency (e.g., How many hours per day will workers be involved in excavation?)
- Exposure duration (e.g., How many days will the excavation take?)
- Dermal surface area (e.g., Will workers be in short sleeves or long sleeves?)
- Media ingestion (e.g., How much soil or groundwater might workers ingest in the course of a work day?)

Little guidance exists for developing activity- and site-specific exposure factors for pathways not covered by traditional CSMs. Generally, professional judgment must be applied to their development. *When an LRS anticipates that the future use of a site might reasonably include direct exposure to subsurface contamination, then the anticipated exposure scenario should be described, a risk assessment should be performed on the scenario, and a clear justification for the development of the exposure factors used should be submitted to WVDEP for review and approval.*

6.10.3.2 Physical Property Data for COCs

The physical properties of COCs affect their fate, transport, and availability in the environment. As a result, the properties ultimately affect the potential for exposure to the COCs. Several of the Uniform and Site-Specific risk-based equations require these properties as input values. UG Table 6-4 lists the value of these properties for the COCs commonly found at petroleum sites. The sources of the values are noted in the table. Physical property data for COCs is periodically reassessed and new values developed. USEPA's

Table 6-4 COC-Specific Physical Properties*

Contaminant	CAS#	D_i (cm²/s)	D_w (cm²/s)	H (atm-m³/mole)	H' (Dimensionless)	K_{oc} Eq. D-7 (cm³/g)	K_d Eq. D-7 or Eq. D-9 (cm³/g)(L/kg)	K_d Eq. D-11 (L/kg)	S (mg/L$_{water}$)	ABS (Unitless)	PC (cm/hr)
VOCs											
Benzene	71-43-2	0.0880 S	0.00000980 S	0.00555 S	0.228 S	58.9 S	0.353	0.118	1750 S	0.10 G	0.10 IR
Toluene	108-88-3	0.0870 S	0.00000860 S	0.00664 S	0.272 S	182 S	1.092	0.364	526 S	0.10 G	1.00 IR
Ethylbenzene	100-41-4	0.0750 S	0.00000780 S	0.00788 S	0.323 S	363 S	2.178	0.726	169 S	0.10 G	1.00 IR
m-Xylene	108-38-3	0.0700 S	0.00000780 S	0.00734 S	0.301 S	407 S	2.442	0.814	161 S	0.10 G	
o-Xylene	95-47-6	0.0870 S	0.0000100 S	0.00519 S	0.213 S	363 S	2.178	0.726	178 S	0.10 G	
p-Xylene	106-42-3	0.0769 S	0.00000844 S	0.00766 S	0.314 S	389 S	2.334	0.778	185 S	0.10 G	
SVOCs											
Acenapthene	83-32-9	0.0421 S	0.00000769 S	0.000155 S	0.00636 S	7080 S	42.480	14.16	4.24 S	0.10 G	
Acenapthylene	208-96-8									0.10 G	
Anthracene	120-12-7	0.0324 S	0.00000774 S	0.0000650 S	0.00267 S	29500 S	177	59	0.0434 S	0.10 G	
Benz(a)anthracene	56-55-3	0.0510 S	0.00000900 S	0.00000335 S	0.000137 S	398000 S	2388	796	0.00940 S	0.10 G	
Benzo(b)fluoranthene	205-99-2	0.0226 S	0.00000556 S	0.000111 S	0.00455 S	1230000 S	7380	2460	0.00150 S	0.10 G	
Benzo(k)fluoranthene	207-08-9	0.0226 S	0.00000556 S	0.000000829 S	0.0000340 S	1230000 S	7380	2460	0.000800 S	0.10 G	
Benzo(g,h,l)perylene	191-24-2									0.10 G	
Benzo(a)pyrene	50-32-8	0.0430 S	0.00000900 S	0.00000113 S	0.0000463 S	1020000 S	6120	2040	0.00162 S	0.10 G	
Chrysene	218-01-9	0.0248 S	0.00000621 S	0.0000946 S	0.00388 S	398000 S	2388	796	0.00160 S	0.10 G	
Dibenz(a,h)anthracene	53-70-3	0.0202 S	0.00000518 S	0.0000000147 S	0.000000603 S	3800000 S	22800	7600	0.00249 S	0.10 G	
Ethylene glycol	107-21-1			0.00000000000959 T	0.000000000234 T	3.91 T	0.02	0.0078	Miscible T	0.10 G	
Fluoranthene	206-44-0	0.0302 S	0.00000635 S	0.0000161 S	0.000660 S	107000 S	642	214	0.206 S	0.10 G	
Fluorene	86-73-7	0.0363 S	0.00000788 S	0.0000636 S	0.00261 S	13800 S	82.80	27.60	1.98 S	0.10 G	
Indeno(1,2,3-cd)pyrene	193-39-5	0.0190 S	0.00000566 S	0.0000016 S	0.0000656 S	3470000 S	20820	6940	0.0000220 S	0.10 G	
Napthalene	91-20-3	0.0590 S	0.00000750 S	0.000483 S	0.0198 S	2000 S	12.00	4	31 S	0.10 G	
Phenanthrene	85-01-8									0.10 G	
Pyrene	129-00-0	0.0272 S	0.00000724 S	0.0000110 S	0.000451 S	105000 S	630	210	0.135 S	0.10 G	
Metals											
Cadmium (food)	7440-43-9									0.01 G	
Cadmium (water)	7440-43-9						75.0^a			0.01 G	
Chromium(III)	16065-83-1						1800000^a			0.01 G	
Chromium(VI) particulates	18540-29-9						19.0^a			0.01 G	
Lead	7439-92-1									0.01 G	
Nickel, soluble salts	7440-02-0						65.0^a			0.01 G	
Zinc, metallic	7440-66-6						62.0^a			0.01 G	

D_i = diffusivity in air D_w = diffusivity in water   H = Henry's Law Constant   H' = dimensionless Henry's Law Constant = H x 41

K_{oc} = Calculated Koc values from Table 39 Soil Screening Guidance (USEPA 1996)

K_d = Soil-water partition coefficient = f_{oc} x K_{oc}. For VOCs and SVOCs a default f_{oc} value of 0.006 (= 0.6%) was used in GM Equations D-7 and D-9, and a default f_{oc} value of 0.002 (0.2%) was used in calculating K_d for use in GM Equation D-11.

S = Solubility in water (20–25°C)   ABS = absorption factor   PC = permeability coefficient

*Sources for values listed in the table columns are:

S = USEPA 1996. *Soil Screening Guidance: Technical Background Document*. EPA/540/R-95/128.   IR = USEPA. 1992. *Dermal Exposure Assessment: Principles and Applications*. EPA/600/8-91/011B.

G = *West Virginia Voluntary Remediation and Redevelopment Act Guidance Manual*, Version 1.1, Appendix E.

T = USDHHS. 1997. *Toxicological Profile for Ethylene Glycol and Propylene Glycol*. US Department of Health & Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry.

^{a}Assumes a pH of 6.8. For other pH values, refer to Table 46 of the Soil Screening Guidance (USEPA 1996).

Superfund Chemical Data Matrix is a regularly updated source of physical property data. It is available online at http://www.epa.gov/oerrpage/superfund/resources/scdm/index.htm. *The LRS should make sure that the most current physical property data is used for risk assessment. If a range of values is found from one or more data sources, the LRS should inform WVDEP and justify the use of any value other than most conservative for the risk assessment. WVDEP may require an independent risk assessment if the most conservative value is not used.*

6.10.3.3 Toxicity Data (GM 3.4.1.2)

Toxicity data describes the type and severity of adverse effects that a COC may cause. Carcinogenic slope factors (CSFs) are toxicity values used in the risk assessment of carcinogenic COCs. Reference doses (RfDs) are used for noncarcinogenic COCs. UG Table 6-5 lists toxicity values for COCs likely to be encountered at abandoned service station sites. As indicated in the table, the values were obtained from three sources: (1) USEPA's IRIS database, (2) Region 3 EPA's Risk-Based Concentration Table (Region 3 RBC Table), and (3) Health Affects Assessment Summary Tables (HEAST) (EPA 540/R-94/020, March 1994).

The toxicity values of UG Table 6-5 were used to illustrate the calculation of Uniform Standards and Site-Specific risk levels in UG 7. *The LRS should be aware that toxicity data is subject to frequent revision and may rapidly become outdated. Before using any of the toxicity values of UG Table 6-5 for risk assessment, the appropriate toxicity factors should be verified by referring to the most current versions of one of the sources identified above, and the details of the verification should be included in the final report.* Complete copies of all references used to support toxicity values must be provided to WVDEP upon request. *If verified toxicity values for a COC are not available from either IRIS, the Region 3 RBC Table, or HEAST (USEPA 1994), the LRS should consult with WVDEP prior to relying on other sources of toxicity values.* IRIS, the Region 3 RBC Table, and HEAST are described below.

- IRIS is available online at http://www.epa.gov/iris/subst/index.html. It is updated monthly and is the USEPA's preferred source of toxicity information. Information in IRIS supersedes information from all other sources. Only if values for a COC are unavailable in IRIS should other sources be consulted. Occasionally, toxicity values entered in IRIS are withdrawn. Toxicity values which have been withdrawn from IRIS may be used in the risk assessment provided a discussion is included on the uncertainty associated with using these values.
- Region 3 RBC Table is available online at http://www.epa.gov/reg3hwmd/risk/riskmenu.htm. It is updated periodically. The Region 3 RBC Table contains risk-based concentrations (RBCs), which cannot be used directly as input for risk equations; however, the table also includes the RfDs and CSFs used to calculate the RBCs. These values are appropriate for use as risk equation input. *The instructions concerning the contents, uses, and limitations of the Region 3 RBC Table should be read carefully before the table is used.*
- HEAST should be used if needed values cannot be found in IRIS or the Region 3 RBC Table.

Currently, there are no CSFs and RfDs for dermal exposure; therefore, route-to-route extrapolation is necessary to assess dermal risk. Appendix E of the Guidance Manual outlines how the extrapolation is carried out. This procedure was used to generate the dermal exposure values in UG Table 6-5.

No toxicity values are available for lead. Instead, USEPA relies on benchmark values for blood lead levels that are health protective. GM Appendix F outlines how such levels are derived. (See UG Discussion 6-2)

Table 6-5. COC-Specific Toxicity Factors

Contaminant	CAS#	Carcinogenic CSF_O $(mg/kg\text{-}day)^{-1}$	Carcinogenic CSF_i $(mg/kg\text{-}day)^{-1}$	Carcinogenic CSF_{abs} $(mg/kg\text{-}day)^{-1}$	Noncarcinogenic RfD_O mg/kg-day	Noncarcinogenic RfD_i mg/kg-day	Noncarcinogenic RfD_{abs} mg/kg-day
VOCs							
Benzene	71-43-2	0.029 I	0.029 R	2.90E-01[a]	0.003 R	0.0017 R	0.0003[b]
Toluene	108-88-3				0.2 I	0.114 R	0.02[b]
Ethylbenzene	100-41-4				0.1 I	0.29 R	0.01[b]
m-Xylene	108-38-3				2.0 H	0.2 W	0.2b
o-Xylene	95-47-6				2.0 H	0.2 W	0.2b
p-Xylene	106-42-3					0.0857 W	
SVOCs							
Acenapthene	83-32-9				0.06 I		0.01[b]
Acenapthylene[c]	208-96-8						
Anthracene	120-12-7				0.3 I		0.03[b]
Benz(a)anthracene	56-55-3	0.73 R	0.61 W	7.3[a]			
Benzo(b)fluoranthene	205-99-2	0.73 R	0.61 W	7.3[a]			
Benzo(k)fluoranthene	207-08-9	0.073 R	0.061 W	0.73[a]			
Benzo(g,h,l)perylene[c]	191-24-2						
Benzo(a)pyrene	50-32-8	7.3 I	3.1 R	73.0[a]			
Chrysene	218-01-9	0.0073	R	0.073[a]			
Dibenz(a,h)anthracene	53-70-3	7.3 R	6.1 W	73.0[a]			
Ethylene glycol	107-21-1				2.0 I		
Fluoranthene	206-44-0				0.04 I		0.004[b]
Fluorene	86-73-7				0.04 I		0.004[b]
Indeno(1,2,3-cd)pyrene	193-39-5	0.73 R	0.61 W	7.3[a]			
Napthalene	91-20-3				0.02 I	0.0009 R	0.002[b]
Phenanthrene[c]	85-01-8						
Pyrene	129-00-0				0.03 I		0.003[b]
Metals							
Cadmium (food)	7440-43-9		6.3 R		0.001 I		0.00001[d]
Cadmium (water)	7440-43-9		6.3 R		0.0005	I	0.000005[d]
Chromium(III)	16065-83-1				1.5 I		0.015[d]
Chromium(VI) particulates	18540-29-9				0.003 I	0.00003 R	0.00003[d]
Lead	7439-92-1						
Nickel, soluble salts	7440-02-0				0.02 I		0.0002[d]
Zinc, metallic	7440-66-6				0.3 I		0.003[d]

Sources

I = IRIS database (accessed 28 July 1999).

R = EPA Region III RBC Table (updated 4/12/99).

W = WV VRRA Guidance Manual, v. 1.1, Table C-1).

[a] $CSF_{abs} = CSF_O / 0.10$

[b] $RfD_{abs} = RfD_O \times 0.10$

[c] No toxicity factors reported.

[d] $RfD_{abs} = RfD_O \times 0.01$

Discussion 6-2. Lead (Pb): Risk Assessment Considerations

Until the late 1980s organic lead compounds known as tetraalkyl lead (TAL) were added to gasoline to reduce engine knock. Several TAL compounds were used as antiknock agents but by far the most extensively used TAL was tetraethyl lead. Risk assessment of TAL is problematic for several reasons. As mentioned in Discussion 2-4, individual TAL compounds or degradation products are not commonly or easily measured at sites; therefore, quantification of potential exposure to them is usually not possible. Furthermore, there is scant toxicity information for TAL compounds and none for their predominant degradation products. *If TAL contamination is suspected at a site and the CSM indicates that exposure to TAL compounds or their degradation products is a concern, then the LRS should contact WVDEP to discuss how to proceed.*

Inorganic lead contamination is amenable to risk assessment; however, inorganic lead is assessed in a manner different from other COCs discussed in this User Guide. Neither the Uniform risk-based equations (GM 3.3) nor the Site-Specific risk-based equations (GM 3.4.1) are appropriate for lead-contaminated soil. Appendix F of the Guidance Manual indicates that risks for inorganic lead are assessed by comparing predicted blood lead levels to target blood lead levels. Blood lead levels are predicted based on environmental lead concentrations using either a childhood or an adult model. Soil lead cleanup levels are calculated by selecting a target blood lead level and doing a reverse calculation with the models to solve for soil lead concentration. For service stations, which are typically evaluated as industrial sites, the appropriate model is for adults (GM Appendix F.3). USEPA's recommendation of an approach based on an adult blood lead model developed by Bowers et al. (1994) is used for lead contaminated soil at industrial sites.

Table F-1 in the Guidance Manual illustrates the application of USEPA's adult blood lead model to calculate a lead-in-soil cleanup standard. This illustration calculates a soil lead cleanup level of 7253 mg/kg (7253 ppm) for industrial sites using various default input values. *The LRS should review the default input values to determine whether they are appropriate to the applicant's site. If the LRS wishes to revise the default input values based on site-specific information, the revision(s) should be justified to WVDEP.* The equations for calculating blood lead levels and the default input values are subject to review and updating as the understanding of lead contamination risks develops further. *The LRS should consult with WVDEP to determine that the most current information about lead risks is applied to a site.*

Reference
Bowers, T.S., B.D. Beck, and H.S. Karman. 1994 *Assessing the Relationship Between Environmental Lead Concentrations and Adult Blood Levels.* Risk Analysis. 14:183-189.

MTBE and ethylene glycol are COCs that may pose risk assessment problems due to a lack of toxicity data. UG Discussion 6-3 contains risk assessment guidance for these COCs.

Discussion 6-3. MTBE and Ethylene Glycol: Risk Assessment Considerations

MTBE
MTBE is often encountered as a groundwater contaminant at gasoline release sites where ingestion of drinking water is a groundwater risk concern (UG Discussion 2-3). MTBE has potent taste and odor properties that are detected by many people at low parts per billion (ppb) levels in water. Currently, the toxicity of MTBE is poorly characterized. More is known about its inhalation toxicity than its oral toxicity. The lack of oral toxicity data significantly complicates MTBE risk assessments. Very recent evidence suggests that MTBE is carcinogenic, although USEPA has not formally assigned it a carcinogenicity classification. At the time of preparation of this User Guide, neither a USEPA-approved oral cancer slope factor nor an oral reference dose is available. *Information on MTBE toxicity is developing rapidly, and the LRS should make sure that the most current toxicity information is applied to the risk assessment of MTBE.*

There are currently no West Virginia or federal drinking water standards for MTBE. USEPA has issued a drinking water advisory for MTBE. This advisory recommends that MTBE in the range of 20–40 µg/L or less in *drinking* water be considered protective of both aesthetic (taste and odor) and toxic effects.

There are currently no West Virginia or USEPA standards for MTBE in soil. *An LRS finding MTBE in groundwater above the drinking water advisory range or in soil should contact WVDEP to determine how to proceed.*

Ethylene Glycol
There is currently no drinking water standard (MCL or MCLG) for ethylene glycol. USEPA has not formally classified the carcinogenicity status of ethylene glycol, but studies to date suggest that it is not carcinogenic. USEPA's IRIS database does not list a cancer slope factor but does contain an oral reference dose value. This value can be used to evaluate ingestion exposure risks using either Uniform or Site-Specific risk-based equations as outlined for noncarinogenic SVOCs in UG 7.

References
Agency for Toxic Substances and Disease Registry. 1997. *Toxicological Profile for Ethylene Glycol and Propylene Glycol.*

United States Environmental Protection Agency (USEPA). 1997. *Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Methyl Tertiary-Butyl Ether (MTBE).* EPA-822-F-97-009.

In some cases COCs may not have toxicity values from approved sources. In such cases the LRS should contact WVDEP for guidance on how to proceed. *The absence of toxicity values from approved sources should not result in COCs being disregarded in the risk assessment without prior approval of WVDEP.*

6.10.3.4 Default Medium-Specific Input for Uniform Standard Equations.
UG Table 6-6 lists the default values for medium-specific inputs for the Uniform risk-based equations. Medium-specific inputs are the inputs for which it is most likely that site-specific values will be available. The Guidance Manual permits the use of site-specific values in lieu of default values where the justification of their use is adequately documented by the LRS (GM 3.3 and Appendix D.3).

Table 6-6. Default Medium-Specific Parameter Values

Symbol	Definition	Formula	Value	Units
Θ_a	Air-filled soil porosity	L_{air}/L_{soil} or $n-Q_w$	0.28	Unitless
Θ_w	Water-filled soil porosity	L_{water}/L_{soil}	0.15^a	Unitless
			0.30^b	Unitless
n	Total soil porosity	L_{pore}/L_{soil} or $1-(\rho_b/\rho_s)$	0.43	Unitless
PEF	Particulate emission factor	See GM Equation D-8	1.32×10^9	m^3/kg
ρ_b	Dry soil bulk density		1.5	g/cm^3 or kg/L^c
ρ_s	Soil particle density		2.65	g/cm^3 or kg/L^c
Q/C	Inverse of mean concentration^d		68.81^e	$(g/m^2\text{-}s)/(kg\text{-}m^3)$
f_{oc}	Fraction organic carbon in soil		0.006^f	Unitless
			0.002^g	Unitless

Note: Values in this table are taken from the tables accompanying GM Equations D-7, D-8, D-9, and D-11.
^{a}Use this Θ_w value to calculate volatilization factor (VFs) (GM Equation D-7) and soil saturation concentration (sat) (GM Equation D-9).
^{b}Use this Θ_w value to calculate Uniform Standard for migration to groundwater (GM Equation D-11).
^{c}GM Equation D-7 requires ρ_b and in ρ_s in g/cm^3 units, and GM Equations D-9 and D-11 require them in kg/L units. Because both sets of units are equivalent, the value of the parameters does not change.
^{d}At the center of a 0.5-acre square source.
^{e}Use this Q/C value to calculate volatilization factor (VFs) (GM Equation D-7).
^{f}Use this f_{oc} value to calculate volatilization factor (VFs) (GM Equation D-7) and soil saturation concentration (sat) (GM Equation D-9).
^{g}Use this f_{oc} value to calculate Uniform Standard for migration to groundwater (GM Equation D-11).

6.10.4 Output of Uniform Risk-Based Equations
The output from a Uniform risk-based equation is a Uniform standard expressed as a concentration value (e.g., mg/kg or µg/L) for a single COC in the particular medium and by the particular exposure route evaluated (UG 6.10, Figure 6-2). The Uniform standard is generated by back-calculating from a preselected level of risk for a given exposure scenario. That is, it starts with a specified target risk level for a site and converts that selected risk, using specific equations and inputs, to a contaminant concentration level in soil or groundwater that corresponds to that risk.

6.10.5 Output of Site-Specific Risk-Based Equations
In contrast to the output of Uniform risk-based equations, the output of a Site-Specific risk-based equation is neither a contaminant concentration value nor a Site-Specific standard, but rather a risk value (e.g., cancer risk of 1×10^{-5} or a Hazard Quotient of 0.75) (UG 6.10, Figure 6-2). The risk value is derived by evaluating the exposure level (expressed as "intake" [GM 3.4.1.1 and Appendix H]) and the toxicity (GM 3.4.1.2) of a measured or modeled contaminant concentration for each COC for each exposure pathway of concern.

6.11 Cumulative Risk

6.11.1 Uniform Standards
A separate Uniform standard is calculated for each COC on each exposure pathway identified on the CSM Pathway Analysis Diagram (UG Figure A-1). It is used for comparison with the on-site concentration level of that particular COC by that pathway. Because Uniform standards are derived from a specified, preselected, default target risk level and result in a contaminant concentration level for a particular COC, it is not appropriate to add individual concentrations for a number of COCs to arrive at a concentration that would represent a cumulative Uniform standard. *The discussion of cumulative risk relative to Uniform standards in Version 1.1 of the Guidance Manual (GM 3.3.3) will be removed in subsequent versions and should be disregarded.*

6.11.2 Site-Specific Risk Levels
Site-Specific risk levels are evaluated on the basis of cumulative risk (See box discussion below). Risks associated with simultaneous exposure to more than one carcinogen in a given medium are aggregated to determine a total cancer risk for each pathway. Where multiple exposure pathways exist, total cancer risks for each pathway are then summed for reasonable combinations of exposure pathways to determine the total cancer risk for the population of concern (GM 3.4.1.3).

For noncarcinogenic risks, HQs for individual chemicals are summed for each exposure pathway to determine an HI. Where multiple exposure pathways exist, HIs for each exposure pathway are then summed for reasonable combinations of exposure pathways to determine a total HI (GM 3.4.1.3).

> Section 3.4.2 of Version 1.1 of the Guidance Manual states that the risks from carcinogens and noncarcinogens (systemic toxicants) should be evaluated individually. However, it is WVDEP's policy that both carcinogens and noncarcinogens be evaluated cumulatively, not individually, under the Site-Specific standard process as described in Section 3.4.1.3 of the Guidance Manual. GM Section 3.4.2 will be revised to reflect this policy in subsequent versions.

6.12 Using Standards to Establish Cleanup Levels

6.12.1 Uniform Standards
If concentrations of COCs at a site fall below the Uniform standards, then it can be reasonably assumed that they present no unacceptable exposures to humans, and no further study is warranted (GM Appendix D.1). Figure 3-1 in the Guidance Manual indicates that where concentrations of COCs are greater than the calculated Uniform standard, the LRS has three options:
• Clean up the site to the Uniform standard.
• Reevaluate the site using the Uniform standard equations while substituting site-specific input parameters for the default parameters recommended in the Guidance Manual (GM 3.3 and Appendix D.3). Use of site-specific rather than default inputs must be justified and documented by the LRS.
• Proceed to a Site-Specific risk-based evaluation.

6.12.2 Site-Specific Standards

6.12.2.1 Baseline Risk Assessment and Residual Risk Assessment
The Guidance Manual provides that a Site-Specific standard can be implemented using either a Baseline Risk Assessment or Residual Risk Assessment (GM 3.4). Baseline and Residual Risk Assessments are carried out using the same equations. The differences in the two assessments are the site conditions that determine the intake parameters used in calculating the site risks. A Baseline Risk Assessment (GM 3.4.1) is a Site-Specific analysis of the potential adverse health effects (current or future) caused by a hazardous substance release from a site in the absence of any actions to control or mitigate the release. A Residual Risk Assessment (GM 5) determines the risk that will be present at a site following implementation of a proposed remedy. A Baseline Risk Assessment indicates whether a remedy is needed to control a site's risk. A Residual Risk Assessment indicates whether a selected remedy has adequately controlled a site's risk.

Generally, a Baseline Risk Assessment is first performed to determine whether a site warrants remedial action, and then a Residual Risk Assessment is performed for those sites that require a remedy. However, at some sites, the Residual Risk Assessment may be the only risk assessment performed (GM 5). Examples of such sites include, but are not limited to the following:
• Sites where the applicant has already implemented a remedial action.
• Sites where harm is readily apparent and the applicant has elected not to perform a risk assessment but proceed directly to the remedy evaluation. Readily apparent harm is most commonly determined in an ecological screening evaluation (GM 4).

**6.12.2.2 The Role of Baseline Risk Assessment and
              Residual Risk Assessment in the Site-Specific Standard**

If the cumulative value of the cancer risk levels calculated in the Baseline Risk Assessment for a site using Site-Specific risk-based equations is below one in one million (1×10^{-6}), then cleanup is generally not required. If the baseline cumulative risk exceeds one in ten thousand (1×10^{-4}), then remedial action is generally required. The necessity of remedial action for baseline cumulative risks in the range of one in ten thousand and one in one million will be evaluated by WVDEP on a case-by-case basis. If the baseline cumulative noncancer risks result in a Hazard Index less than 1.0, then cleanup is not required (GM 3.4.2).

If the baseline cumulative cancer risk at a site exceeds one in ten thousand (1×10^{-4}) or the baseline cumulative HI exceeds 1.0, then Site-Specific remedial standards must be developed in consultation with WVDEP as previously described (UG 6.7), and the LRS must propose an action (or actions) to abate the risk. Abatement actions may include active remediation, monitored natural attenuation, engineering controls, institutional controls, or combinations thereof. A Residual Risk Assessment (GM 5) is then performed to demonstrate that the abatement actions proposed will result in a cumulative site risk that is less than one in ten thousand (1×10^{-4}) for carcinogens and a cumulative HI that does not exceed 1.0 for noncarcinogens.

> In cases where the cumulative HI exceeds 1.0, the rules allow for adjustment of the HI for noncarcinogens in instances where it can be demonstrated that noncarcinogenic COCs do not affect the same organ. (GM 3.4.1.3 and 3.4.2)

6.13 Notification Requirements (GM 1.2.3.2 and 3.4.2)

Where, as determined by a Residual Risk Assessment (GM 5), a residual cancer risk level of greater than 1×10^{-6} is proposed for a site with a residential land use or greater than 1×10^{-5} for a site with industrial land use, the Guidance Manual describes a specific public involvement and notification process that must be carried out.

6.14 Demonstration of Attainment of Uniform Standards (GM 3.3.5)

6.14.1 Soils

Attainment of the cleanup standard is achieved when a measure of the average contaminant concentration on the site is less than or equal to the standard. Because average concentrations are uncertain, the 95% UCL on the mean concentration should be calculated for all soil samples within the contaminated areas of the site. The UCL can be calculated using the procedure in *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A)—Supplemental Guidance: Calculating the Concentration Term* (USEPA 1992). Determining the number and location of samples used to calculate the UCL is critical to its accuracy and representativeness. Guidance such as *Methods for Evaluating the Attainment of Cleanup Standards Volume 1: Soils and Solid Media,* EPA 230/02-89-042 (USEPA 1989) should be consulted to support the site characterization approach to determining the UCL.

6.14.2 Groundwater

Several methods can be used to demonstrate compliance with groundwater cleanup standards. Acceptable compliance demonstrations include, but are not limited to
- comparison of highest level in any well to the standard,
- statistical comparison of results from select wells to the standard, and
- other reasonable methods as approved by WVDEP.

Helpful guidance for groundwater compliance attainment can be found in *Methods for Evaluating the Attainment of Cleanup Standards Volume 2: Ground Water,* EPA230-R-92-14 (USEPA 1992). In most situations, it is recommended that a statistical evaluation of the groundwater be conducted. An approved and acceptable method is to calculate a one-sided 95% UCL on the mean on selected wells (GM page H-8). Selection of wells to be used is supported by the site characterization and any relevant risk assessment.

The wells must be part of the same population (e.g., wells within a plume of contamination). If there is an insufficient number of wells (or samples) to do a statistical evaluation, then the results from each well may need to be compared to the standard. In this case, all results would need to be below the standard to demonstrate compliance. The Guidance Manual lists additional factors to consider when deciding upon the method to be used to demonstrate compliance (GM 3.3.5.2).

6.15 Attainment of Site-Specific Remediation Standards
The LRS shall propose for WVDEP's review and approval an approach for determining whether Site-Specific Standards have been attained at a site.

6.16 Uncertainty

The Guidance Manual recommends including in the final report a discussion of uncertainty as it affects the development of Uniform standards (GM 3.3.4) and Site-Specific remediation standards (GM 3.4.1.4). Although a detailed discussion of uncertainty is not required for Uniform standards, the LRS should identify key site-related variables and assumptions that contribute most to their uncertainty. Section 3.3.4 of the Guidance Manual recommends a format developed by USEPA for evaluating and summarizing uncertainties associated with development of Uniform standards.

A more detailed discussion of uncertainty should accompany the description of the development of Site-Specific remediation standards. The Guidance Manual recommends consulting USEPA's *Exposure Factors Handbook, Volume I—General Factors 1996* (EPA/600/P-95/002Fa) for discussions and illustrations of uncertainty analysis in risk assessments.

7 Example Risk Calculations

7.1 General

This section of the User Guide illustrates the performance of risk calculations following risk methodologies described in UG 6 for a hypothetical abandoned service station described in UG 4. Preceding sections of this User Guide have discussed the identification of COCs at the hypothetical abandoned service station and a description of their distribution and concentration in the environmental media (UG 2), the development of the CSM pathway analysis diagram (UG 5), and the selection of the appropriate Human Health Standard (UG 6). These preliminary steps must be completed before calculating the actual risk-based cleanup standards and/or risk levels that will be in effect at the site. Familiarity with the assumptions and conclusions developed for the hypothetical abandoned service station in previous sections of this guide will facilitate understanding the risk assessment procedures illustrated below.

The calculations depicted in this section are for illustration purposes only. They may or may not be applicable to a real site. The LRS must carry out the risk calculations that are indicated by the CSM developed for a site.

The basic division of this section is between Uniform and Site-Specific standards. The organization of each of these subsections is based on exposure pathways through environmental media (i.e., surface soil, subsurface soil, and groundwater). Exposure routes that are discussed in relation to each environmental medium include ingestion, inhalation, dermal contact, and migration to groundwater. Carcinogenic and noncarcinogenic COCs are evaluated separately for each exposure route except migration to groundwater. Industrial land use and an adult site worker receptor are assumed for all on-site exposure routes. Off-site exposures are restricted to in situ groundwater and groundwater used as tapwater and are evaluated as residential. UG Table 7-1 shows the layout of UG Section 7. It provides an overview of the exposure pathways discussed and the Guidance Manual equations whose use is illustrated.

Table 7-1. Overview of the Exposure Pathways Illustrated and/or Discussed in Section 7. Bold items indicate illustrated use of Guidance Manual risk-based equations.

UNIFORM		
	UG Section	**GM Equation**
General		
Soil Saturation Concentration (sat)	7.2.1	Eq. D-9
Surface Soil	7.2.2	
Ingestion and Inhalation	7.2.2.1	
Noncarcinogen—Ingestion and Inhalation	7.2.2.1.a	Eq. D-4
Carcinogen—Ingestion and Inhalation	7.2.2.1.b	Eq. D-3
Dermal Exposure	7.2.2.2	
Subsurface Soil	7.2.3	
Ingestion	7.2.3.1	
Inhalation	7.2.3.2	
Volatilization to Indoor Air	7.2.3.2.a	
Volatilization to Ambient Air	7.2.3.2 b	
Noncarcinogen—Inhalation Only	7.2.3.2.b1	Eq. D-4
Carcinogen—Inhalation Only	7.2.3.2.b2	Eq. D-3
Dermal Exposure	7.2.3.3	
Migration to Groundwater	7.2.3.4	
Migration to Groundwater	7.2.3.4.a	Eq. D-11

UNIFORM (continued)		
	UG Section	**GM Equation**
Groundwater	7.2.4	
Ingestion and inhalation	7.2.4.1	
(In Situ) Volatilization to Ambient or Indoor Air	7.2.4.1.a	
(As Tapwater) Noncarcinogen—Ingestion and Inhalation	7.2.4.1.b	Eq. D-6
(As Tapwater) Carcinogen—Ingestion and Inhalation	7.2.4.1.c	Eq. D-5
Dermal Exposure	7.2.4.2	
SITE SPECIFIC		
Surface Soil	7.3.1	
Ingestion	7.3.1.1	
Noncarcinogenic—Ingestion	7.3.1.1.a	Eq. H.1.3
Carcinogenic—Ingestion	7.3.1.1.b	Eq. H.1.3
Inhalation	7.3.1.2	
Dermal Exposure	7.3.1.3	
Noncarcinogenic—Dermal Exposure	7.3.1.3.a	Eq. H.1.4
Carcinogenic—Dermal Exposure	7.3.1.3.b	Eq. H.1.4
Subsurface Soil	7.3.2	
Ingestion	7.3.2.1	
Inhalation	7.3.2.2	
Dermal Exposure	7.3.2.3	
Groundwater	7.3.3	
Ingestion	7.3.3.1	
(As Tapwater) Noncarcinogenic—Ingestion	7.3.3.1.a	Eq. H.1.1
(As Tapwater) Carcinogenic—Ingestion	7.3.3.1.b	Eq. H.1.1
Inhalation	7.3.3.2	
Dermal Exposure	7.3.3.3	
(As Tapwater) Noncarcinogen—Dermal Exposure	7.3.3.3.a	Eq. H.1.2
(As Tapwater) Carcinogen—Dermal Exposure	7.3.3.3.b	Eq. H.1.2
Analysis of Cumulative Risk	7.4	

7.2 Uniform Standard Calculations

7.2.1 Uniform Standard—Soil Saturation Concentration

Soil saturation (sat) corresponds to the contaminant concentration in soil at which the sorptive limits of the soil particles and the solubility limits of the available soil moisture have been reached. Contamination above this value suggests that free product is present in the soil. UG 3 describes how to proceed if free product is present at a site. If a VOC's Uniform Standard, that is, a standard calculated using the volatilization factor VFs (GM D.4.3.1, Equation D-7), is greater than the calculated sat, the standard should be set equal to sat value (GM D.4.4).

Step 1: *Calculate the soil saturation concentration (sat) (GM D.4.4, Equation D-9) for benzene using default medium-specific physical parameter values (UG Table 6-6) and chemical-specific parameter values (UG Table 6-4).*

$$sat = \frac{S}{\rho_b} \left(K_d\, \rho_b + \theta_w + H'\theta_a \right)$$

$$= \frac{1750\ mg/L}{1.5\ kg/L} (0.353\,L/kg \times 1.5\ kg/L + 0.15 + 0.228 \times 0.28)$$

$$= 868\ mg/kg$$

Step 2: *Compare the calculated sat to the benzene concentration in soil samples from Table 4-1. The calculated sat is greater than the soil benzene concentration; therefore, it is unlikely that free product is present. This conclusion indicates that it is appropriate to use the Uniform risk-based equations to calculate the volatilization of VOCs from soil (UG 7.2.3.2).*

Uniform Standard sat values for all of the petroleum VOCs typically encountered at an abandoned service station site are presented in UG Table 7-2. The values were calculated as illustrated above.

Table 7-2. Soil Saturation Concentrations (sat)

VOC	CAS #	sat (mg/kg)
Benzene	71-43-2	868
Toluene	108-88-3	654
Ethylbenzene	100-41-4	395
m-Xylene	108-38-3	418
o-Xylene	95-47-6	413
p-Xylene	106-42-3	461
Naphthalene	91-20-3	375

7.2.2 Surface Soil
The Uniform risk-based equations for soil are used for both surface and subsurface soil. The reason for distinguishing between the two soil regions is that they often contain different COCs and have different exposure pathways. PAHs and metals are the only COCs likely to be encountered in surface soils at the typical abandoned service station site (UG 2.5.1 and 2.5.2), whereas PAHs, VOCs, metals, and ethylene glycol may be encountered in subsurface soils (UG 2.5.4, 2.5.5, and 2.5.6). Exposure pathways available for surface soils include ingestion, inhalation of particulates, and dermal absorption. Where large releases of used motor oil have occurred, the potential risk posed by inhalation of volatilized naphthalene in ambient air should also be considered.

7.2.2.1 Ingestion and Inhalation
a) Uniform Standard—Noncarcinogenic—Surface Soil—Ingestion and Inhalation
Naphthalene is the only noncarcinogenic PAH for which toxicity factors are available for both ingestion and inhalation exposure routes. The method of calculating the Uniform Standard is illustrated below.

Step 1: *Calculate the Uniform standard for naphthalene in industrial surface soil for an adult receptor for the combined inhalation and ingestion exposure routes (GM D.4.1, Equation D-4) using naphthalene-specific exposure factors (UG Table 6-1) and toxicity parameter values (UG Table 6-5) and the default PEF value (UG Table 6-6).*

$$C\,(mg/kg) = \frac{THQ \times BW_a \times AT_n}{EF_o \times ED_o \left[\left(\frac{1}{RfD_o} \times \frac{IRS_o}{10^6\,mg/kg} \right) + \left(\frac{1}{RfD_i} \times \frac{IRA_a}{PEF} \right) \right]}$$

$$= \frac{1 \times 70\,kg \times 25\,yrs \times 365\,days/yr}{250\,days/yr \times 25\,yrs \left[\left(\frac{1}{0.02\,mg/kg\text{-}day} \times \frac{50\,mg/day}{10^6\,mg/kg} \right) + \left(\frac{1}{0.0009\,mg/kg\text{-}day} \times \frac{20\,m^3/day}{1.39 \times 10^9\,m^3/kg} \right) \right]}$$

$$= 40{,}900\,mg/kg$$

Step 2: *The naphthalene concentration in surface soil samples (UG Table 4-1) is lower than the Uniform standard for naphthalene calculated in Step 1. In this situation, no remedial action would be required. In the alternate scenario, in which the sampling concentration is higher than the Uniform standard, the LRS would have the option of remediating the naphthalene contamination to the Uniform standard or carrying out a Site-Specific risk assessment. A much higher naphthalene concentration than that indicated in UG Table 4-1 was used in UG 7.3.1.1 and UG 7.3.1.3 to illustrate the Site-Specific risk evaluation for naphthalene in surface soil.*

b) Uniform Standard—Carcinogen—Surface Soil—Ingestion and Inhalation
Benzo(a)pyrene is one of several carcinogenic PAHs likely to be encountered in surface soils at the typical abandoned service station site (UG 2.5.1). Calculation of a Uniform standard for benzo(a)pyrene is illustrated below.

Step 1: *Calculate the Uniform standard for benzo(a)pyrene in industrial surface soil for an adult receptor for the combined inhalation and ingestion exposure routes (GM D.4.1, Equation D-3) using benzo(a)pyrene-specific exposure factors (UG Table 6-1) and toxicity parameter values (UG Table 6-5) and the default PEF value (UG Table 6-6).*

$$C\,(mg/kg) = \frac{TR_I \times BW_a \times AT_c}{EF_o \times ED_o \left[\left(\frac{IRS_o \times CSF_o}{10^6\,mg/kg} \right) + \left(\frac{IRA_a \times CSF_i}{PEF} \right) \right]}$$

$$= \frac{10^{-5} \times 70\,kg \times 25{,}550\,days}{250\,days/yr \times 25\,yrs \left[\left(\frac{50\,mg/day \times 7.3\,\,1/mg/kg\text{-}day}{10^6\,mg/kg} \right) + \left(\frac{20\,m^3/day \times 3.1(mg/kg\text{-}day)^{-1}}{1.32 \times 10^9\,m^3/kg} \right) \right]}$$

$$= 7.8\,mg/kg$$

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> ***Step 2:*** *Compare the benzo(a)pyrene concentration in surface soil samples (UG Table 4-1) to the Uniform standard for benzo(a)pyrene calculated in Step 1. The sampling concentration is higher than the standard. The LRS has the option of remediating the benzo(a)pyrene contamination to the Uniform standard or carrying out a Site-Specific risk assessment.*

7.2.2.2 Dermal Exposure

a) Uniform Standard—Surface Soil—Dermal Exposure

PAHs and metals are the COCs most commonly encountered in surface soils. The pathway analysis diagram for the abandoned service station site (UG Figure A-2) indicates that dermal exposure to surface soil should be evaluated in the risk assessment. However, there is no Uniform risk-based equation for the dermal exposure route. *The LRS should consider the possibility of performing a Site-Specific risk assessment (UG 7.3.1.3) or propose to WVDEP another approach to evaluating this exposure route. The route must not simply be ignored.*

7.2.3 Subsurface Soil

At the typical abandoned service station site, subsurface soils may contain VOCs, PAHs, metals, and ethylene glycol (UG 2.5.5 and 2.5.6). (See UG Discussion 6-1)

7.2.3.1 Ingestion

a) Uniform Standard—Subsurface Soil—Ingestion

Subsurface soils are typically unavailable for ingestion, so they are unlikely to pose a risk to human receptors. (See UG Discussion 6-1)

7.2.3.2 Inhalation

a) Uniform Standard—Subsurface Soil—Volatilization to Indoor Air

PAHs, metals, and ethylene glycol do not pose a risk due to volatilization. VOCs and naphthalene may contaminate indoor air and be inhaled after volatilizing from subsurface soil and infiltrating into buildings (UG Figure 4-3). The pathway analysis diagram (UG Figure A-2) indicates that this pathway should be evaluated at the hypothetical abandoned service station. However, there are no Uniform risk-based equations for exposure pathways for inhalation of indoor air, and use of the Site-Specific risk-based inhalation equation (GM Equation H.1.5) is often difficult (UG 7.3.2.2). *If this pathway is present at the site, the LRS should consult with WVDEP on how to proceed.*

b) Uniform Standard—Subsurface Soil—Volatilization to Ambient Air

PAHs, metals, and ethylene glycol do not pose a risk due to volatilization. VOCs and naphthalene in subsurface soil may be inhaled after volatilization to ambient air. Because the Guidance Manual does not provide a Uniform risk-based equation that is intended for use in evaluating inhalation risk alone, the following steps illustrate the use of a combined (inhalation and ingestion) Uniform risk-based equation for the purpose of assessing risk to an adult industrial worker due to inhalation of vapors from subsurface soil contaminated by VOCs.

b.1) Uniform Standard—Noncarcinogen -Subsurface Soil—Inhalation Only

Step 1: *Calculate the Apparent Diffusivity (D_A) for toluene (GM D.4.3, Equation D-7) using default values of medium-specific physical parameters (UG Table 6-6) and toluene-specific physical parameter values (UG Table 6-4).*

$$D_A = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'}$$

$$= \frac{\left[(0.28^{10/3} \times 0.087 \ cm^2/s \times 0.272 + 0.15^{10/3} \times 0.0000086 \ cm^2/s)/0.43^2\right]}{1.5 \ g/cm^3 \times 1.09 \ cm^3/g + 0.15 + 0.28 \times 0.272}$$

$$= 0.00099 \ cm^2/s$$

Step 2: *Calculate the toluene Volatilization Factor for Soil (VF_s) (GM D.4.3, Equation D-7) using default values of physical (UG Table 6-6) and exposure (UG Table 6-1) parameters and the D_A value for toluene calculated in Step 1.*

$$VF_s \left(m^3/kg\right) = (Q/C) \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4} \left(m^2/cm^2\right)$$

$$= 68.81 \ g/m^2\text{-}s/kg/m^2 \times \frac{(3.14 \times 0.00099 \ cm^2/s \times 9.5 \times 10^8 s)^{1/2}}{2 \times 1.5 \ g/cm^3 \times 0.00099 \ cm^2/s} \times 10^{-4} m^2/cm^2$$

$$= 3989 \ m^3/kg$$

Step 3: *Because ingestion exposure does not apply to this illustration set, the ingestion term in the denominator of GM Equation D-4 to zero, as shown below. Calculate the Uniform Standard for toluene in industrial subsurface soil for the inhalation exposure pathway for an adult worker using default values of exposure factors (UG Table 6-1), toluene-specific toxicity factors (UG Table 6-5), and the VF_s value for toluene calculated in Step 2.*

$$C \ (mg/kg) = \frac{THQ \times BW_a \times AT_n}{EF_o \times ED_o \left[\left(\frac{1}{RfD_o} \times \frac{IRS_o}{10^6 \ mg/kg}\right) + \left(\frac{1}{RfD_i} \times \frac{IRA_a}{VF_s}\right)\right]}$$

$$= \frac{1 \times 70 \ kg \times 25 \ yrs \times 365 \ days/yr}{250 \ days/yr \times 25 \ yrs \left[(0) + \left(\frac{1}{0.114 \ mg/kg\text{-}day} \times \frac{20 \ m^3/day}{3989 \ m^3/kg}\right)\right]}$$

$$= 2324 \ mg/kg$$

Step 4: *Compare the toluene concentration in subsurface soil samples (UG Table 4-1) to the Uniform standard calculated in Step 3. The sampling concentration is higher than the standard. For reasons discussed in Section 7.3.2.2, the Site-Specific inhalation equation is not suitable for this exposure pathway; therefore, the LRS has the option of remediating to the Uniform standard or consulting with WVDEP to determine whether an alternative approach is available.*

b.2) Uniform Standard—Carcinogen—Subsurface Soil—Inhalation Only

Benzene is the only BTEX constituent with carcinogenic effects. Because benzene also has noncarcinogenic effects, both carcinogenic and noncarcinogenic Uniform standards must be calculated, and the lower value taken as the Uniform standard for benzene in subsurface soil.

Step 1: *Calculate the Apparent Diffusivity (D_A) for benzene (GM D.4.3, Equation D-7) using default values of medium-specific physical parameters (UG Table 6-6) and benzene-specific physical parameter values (UG Table 6-4).*

$$D_A = \frac{\left[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2\right]}{\rho_b K_d + \theta_w + \theta_a H'}$$

$$= \frac{\left[(0.28^{10/3} \times 0.088 \ cm^2/s \times 0.228 + 0.15^{10/3} \times 0.0000098 \ cm^2/s) / 0.43^2\right]}{1.5 \ g/cm^3 \times 0.353 \ cm^3/g + 0.15 + 0.28 \times 0.228}$$

$$= 0.0021 \ cm^2/s$$

Step 2: *Calculate the benzene Volatilization Factor for Soil (VF_s) (GM D.4.3, Equation D-7) using default values of physical (UG Table 6-6) and exposure (UG Table 6-1) parameters and the D_A value for benzene calculated in Step 1.*

$$VF_s \ (m^3/kg) = (Q/C) \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4} \ (m^2/cm^2)$$

$$= 68.81 \ g/m^2\text{-}s/kg/m^2 \times \frac{(3.14 \times 0.0021 \ cm^2/s \times 9.5 \times 10^8 s)^{1/2}}{2 \times 1.5 \ g/cm^3 \times 0.0021 \ cm^2/s} \times 10^{-4} m^2/cm^2$$

$$= 2734 \ m^3/kg$$

Step 3: *Because ingestion exposure does not apply to this illustration, set the ingestion term in the denominator of GM Equation D-3 to zero, as illustrated below. Calculate the Uniform standard for benzene in industrial subsurface soil for the inhalation exposure pathway using default values of exposure factors (UG Table 6-1), benzene-specific toxicity factors (UG Table 6-5), and the VF_s value for benzene calculated in Step 2.*

$$C \ (mg/kg) = \frac{TR_I \times BW_a \times AT_c}{EF_o \times ED_o \left[\left(\dfrac{\cancel{IRS_o \times CSF_o}}{\cancel{10^6 \ mg/kg}}\right)_{\searrow 0} + \left(\dfrac{IRA_a \times CSF_i}{VF_s}\right)\right]}$$

$$= \frac{10^{-5} \times 70 \ kg \times 25{,}550 \ days}{250 \ days/yr \times 25 \ yrs \left[(0) + \dfrac{20 \ m^3/day \times 0.029(mg/kg\text{-}day)^{-1}}{2734 \ m^3/kg}\right]}$$

$$= 13.5 \ mg/kg$$

Step 4: *Calculate the Uniform standard for the noncarcinogenic effects of benzene inhalation by the method demonstrated above for toluene (UG 7.3.3.2.b.1), a noncarcinogenic VOC. The noncarcinogenic value is 24 mg/kg. Compare it with the concentration calculated in Step 3 for benzene as a carcinogen. The latter concentration is lower; therefore, the carcinogenic value is used as the Uniform standard for inhalation of benzene volatilizing from subsurface soil.*

Step 5: *Compare the benzene concentration in subsurface soil samples (UG Table 4-1) to the Uniform standard for benzene calculated in Step 4. The sampling concentration is higher than the standard. For reasons discussed in Section 7.3.2.2, the Site-Specific inhalation equation is not suitable for this exposure pathway; therefore, the LRS has the option of remediating to the Uniform standard or consulting with WVDEP to determine whether an alternate approach is available.*

7.2.3.3 Dermal Exposure
a) Uniform Standard—Subsurface Soil—Dermal Exposure
VOCs, PAHs, metals, and ethylene glycol may occur in the subsurface. Although no Uniform standard equation is available for the dermal contact exposure route (UG 7.2.2.2), subsurface soils are typically unavailable for dermal exposure. Therefore, they are unlikely to pose a risk to human receptors. (See UG Discussion 6-1)

7.2.3.4 Migration to Groundwater
a) Uniform Standard—Subsurface Soil—Migration to Groundwater
The procedure illustrated below identifies chemical concentrations in soil that have the potential to leach to groundwater and result in groundwater levels in excess of human health standards. A target leachate concentration is used to determine this Uniform standard. The standard is designed for use during the early stages of a site evaluation, when information about subsurface conditions may be limited (GM D.4.5). In most cases, the only COCs that will be encountered at the typical abandoned service station site that have sufficient mobility to reach groundwater are VOCs, naphthalene (UG 2.5.6) and ethylene glycol (UG 2.5.5). The example below uses the VOC benzene to illustrate the calculation.

Step 1: *Use a default value of 20 as the dilution factor (GM D.4.5). Alternatively, calculate a dilution factor using site-specific values and GM Equation D-10 as explained in Appendix D of the Guidance Manual (GM D.4.5).*

Step 2: *Calculate the target leachate concentration (C_w) for benzene by multiplying the dilution factor determined in Step 1 by an acceptable groundwater concentration such as an MCLG, MCL, or health-based factor. MCL values for BTEX are presented in UG Table 7-3. For benzene, the MCL of 0.005 mg/L was multiplied by the default dilution factor, as shown.*

$$C_w = dilution\ factor \times MCL_{benzene} = 20 \times 0.005\ mg/L = 0.1\ mg/L$$

Step 3: *Calculate the Uniform standard for protection against migration to groundwater for benzene in subsurface soil by use of GM Equation D-11, as illustrated below. Use default medium-specific parameter values (UG Table 6-6), benzene-specific physical property values (UG Table 6-4), and the C_w value for benzene calculated in Step 2.*

$$screening\ level\ in\ soil\ (mg/kg) = C_w \left[K_d + \frac{(\theta_w + \theta_a H')}{\rho_b} \right]$$

$$= 0.1\ mg/L \left[0.118\ L/kg + \frac{(0.3 + 0.28 \times 0.228)}{1.5\ kg/L} \right]$$

$$= 0.036\ mg/kg$$

Step 4: *Compare the benzene concentration in subsurface soil samples (UG Table 4-1) to the Uniform standard for protection against benzene migration to groundwater calculated in Step 3. The sampling concentration is higher than the standard. Because there is no Site-Specific equation for the migration to groundwater, the LRS has the option of remediating to the Uniform standard or consulting with WVDEP to determine whether an alternative approach is available.*

Table 7-3 Maximum Contaminant Levels (MCLs)[a]

COC	MCL (mg/L)
Benzene	0.005
Toluene	1.00
Ethylbenzene	0.70
m-Xylene	10.00
o-Xylene	10.00
p-Xylene	10.00
Naphthalene	1.00[b]
Ethylene glycol	20.00[b]

[a] The LRS should confirm that these MCL
values are current before using them.

[b] Health-based level from Soil Screening Guidance.

7.2.4   Groundwater

As previously discussed (UG 7.2.3.4), at the typical abandoned service station site, only VOCs (BTEX and MTBE) and the SVOCs naphthalene and ethylene glycol are likely to have the mobility to reach groundwater. They pose potential risks to on-site workers and off-site residents through several exposure pathways discussed below.

7.2.4.1 Ingestion and Inhalation

a) Uniform Standard—Groundwater (In Situ)—Volatilization to Ambient or Indoor Air

PAHs, metals, and ethylene glycol do not need to be considered for exposure pathways that include volatilization from in situ groundwater. VOCs may volatilize from in situ groundwater to ambient and/or indoor air. However, there are no Uniform or Site-Specific risk-based equations available to evaluate these exposure routes. *If these routes apply at a site, the LRS should consult with WVDEP to determine how to proceed.*

b) Uniform Standard—Noncarcinogen—Groundwater (As Tapwater)—Ingestion and Inhalation

Exposure to VOCs in groundwater can occur as a result of drinking (ingesting) the water or inhaling the VOCs that volatilize from the water during showering, bathing, dishwashing, or other domestic activities (UG 2.5.5). PAHs (with the exception of naphthalene), metals, and ethylene glycol do not volatilize appreciably; therefore, only the ingestion route would be applicable. The use of a combined inhalation-ingestion risk-based equation to generate a Uniform standard for inhalation alone is illustrated for soil in UG 7.2.3.2. The same principle can be applied for ingestion of PAHs, metals, and ethylene glycol in the present case. The following example illustrates the calculation of the Uniform standard for a noncarcinogenic VOC (toluene) in groundwater used as residential tapwater for the combined ingestion and inhalation exposure routes.

Step 1: *Calculate the Uniform standard for toluene in residential groundwater by means of GM Equation D-6, as illustrated below. Use default values of exposure parameters (UG Table 6-1) and toluene-specific toxicity parameter values (UG Table 6-5).*

$$C\,(\mu g/L) = \frac{THQ \times BW_a \times AT_n \times 1000\ \mu g/mg}{EF_r \times ED_r \left[\left(\dfrac{IRW_a}{RfD_o} \right) + \left(\dfrac{VF_w \times IRA_a}{RfD_i} \right) \right]}$$

$$= \frac{1 \times 70\ kg \times 30\ yr \times 365\ days/yr \times 1000\ \mu g/mg}{350\ days/yr \times 30\ yrs \left[\left(\dfrac{2\ L/day}{0.2\ mg/kg\text{-}day} \right) + \left(\dfrac{0.5\ L/m^3 \times 20\ m^3/day}{0.114\ mg/kg\text{-}day} \right) \right]}$$

$$=\ 747\ \mu g/L$$

Step 2: *Compare the toluene concentrations in groundwater samples (UG Table 4-1) to the Uniform standard for toluene in groundwater calculated in Step 1. The sampling concentration is higher than the Standard. The LRS has the option of remediating the toluene contamination to the Uniform standard or proceeding to a Site-Specific risk assessment.*

c) Uniform Standard—Carcinogen—Groundwater (As Tapwater)—Ingestion and Inhalation
Refer to UG 7.2.4.1b for a discussion of the applicability of these exposure routes to VOCs, PAHs, metals, and ethylene glycols. The following example illustrates the calculation of the Uniform standard for a carcinogenic VOC (benzene) in groundwater used as residential tapwater for the combined ingestion and inhalation exposure routes.

Step 1: *Calculate the Uniform standard for benzene as a carcinogen in groundwater for residential exposure (GM D.4.2, Equation D-5) using default values of exposure parameters (UG Table 6-1) and benzene-specific toxicity parameter values (UG Table 6-5).*

$$C\,(\mu g/L) = \frac{TR_R \times AT_c \times 1000\ \mu g/mg}{EF_r\,[(IFW_{adj} \times CSF_o) + (VF_w \times InhF_{adj} \times CSF_i)]}$$

$$= \frac{10^{-6} \times 25{,}550\ days \times 1000\ \mu g/mg}{350\ days\left[(1.1\ L\text{-}yr/kg\text{-}day \times 0.029(mg/kg\text{-}day)^{-1}) + (0.5\ L/m^3 \times 11\ m^3\text{-}yr/kg\text{-}day \times 0.029(mg/kg\text{-}day)^{-1}\right]}$$

$$= 0.38\ \mu g/kg$$

Step 2: *Calculate the Uniform standard for benzene as a noncarcinogen in groundwater by the method demonstrated in UG 7.2.4.1.b for the noncarcinogenic VOC toluene The noncarcinogenic Uniform standard for benzene is 11.1 µg/L. Compare this with the concentration calculated in Step 1 for benzene as a carcinogen. The latter concentration is lower; therefore, the carcinogenic value is used as the Uniform standard for benzene in groundwater used as tapwater.*

Step 3: *Compare the benzene concentrations in groundwater samples (UG Table 4-1) to the Uniform standard for benzene in groundwater calculated in Step 2. The sampling concentration is higher than the standard. The LRS has the option of remediating the benzene contamination to the Uniform standard or proceeding to a Site-Specific risk assessment.*

7.2.4.2 Dermal Exposure
a) Uniform Standard—Groundwater (As Tapwater)—Dermal Exposure
VOCs, PAHs, metals, and ethylene glycol are COCs that may occur in groundwater. The pathway analysis diagram for the abandoned service station site (UG Figure A-2) indicates that dermal exposure to groundwater used as tapwater should be evaluated in the risk assessment. However, there is no Uniform standard equation for the dermal exposure route. *The LRS should consider the possibility of performing a Site-Specific risk assessment (as illustrated in Section 7.3.3.3 below) or propose to WVDEP another approach to evaluating this exposure route. The route must not simply be ignored.*

7.3 Site-Specific Calculations

The Site-Specific risk-based equations in Appendix H of the Guidance Manual are used to calculate exposure (intake). The intake values calculated for the COCs are multiplied by the appropriate toxicity factors according to the equations in GM 3.4.1.2 to determine a Site-Specific risk level for each exposure pathway. The examples below illustrate this process.

7.3.1 Surface Soil

At the typical abandoned service station site, only PAHs and metals are likely to be found in surface soils (UG 2.5.1 and 2.5.2), where they pose a potential risk due to soil ingestion, inhalation of particulates, and dermal exposure. Where large releases of used motor oil have occurred, the potential risk posed by inhalation of volatilized naphthalene in ambient air should also be considered. The determination of Site-Specific risk levels for these COCs and exposure routes is discussed below.

7.3.1.1 Ingestion

a) Site Specific—Noncarcinogen—Surface Soil—Ingestion

Several PAHs are noncarcinogens, and all COC metals are noncarcinogenic when ingested (UG Table 6-5). The individual Site-Specific risk of adverse health effects due to ingestion of contaminated surface soil must be calculated for each. The example below illustrates the determination of the Site-Specific risk due to ingestion of naphthalene-contaminated surface soil for an adult site worker.

Step 1: *Calculate the Site-Specific naphthalene intake via ingestion of contaminated surface soil for an adult site worker using GM Equation H.1.3 below, where:*

I = chronic daily intake (CDI) averaged over 30 years

CS= calculated 95% UCL of arithmetic mean of naphthalene concentrations in soil samples or maximum sample concentration (A much higher value than the sampling concentration shown in UG Table 4-1 is used in this calculation. Refer to UG 7.2.2.1a Step 2 for the justification.)

CF= conversion factor (10^{-6} kg/mg)

FI = fraction ingested from contaminated source—a site-specific value (For purposes of illustrating this calculation, it was assumed that the area contaminated by used oil represented one-tenth [0.1] the area of the site. As a result, the fraction of all soil ingested at the site that originates from the contaminated area is assumed to be 0.1. Justification for all assumptions should be included in the report.*)*

IRS, EF, ED, BW= exposure parameters (UG Table 6-2)

$$I = \frac{CS \times IRS \times CF \times FI \times EF \times ED}{BW \times AT}$$

$$= \frac{43{,}000 \; mg/kg \times 100 \; mg/day \times 10^{-6} \; kg/mg \times 0.1 \times 350 \; days/yr \times 30 \; yr}{70 \; kg \times 10{,}950 \; days}$$

$$= 5.9 \times 10^{-3} \; mg/kg\text{-}day$$

Step 2: *Calculate the HQ representing the Site-Specific noncancer risk of adverse health effects due to ingestion of naphthalene in surface soils by following the "Approach for Calculating Noncancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the oral reference dose (RfD$_o$) for naphthalene from UG Table 6-5 in the following Guidance Manual equation (GM 3.4.1.3).*

$$HQ = CDI/RfD_o$$
$$= 5.9 \times 10^{-3} \; mg/kg\text{-}day/0.02 \; mg/kg\text{-}day$$
$$= 0.29$$

b) Site Specific—Carcinogen—Surface Soil—Ingestion
Several PAHs are known to be carcinogens when ingested (UG Table 6-5). For each carcinogen and each receptor, the individual Site-Specific upper-bound excess cancer risk due to ingestion of contaminated soil must be calculated. The example below illustrates the determination of the Site-Specific risk due to ingestion of benzo(a)pyrene-contaminated surface soil for an adult site worker.

Step 1: *Calculate the Site-Specific ingestion intake of benzo(a)pyrene-contaminated surface soil for an adult site worker using GM Equation H.1.3 below, where:*
I = chronic daily intake (CDI) averaged over 70 years
CS = calculated 95% UCL of arithmetic mean of benzo(a)pyrene concentrations in soil samples or maximum sample concentration (UG Table 4-1)
CF = conversion factor (10^{-6} kg/mg)
FI = fraction ingested from contaminated source—a site-specific value (For purposes of illustrating this calculation, it was assumed that the area contaminated by used oil represented one-tenth [0.1] the area of the site. As a result, the fraction of all soil ingested at the site that originates from the contaminated area is assumed to be 0.1. Justification for all assumptions should be included in the risk assessment report.)
IRS, EF, ED, BW, AT = exposure parameters (UG Table 6-2)

$$I = \frac{CS \times IRS \times CF \times FI \times EF \times ED}{BW \times AT}$$

$$= \frac{10 \; mg/kg \times 100 \; mg/day \times 10^{-6} \; kg/mg \times 0.1 \times 350 \; days/yr \times 30 \; yr}{70 \; kg \times 25,550 \; days}$$

$$= 5.9 \times 10^{-7} \; mg/kg\text{-}day$$

Step 2: *Calculate the Site-Specific upper-bound excess lifetime cancer risk due to ingestion of benzo(a)pyrene-contaminated surface soil by following the "Approach for Calculating Cancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the oral cancer slope factor (CSF_o) for benzo(a)pyrene from UG Table 6-5 in the following Guidance Manual equation (GM 3.4.1.3).*

$$Risk = CDI \; x \; CSF_o$$
$$= 5.9 \times 10^{-7} \; mg/kg\text{-}day \times 73(mg/kg\text{-}day)^{-1}$$
$$= 4.3 \times 10^{-5}$$

7.3.1.2 Inhalation
a) Site Specific—Surface Soil—Inhalation
The Guidance Manual provides a Site-Specific inhalation intake equation for airborne chemicals (GM H.1.5). The equation requires as an input parameter the contaminant concentration in air (expressed as mg/m^3). This parameter is suitable for vapor phase contaminants but not for contaminants present as particulate matter. Therefore, the intake equation is not suitable for inhalation of PAHs (with the exception of naphthalene) and metals. *The LRS should consult WVDEP to determine how to conduct a site-specific evaluation of inhalation exposure to particulates.*

7.3.1.3 Dermal Exposure
At the typical abandoned service station site, only PAHs and metals are likely to be found in surface soils (UG 2.5.1) where they pose a potential risk due to absorption through dermal exposure.

a) Site Specific—Noncarcinogen—Surface Soil—Dermal Exposure
Several commonly encountered PAH COCs are noncarcinogens (systemic toxicants) when dermally absorbed (UG Table 6-5). The individual Site-Specific risk of adverse health effects due to dermal contact with contaminated surface soil must be calculated for each. The example below illustrates the determination of the Site-Specific risk due to dermal contact with naphthalene-contaminated surface soil for an adult site worker.

Step 1: *Calculate the Site-Specific naphthalene intake via dermal contact with contaminated surface soil for an adult site worker using GM Equation H.1.4 below, where:*

I = *chronic daily intake (CDI) averaged over 30 years*

CS = *95% UCL of the arithmetic mean of naphthalene concentrations in soil samples (mg/kg) or maximum sample concentration (A much higher value than the sampling concentration shown in UG Table 4-1 is used in this calculation. Refer to UG 7.2.2.1a Step 2 for the justification.)*

ABS = *naphthalene-specific absorption factor (UG Table 6-4)*

CF = *conversion factor (10^{-6} kg/mg)*

SA = *skin surface area available for contact (cm^2/event)—based on UG Table 6-3 surface area of adult hands at 50th percentile (UG Table 6-3)*

EF = *exposure frequency (events per year)—assumes site worker would be exposed 50 times per year while sweeping the lot (Justification for all exposure assumptions should be included in the risk assessment report.)*

AF, ED, BW, AT = *exposure parameters (UG Table 6-2)*

$$I = \frac{CS \times CF \times SA \times AF \times ABS \times ED \times EF}{BW \times AT}$$

$$= \frac{43{,}000 \ mg/kg \times 10^{-6} \ kg/mg \times 820 \ cm^2/event \times 1.45 \ mg/cm^2 \times 0.1 \times 30 \ years \times 50 \ events/yr}{70 \ kg \times 10{,}950 \ days}$$

$$= 1.0 \times 10^{-2} \ mg/kg\text{-}day$$

Step 2: *Calculate the HQ representing the Site-Specific noncancer risk of adverse health effects due to dermal contact with naphthalene in surface soils by following the "Approach for Calculating Noncancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the absorbed reference dose (RfD_{abs}) for naphthalene from UG Table 6-5 in the following Guidance Manual equation (GM 3.4.1.3).*

$$HQ = CDI/RfD_{abs}$$
$$= 1.0 \times 10^{-2} \ mg/kg\text{-}day/0.002 \ mg/kg\text{-}day$$
$$= 5.0$$

b) Site Specific—Carcinogen—Surface Soil—Dermal Exposure
Several PAHs are known to be carcinogens (UG Table 6-5). For each carcinogen, the individual Site-Specific upper-bound excess cancer risk due to dermal contact with contaminated soil must be calculated. The example below assesses Site-Specific risk due to dermal contact with benzo(a)pyrene-contaminated surface soil for an adult site worker.

Step 1: *Calculate the Site-Specific intake via dermal contact with benzo(a)pyrene-contaminated surface soil for an adult site worker using GM Equation H.1.4) below, where:*

I   *= chronic daily intake (CDI) averaged over 70 years*

CS *= 95% UCL of the arithmetic mean of benzo(a)pyrene concentrations in soil samples (mg/kg) or maximum sample concentration (UG Table 4-1)*

ABS= benzo(a)pyrene-specific absorption factor (UG Table 6-4)

CF *= conversion factor (10^{-6} kg/mg)*

SA *= skin surface area available for contact (cm^2/event)—based on UG Table 6-3 surface area of adult hands at 50th percentile (UG Table 6-3)*

EF *= exposure frequency (events per year)—assumes site worker would be exposed 50 times per year while sweeping the lot* (Justification of all assumptions should be included in the risk assessment report.)

AF, ED, BW, AT = exposure parameters (UG Table 6-2)

$$I = \frac{CS \times CF \times SA \times AF \times ABS \times ED \times EF}{BW \times AT}$$

$$= \frac{10 \; mg/kg \times 10^{-6} \; mg/kg \times 820 \; cm^2/event \times 1.45 \; mg/cm^2 \times 0.1 \times 30 \; years \times 50 \; events/yr}{70 \; kg \times 25{,}550 \; days}$$

$$= 1.0 \times 10^{-6} \; mg/kg\text{-}day$$

Step 2: *Calculate the Site-Specific upper-bound excess lifetime cancer risk due to dermal contact with benzo(a)pyrene-contaminated surface soil by following the "Approach for Calculating Cancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the absorbed cancer slope factor (CSF_{abs}) for benzo(a)pyrene from UG Table 6-5 in the following Guidance Manual equation (GM 3.4.1.3).*

$$Risk = CDI \times CSF_{abs}$$
$$= 1.0 \times 10^{-6} \; mg/kg\text{-}day \times 7.3(mg/kg\text{-}day)^{-1}$$
$$= 7.3 \times 10^{-6}$$

7.3.2   Subsurface Soil

At the typical abandoned service station site, subsurface soils may contain VOCs, PAHs, metals, and ethylene glycol (UG 2.5.5 and 2.4.6).

7.3.2.1 Ingestion
a) Site Specific—Subsurface Soil—Ingestion
Subsurface soils are typically unavailable for ingestion, so their COCs are unlikely to pose a risk to human receptors. (See UG Discussion 6-1)

7.3.2.2 Inhalation
a) Site Specific—Subsurface Soil—Inhalation
PAHs, metals, and ethylene glycol do not need to be considered for exposure routes that involve volatilization. However, the VOCs in subsurface soil may volatilize to ambient air or infiltrate into on-site buildings (UG Figure 4-3). The Site-Specific inhalation intake equation requires as input the contaminant concentration in air. This value can be determined either by site-specific measurement or by modeling. Both site-specific measurement and site-specific modeling of contaminant concentrations in ambient or indoor air are complex and difficult. *When the Site-Specific evaluation of inhalation pathways is called for by the CSM, the LRS's proposed procedure should be reviewed by WVDEP before it is implemented.*

7.3.2.3 Dermal Exposure
a) Site Specific—Subsurface Soil—Dermal Exposure
COCs encountered in subsurface soils include VOCs, PAHs, metals, and ethylene glycol. Subsurface soils are typically unavailable for dermal exposure, so their COCs are unlikely to pose a risk to human receptors (See UG Discussion 6-1 for exceptions).

7.3.3 Groundwater
At the typical abandoned service station site, only VOCs (BTEX and MTBE) , naphthalene, and ethylene glycol are likely to be found in groundwater and, therefore, in the residential tapwater originating from the contaminated aquifer (UG 2.5.5).

7.3.3.1 Ingestion
The VOCs listed in UG Table 2-1 are systemic toxicants (i.e. noncarcinogenic) when ingested. Benzene is also carcinogenic (UG Table 6-5). The individual Site-Specific risk of adverse health effects due to ingestion of contaminated groundwater must be calculated for each of the COCs, as illustrated below for toluene.

a) Site Specific—Noncarcinogen—Groundwater (As Tapwater)—Ingestion
The example below illustrates the determination of the site-specific risk due to ingestion of toluene-contaminated water for adult residential exposure.

Step 1: *Calculate the Site-Specific toluene intake via ingestion of contaminated water for adult residential exposure using GM Equation H.1.1 below, where:*
I   = chronic daily intake (CDI) averaged over 30 years.
CW = 95% UCL of arithmetic mean of toluene concentrations in groundwater samples in mg/L or
*   maximum sample concentration (UG Table 4-1)*
IRW, EF, ED, BW, AT = exposure parameters (UG Table 6-2)

$$I = \frac{CW \times IRW \times EF \times ED}{BW \times AT}$$

$$= \frac{1.0\ mg/L \times 2.32\ L/day \times 350\ days/yr \times 30\ yr}{70\ kg \times 10950\ days}$$

$$= 3.2 \times 10^{-2}\ mg/kg\text{-}day$$

Step 2: *Calculate the HQ representing the Site-Specific noncancer risk of adverse health effects due to ingestion of toluene in groundwater by following the "Approach for Calculating Noncancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the oral reference dose (RfD$_o$) for toluene from UG Table 6-5 in the following Guidance Manual equation (GM 3.4.1.3).*

$$HQ = CDI/RfD_o$$
$$= 3.2 \times 10^{-2}\ mg/kg\text{-}day/0.2\ mg/kg\text{-}day$$
$$= 1.6 \times 10^{-1}$$

b) Site Specific—Carcinogen—Groundwater (As Tapwater)—Ingestion
Benzene is the only carcinogen among the VOCs listed in UG Table 2-1. The Site-Specific upper-bound excess cancer risk posed by the ingestion of benzene-contaminated water must be calculated. The example below assesses Site-Specific risk due to ingestion of benzene-contaminated groundwater used as tapwater for an adult residential receptor.

Step 1: *Calculate the Site-Specific benzene intake via ingestion of water for an adult residential receptor using GM Equation H.1.1 below, where:*
I   = chronic daily intake (CDI) averaged over 70 years
CW= 95% UCL of arithmetic mean of benzene concentrations in groundwater samples in mg/L or maximum sample concentration (UG Table 4-1)
IRW, EF, ED, BW, AT = exposure parameters (UG Table 6-2)

$$I = \frac{CW \times IRW \times EF \times ED}{BW \times AT}$$

$$= \frac{0.001 \ mg/L \times 2.32 \ L/day \times 350 \ days/yr \times 30 \ yr}{70 \ kg \times 25{,}550 \ days}$$

$$= 1.4 \times 10^{-5} \ mg/kg\text{-}day$$

Step 2: *Calculate the Site-Specific upper-bound excess lifetime cancer risk due to ingestion of benzene in groundwater by following the "Approach for Calculating Cancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the oral cancer slope factor (CSF$_o$) for benzene from UG Table 6-5 in the following equation.*

$$Risk = CDI \times CSF_o$$
$$= 1.4 \times 10^{-5} \ mg/kg\text{-}day \times 0.029 (mg/kg\text{-}day)^{-1}$$
$$= 4.1 \times 10^{-7}$$

7.3.3.2 Inhalation

a) Site Specific—Volatilization from In Situ Groundwater—Inhalation
PAHs, metals, and ethylene glycol do not need to be considered for exposure routes that involve volatilization. However, VOCs may volatilize from in situ groundwater to contaminate ambient or indoor air (UG Figure 4-3). For reasons presented in Section 7.3.2.2, application of the Site-Specific risk-based inhalation intake equation may be difficult. *The LRS's proposed procedure for evaluating this exposure pathway should be reviewed by WVDEP before it is implemented.*

b) Site Specific—Volatilization from Groundwater (As Tapwater)—Inhalation
PAHs (with the exception of naphthalene), metals, and ethylene glycol do not need to be considered for exposure routes that involve volatilization. Although Uniform equations are available to evaluate risk posed by volatilization of VOCs from groundwater used as tapwater (UG 7.2.4.1) for reasons presented in Section 7.3.2.2, application of the Site-Specific risk-based inhalation intake equation may be difficult. *The LRS's proposed procedure for evaluating this exposure pathway should be reviewed by WVDEP before it is implemented.*

7.3.3.3 Dermal Exposure
Only VOCs (BTEX and MTBE), naphthalene, and ethylene glycol are likely to be found in significant con-centrations in groundwater contaminated with COCs originating from the typical abandoned service sta-tion site and, consequently, in the residential tapwater from the contaminated aquifer (UG 2.5.4). VOCs and naphthalene are systemic toxicants (i.e., noncarcinogenic). Benzene is also carcinogenic (UG Table 6-5). The individual Site-Specific risk of adverse health effects due to dermal contact with contaminated groundwater must be calculated for each, as illustrated below for toluene and benzene.

a) Site Specific—Noncarcinogen—Groundwater (As Tapwater)—Dermal Exposure
The following example illustrates the determination of Site-Specific risk due to dermal contact with toluene-contaminated water for an adult residential exposure.

Step 1: *Calculate the site-specific toluene intake via dermal contact with toluene-contaminated water for an adult residential exposure using GM Equation H.1.2 below, where:*

I = *chronic daily intake (CDI) averaged over 30 years*

CW= *calculated 95% UCL of arithmetic mean of toluene concentrations in mg/L in groundwater samples or maximum sample concentration (UG Table 4-1)*

PC = *toluene-specific dermal permeability constant (UG Table 6-4)*

ET = *exposure time based on Table 6-2 and assuming one shower per day with 90th percentile duration (0.2 hr/day)* (Justification for all assumptions must be included in the risk assessment report.)

CF = *volumetric conversion factor (1 L/1000 cm³)*

SA, EF, ED, BW, AT = *exposure parameters (UG Table 6-2)*

$$I = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

$$= \frac{1.0 \ mg/L \times 19{,}400 \ cm^2 \times 1 \ cm/hr \times 0.2 \ hr/day \times 350 \ days/yr \times 30 \ yr \times 1 \ L/1000 \ cm^3}{70 \ kg \times 10{,}950 \ days}$$

$$= 0.053 \ mg/kg\text{-}day$$

Step 2: *Calculate the HQ representing the Site-Specific noncancer risk of adverse health effects due to dermal contact with toluene in tapwater by following the "Approach for Calculating Noncancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the absorbed reference dose (RfD$_{abs}$) for toluene from UG Table 6-5 in the following equation.*

$$HQ = CDI/RfD_{abs}$$
$$= 0.053 \ mg/kg\text{-}day/0.02 \ mg/kg\text{-}day$$
$$= 2.6$$

b) Site Specific—Carcinogen—Groundwater (As Tapwater)—Dermal Exposure

Benzene is the only carcinogen among the BTEX constituents. The calculation of the Site-Specific upper-bound excess cancer risk posed by dermal contact with water containing benzene at the levels found at the example site (UG Table 4-1) is illustrated below for an adult residential receptor.

Step 1: *Calculate the Site-Specific benzene intake via dermal contact with benzene-contaminated tapwater for an adult residential exposure using GM Equation H-1.2 below, where:*

I = chronic daily intake (CDI) averaged over 30 years

CW = calculated 95% UCL of arithmetic mean of benzene concentrations in mg/L in groundwater samples or maximum sample concentration (UG Table 4-1)

PC = benzene-specific dermal permeability constant (UG Table 6-4)

ET = exposure time based on Table 6-2 and assuming one shower per day with 90th percentile duration (0.2 hr/day) (Justification for all assumptions should be included in the risk assessment report.)

CF = volumetric conversion factor (1 L/1000 cm^3)

SA, EF, ED, BW, AT = exposure parameters (UG Table 6-2)

$$I = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

$$= \frac{0.001 \; mg/L \times 19{,}400 \; cm^2 \times 0.1 \; cm/hr \times 0.2 \; hr/day \times 350 \; days/yr \times 30 \; yr \times 1 \; L/1000 \; cm^3}{70 \; kg \times 25{,}550 \; days}$$

$$= 2.3 \times 10^{-6} \; mg/kg\text{-}day$$

Step 2: *Calculate the Site-Specific upper-bound excess lifetime cancer risk due to dermal contact with benzene-contaminated tapwater by following the "Approach for Calculating Cancer Risks" described in the Guidance Manual (GM 3.4.1.3). Use the CDI value calculated in Step 1 and the absorbed cancer slope factor (CSF$_{abs}$) for benzene from UG Table 6-5 in the following equation.*

$$\begin{aligned} Risk &= CDI \times CSF_{abs} \\ &= 2.3 \times 10^{-6} \; mg/kg\text{-}day \times 0.29 (mg/kg\text{-}day)^{-1} \\ &= 6.7 \times 10^{-7} \end{aligned}$$

7.4 Analysis of Cumulative Risk

After the Site-Specific risk values are determined for each individual COC for each applicable pathway, the cumulative site-specific carcinogenic and noncarcinogenic risks are determined as described in Section 6.11.2 and 6.12.2.2.

APPENDIX A

Appendix A. Figure A-1. Generic Conceptual Site Model Human Receptor Pathway Analysis Diagram
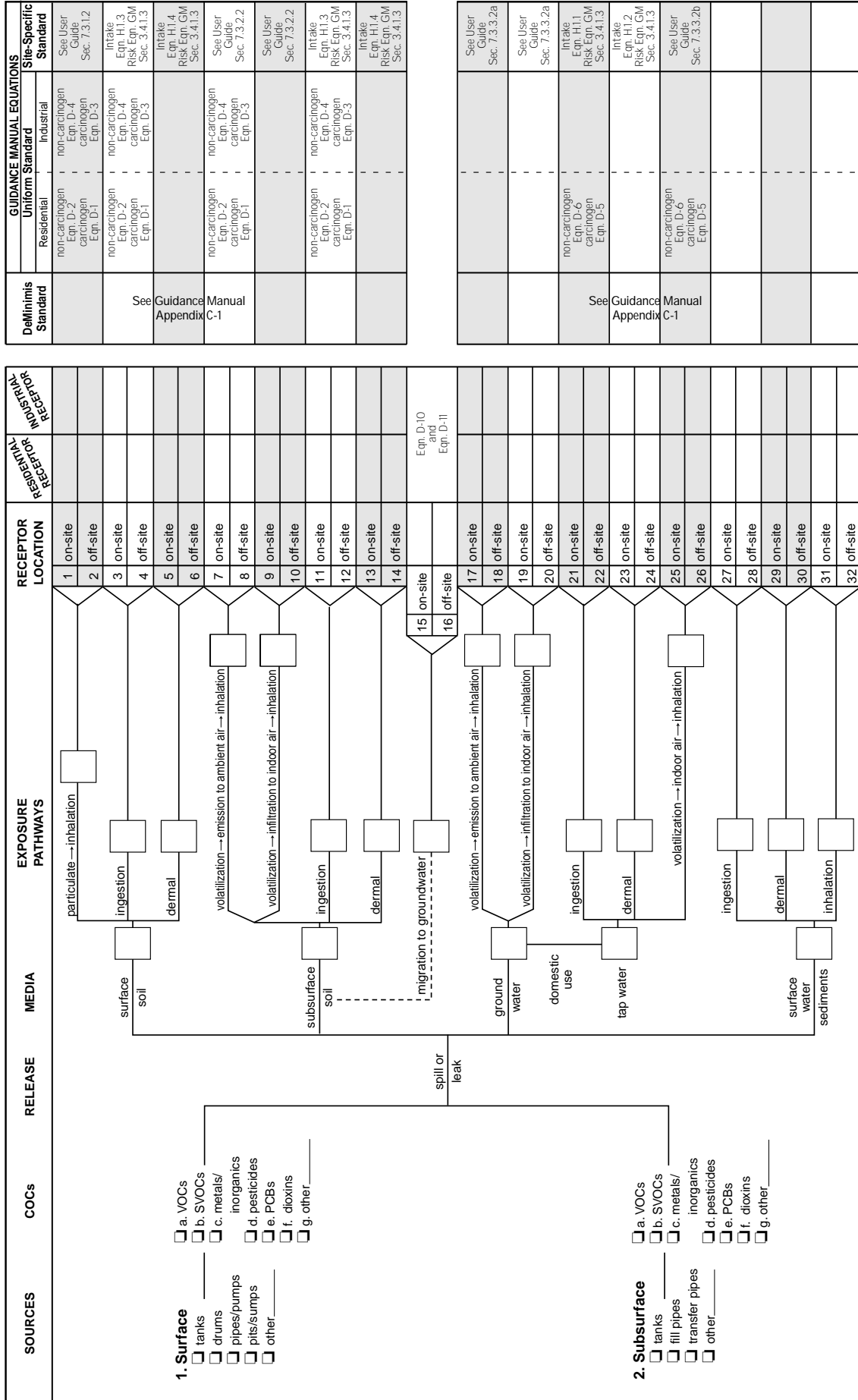
Appendix A. Figure A-2. Hypothetical Abandoned Service Station CSM Human Receptor Pathway Analysis Diagram
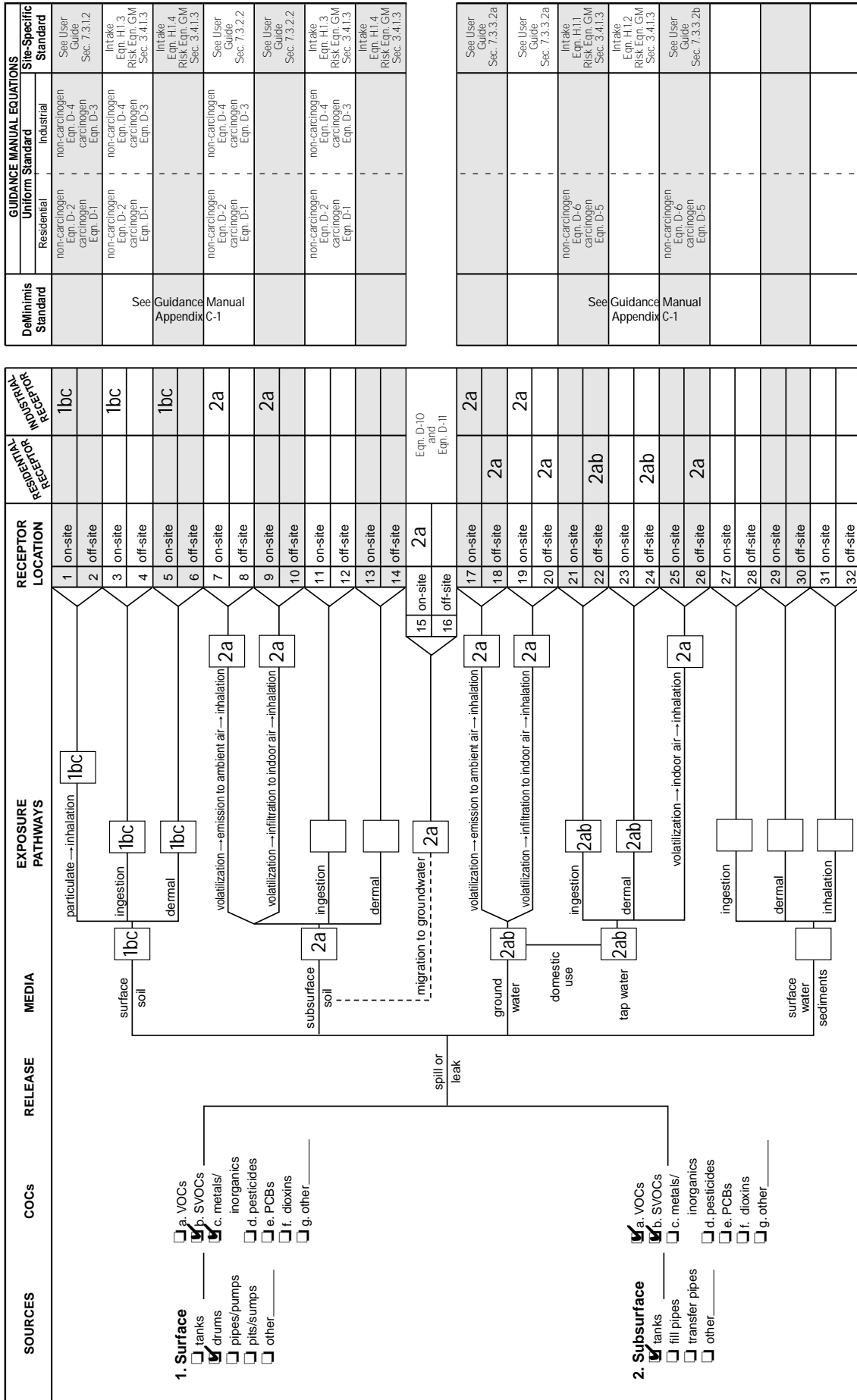
APPENDIX B

Appendix B. Figure B-1.

CHECKLIST FOR CONCEPTUAL SITE MODEL DEVELOPMENT

This checklist is to be submitted with the application and should incorporate information available at the time of submittal.

Step 1. Define Site Characteristics

1.1 Check geologic setting characteristics that apply ("yes" situation found at/near site)
❏ fractured rock ❏ fill material ❏ none as listed above
☑ alluvial aquifer ❏ karst

1.2 Depth to groundwater: _____20_____ feet.
Is the underlying aquifer
❏ confined ❏ perched ☑ unconfined ❏ don't know

1.3 General direction of groundwater flow across the site:
❏ NW ❏ N ☑ NE ❏ E ❏ SE ❏ W

1.4 Local surface water bodies:
❏ wetlands ❏ spring/seep ❏ stream ❏ river ❏ lake ❏ pond/impoundment
Surface water distance(s) from site: _____ miles(s)

1.5 Are there known discharge points/springs from the underlying aquifer?
❏ yes ☑ no
Distance from site to known discharge points: _____ miles(s)

1.6 Determine average soil characteristics for usual site conditions:
1. Soil type (check appropriate)
❏ clay ☑ silt ☑ sand ❏ gravel
2. Is the average soil or water pH less than or equal to 3 or greater than or equal to 9?
❏ yes ☑ no

1.7 Have any of the following activities occurred at the site?
❏ surface mining ❏ deep mining ❏ injection or extraction wells ☑ monitoring wells

Step 2. Define the Contaminant Characteristics

2.1 Basic Contaminant Information

Contaminant Category	Petroleum	Metals	Other Inorg.	SVOCs	VOCs	PCBs	Pests.	Other
Surface impoundments	❏	❏	❏	❏	❏	❏	❏	❏
Aboveground drums	☑	☑	❏	☑	❏	❏	❏	❏
Buried drums	❏	❏	❏	❏	❏	❏	❏	❏
AST	❏	❏	❏	❏	❏	❏	❏	❏
UST	☑	❏	❏	❏	☑	❏	❏	❏
Piles	❏	❏	❏	❏	❏	❏	❏	❏
Landfill	❏	❏	❏	❏	❏	❏	❏	❏
Open dump	❏	❏	❏	❏	❏	❏	❏	❏
Other_____	❏	❏	❏	❏	❏	❏	❏	❏

2.2 Indication of Suspected Contamination
❏ unusual level of vapors ❏ erratic behavior of product-dispensing equipment
❏ release detection results indicate a release ☑ discovery of holes in a storage tank
❏ spill/release ❏ other (specify) _____

2.3 Visible evidence of contamination (check all that apply):
    ☑ contaminant-stained or contaminant-saturated soil or backfill
    ❑ ponded contaminants
    ❑ free products or sheen on ponded water
    ❑ free product or sheen on the groundwater surface
    ❑ free product or sheen surface water
    ❑ visual evidence of stressed biota (fish kills, stressed vegetation, etc.)
    ❑ visible presence of oil, tar, or other nonaqueous-phase contaminant $> = 1,000$ ft^2
    ❑ other (specify) _____

2.4 Are there any interim remedial actions that have or will take place?
    ❑ yes   ☑ no (if "yes," fill out 2.5)

2.5 Interim remedial actions (check all that apply):

	Planned	Initiated	Completed	Not Applicable
Regulated substance removed from storage tanks	❑	❑	❑	❑
Containment of contamination	❑	❑	❑	❑
Contaminated soil excavated	❑	❑	❑	❑
Free product recovered	❑	❑	❑	❑
Temporary water supplies provided	❑	❑	❑	❑
Other (specify) _____	❑	❑	❑	❑

Step 3. Define Exposure Media and Transport Pathways

3.1 Identify media affected (or potentially affected by contaminants):

Contaminant						
gasoline	☑ air	☑ groundwater	❑ surface water	☑ soil	❑ sediments	❑ biota
used oil	☑ air	❑ groundwater	❑ surface water	☑ soil	❑ sediments	❑ biota
_____	❑ air	❑ groundwater	❑ surface water	❑ soil	❑ sediments	❑ biota

3.2 Identify contaminant release mechanisms (check all that apply):

Contaminant				
gasoline	☑ leaching	☑ volatilization	❑ fugitive dust	❑ erosion/runoff
used oil	❑ leaching	❑ volatilization	☑ fugitive dust	❑ erosion/runoff
_____	❑ leaching	❑ volatilization	❑ fugitive dust	❑ erosion/runoff

3.3 Groundwater use:
  Is the groundwater connected to or part of an aquifer that serves as a source of drinking water?
    ☑ yes   ❑ no (if "yes," groundwater is of concern)

  Are there reasonably expected future groundwater uses based on state or local planning?
    ❑ yes   ❑ no (if "yes," groundwater is of concern)

3.4 Local water supplies:

Industrial/municipal	❑ surface	❑ well
Residential	❑ surface	☑ well
Agricultural	❑ surface	❑ well

  Water supply distance from site: _____.01_____ miles(s)

3.5 Local surface water (check all that apply):
  Use

Domestic supply	❑	Not currently used	❑	
Recreation	❑	Fisheries	❑	N/A
Irrigation/stock watering	❑	Other _____	❑	
Industrial supply	❑			

3.6 Local groundwater use (check all that apply):
   Use
   Domestic supply   ☑
   Irrigation/stock watering ❏
   Industrial supply   ❏
   Not currently used   ❏
   Other _____   ❏

3.7 Check if the following exposure pathways are applicable under foreseeable use of the site:
   ☑ soil ingestion   ❏ surface water ingestion
   ☑ inhalation of soil particles/vapors   ❏ dermal contact with surface water
   ☑ dermal contact with soil   ☑ groundwater ingestion
   ❏ consumption of plants   ❏ consumption of terrestrial animals
   ❏ consumption of aquatic organisms   ❏ other _____
   ☑ inhalation of vapors released from groundwater