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Technical Report:

Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C.

Prepared for the
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Florida Department of Environmental Protection

by

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I. Introduction

This document describes a procedure for the development of risk-based cleanup target levels for chemicals of concern in soil based on direct human contact and migration of chemicals of concern from soil to groundwater. It provides equations that can be used for calculating these values and recommended sources for input values for these equations. In addition, it provides the information necessary for the derivation of the soil cleanup target levels (SCTLs) which are found in Table IV of Chapter 62-770, F.A.C., and here as Table 1. For purposes of calculating SCTLs that are site-specific, procedures for identifying the necessary input values are also presented.

The approach in calculating SCTLs described here borrows from methodologies developed and described elsewhere, most notably the USEPA Soil Screening Guidance (SSG; USEPA, 1996a, 1996b) and the USEPA Region IX Preliminary Remediation Goals (USEPA, 1996c). The rationale for selecting specific aspects of the methodology developed for Florida from these and other sources is discussed in this report. While an attempt has been made to provide a comprehensive description of methods for calculating Florida SCTLs, in some instances the reader is referred to the source document for a more detailed explanation.

SCTLs for direct human contact can be developed for a variety of exposure scenarios. Only two scenarios are presented in this report — exposure from residential and commercial/industrial land use — although SCTLs for other scenarios can also be calculated using this methodology. SCTLs based on either default or site-specific characteristics can also be used as remediation goals.

It is important to note that the SCTL methods for direct human contact described in this report are based on protection of human health only. Soil contamination limits to protect non-human species or ecosystems are very much dependent upon the site characteristics and species present and are therefore difficult to generalize. Under some circumstances, the SCTLs based on human health may not be protective of other species; for example, human health SCTLs for some metals exceed concentrations shown to produce phytotoxicity (USEPA, 1996b). It should also be recognized that the SCTL methodology described here is based on direct exposure, and does not consider intake and human health risk that may occur via indirect pathways such as uptake into plants and animals that are used as a food source.[1] As such, depending upon the setting and the management for a site, the SCTLs described here may not address all of the potential issues of concern.

II. Development of SCTLs Based on Direct Contact

A. Equation for calculating direct contact SCTLs

The equations for calculating SCTLs based on direct contact are shown in Figures 1 and 2. These equations are functionally equivalent to those used by USEPA Region IX in developing their preliminary remediation goals (USEPA, 1996c). One equation is provided for calculating an SCTL based on non-cancer health effects and another for calculating an SCTL based on cancer risk, if appropriate (i.e., if the chemical is regarded as a potential carcinogen). Both equations consider intake from ingestion of contaminated soil, dermal contact with the soil, and inhalation of chemicals of concern present in soil that have volatilized or have adhered to soil-derived particulates [dust]. The combined impact of

[1] While not commonly considered a pathway at petroleum contaminated sites (i.e., gas stations), it can be an issue for other risk assessments.

exposure from all three routes[2] simultaneously is used to calculate the SCTL. For purposes of discussion, this is termed the *multi-route approach*.

In their Soil Screening Guidance (SSG), the USEPA has employed a somewhat different approach from the one used here. In the SSG, SSLs[3] for a chemical are calculated separately for ingestion and inhalation exposure, in what could be called a *route-specific approach*. In determining an SSL based on direct contact, the lower of the two values for a chemical would be selected. As a general rule, dermal intake is ignored unless there is evidence in the literature of substantial dermal absorption of the chemical (e.g., pentachlorophenol). In such instances, some adjustment of the SSL is made to account for this uptake.

The principal advantage of the multi-route approach is that it is easier to defend on conceptual grounds. In all but the most unusual circumstances, an individual exposed to contaminated soil will be exposed by all three routes simultaneously. The multi-route approach considers the risk or hazard from a chemical to that individual to be the sum of the risks or hazards from each of these exposure routes. The route-specific approach, in contrast, considers the risk or hazard posed by each route of exposure in isolation and makes the implicit assumption that risks or hazards from exposure to a chemical by multiple routes are unrelated, even if they involve the same target organ. Such an argument could be made if the toxicity posed by the chemical is route-dependent, i.e., is associated specifically and exclusively with a particular route of exposure. This situation is seldom the case. For the vast majority of chemicals, the toxicity upon which the SSL/SCTL is based is systemic in nature. That is, the reference doses and slope

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[2] In this context, *route* refers to route of entry into the body, such as through dermal contact or inhalation. Pathway refers to the means by which chemicals of concern in soil (or other environmental media) reach the body, such as volatilization into the air, direct contact with the skin, migration to groundwater which is used as a drinking water source, etc.

[3] The USEPA Soil Screening Guidance soil concentrations are defined as Soil Screening Levels (SSLs). The Florida soil values are defined as Soil Cleanup Target Levels (SCTLs).

factors used to calculate the soil values are based on systemic toxicity endpoints, and a chemical reaching the target organ from any and all routes is likely to contribute to toxicity.[4] Under these circumstances it is difficult to consider the risks to be less than additive.

From a practical standpoint, the difference between the values derived for a given chemical by the multi-route and route-specific approaches is relatively small, provided both ingestion and inhalation toxicity values are available and the risk from dermal exposure is small. In basing an SSL on only one route of exposure, and ignoring other routes, the route-specific approach will tend to underestimate exposure and risk. Assuming for the moment that risks from dermal exposure are negligible and that the lower of the ingestion and inhalation SSLs is selected, the maximum underestimation of risk would be by a factor of 2. This maximum underestimation would occur when ingestion and inhalation risks from a chemical in soil are equal. Under these circumstances, choosing either the ingestion or inhalation SSL as the value for that chemical will capture only 50% of the total risk. In situations where risk from soil contamination is dominated by one exposure route — ingestion, for example — ignoring other routes has little effect on risk, and the error introduced into soil target level development by the route-specific approach is minimal. In this situation, the multi-route and route-specific approaches should yield nearly identical soil target levels.

Despite this small theoretical difference in soil levels between the multi-route and the route-specific approaches, the route-specific approach could conceivably result in compatibility problems with baseline risk assessments. In baseline risk assessments, the hazard index for a chemical is calculated from the sum of the

[4] The *amount* of chemical reaching the target organ can be affected by the route of entry through physiological processes such as extent of local vascularization, diffusional barriers, presence or absence of transport mechanisms, pre-systemic elimination, and distribution. Such differences can be taken into account through estimation of relative systemic bioavailability from different routes.

hazard quotients for each of the exposure routes. When a soil target level is based on exposure from only one of those routes, it can provide a different indication of hazard potential. To illustrate the potential problem, suppose a site has Chemical A in the soil at a concentration just below a soil target level developed using a route-specific approach. Because the concentration of Chemical A is below the target level, the risk assessor for the site might choose to drop it from the baseline risk assessment. If it is retained, however, its hazard index could be as high as 2 (based on the discussion in the preceding paragraph). Any value greater than 1 signals a possible non-cancer health problem. In this example, the use of a route-specific soil target level can make possible the elimination from a baseline risk assessment of a chemical that would otherwise be flagged as posing a potentially unacceptable health risk. This inconsistency cannot occur for soil target levels developed using the multi-route approach since, like baseline risk assessments, they are based on risks summed from all relevant routes.

The multi-route approach does not preclude the development of soil target levels based on route-specific toxicity. For chemicals with toxicities unique and specific to certain routes of administration, the analysis may default to a route-specific approach. Perhaps the best example of this situation is toxicity resulting strictly from local effects at the site of contact (e.g., skin, gastrointestinal tract, or lungs). In this case, chemical exposure by other routes would probably not contribute to this toxicity, and risks for individual routes arguably should not be summed. In these instances, while the multi-route approach forces all routes to be considered, it results in a route-specifically determined soil target level. In order to derive a route-specific soil target level, the equations presented in Figures 1 and 2 can be modified by deleting equation components for all but the relevant exposure route (e.g., delete the dermal and inhalation equation components when developing a soil target level based solely on ingestion). In many cases it can be difficult to determine whether or not a toxicity value is route-specific. In the absence of

definitive information, one approach is to infer route specificity when the target organ is the portal of entry for the administered dose (i.e., the GI tract in the case of ingestion and the pulmonary tract in the case of inhalation) in the study providing the toxicity information. While no doubt imperfect, this approach allows route specificity to be addressed in soil target level development for a broad range of chemicals.

Unlike the SSG, the approach presented here explicitly includes dermal exposure as a contributor to risk and a component of the SCTL for direct contact with soil. Using default assumptions regarding the absorption of chemicals in soil through the skin, the contribution of this route to risk and to the SCTL for most chemicals is very small. This method is consistent with the generally held notion that dermal absorption of chemicals of concern present in soil is a minor exposure route for all but a few chemicals. Despite the typically small contribution of dermal exposure, it is included in the SCTL equations for two reasons: 1) so that the equations can be considered complete with respect to potential exposure routes; and 2) from a practical perspective, so that a mechanism is in place to address those chemicals for which dermal absorption truly represents a significant exposure route.

The inhalation component of both equations includes intake from airborne concentrations of chemicals of concern resulting from volatilization as well as contaminated soil-derived dust particles. As noted in the SSG, inhalation of soil-derived particulates is a significant contributor to risk in only a few instances, such as the risk of cancer from hexavalent chromium. Volatilization is an issue only for chemicals with the appropriate physical/chemical properties. In response to this fact, when developing their SSLs the SSG evaluates separately the particulate inhalation of non-volatile inorganics in surface soil and volatilization for subsurface chemicals of concern. This approach requires the use of different equations for

different chemicals, depending upon their classification or grouping. Rather than develop multiple equations, the approach taken in this report is to use a single equation each for cancer and non-cancer health effects, with the influence of physical/chemical properties on inhalation exposure handled through the input values selected for use in the equation rather than through changes in the equation itself.

B. Input values for direct exposure

Risk or hazard. When calculating an SCTL for direct exposure, the target risk or hazard must be specified. In the examples included in this report for petroleum site related chemicals of concern, SCTLs are calculated to correspond to an excess cancer risk of 10^{-6} and a hazard index of 1, as these are the target risks specified in Section 376.3071(5), F.S. When selecting the target risk or hazard for SCTL development, it must be kept in mind that this is the accepted incremental excess risk per chemical, and not necessarily the accepted increase in risk to the individual. For many (perhaps most) sites, exposure is to more than one chemical, and the overall risk to the individual posed by contamination at the site will be some composite of the individual chemical risks. SCTLs for generic application cannot be developed based on total target risk to the exposed individual, since this risk will vary depending upon the number and type (i.e., carcinogenic versus non-carcinogenic) of chemicals present at specific sites. However, SCTLs based on total target risk to the individual can be developed on a site-specific basis using methods described in the SSG Section 2.5.3 (USEPA, 1996a). [For more discussion of risks from multiple chemicals of concern, see Section II E.]

Virtually all carcinogenic chemicals are also capable of producing non-cancer health effects. At target cancer risks typically employed by regulatory agencies,

SCTLs based on carcinogenicity are usually lower than SCTLs based on non-cancer health effects for the same chemical. This is not always the case, however (e.g., the residential SCTL for the carcinogen cadmium is based on non-cancer effects because it is lower than the SCTL based on carcinogenicity). When developing SCTLs for carcinogens, it is important to also consider non-carcinogenic effects to insure that the SCTL for that chemical is protective for both kinds of toxicity.

Exposure parameters. Most sites can be evaluated using SCTLs based on either of two basic land uses — residential and industrial/commercial. In the case of residential land use, potentially exposed individuals include both children and adults. For industrial/commercial land use, only adult exposure to contaminated soil is assumed to exist.

Children are assumed to experience the greatest daily exposure to soil under residential land use scenarios. When risk is a function of the daily intake rate of a chemical of concern (as in the evaluation of non-cancer health effects), SCTLs must be based on childhood exposure assumptions in order to be protective. When risk is a function of cumulative exposure (as in the evaluation of cancer risk), the exposure period may cover time spent both as a child and as an adult for the residential scenario. Physiological parameters such as body weight, surface area, and inhalation rate of course change with age. Other exposure parameters such as soil ingestion rate are also age-dependent. In this situation, time-weighted average values reflecting both childhood and adult exposures must be used in calculating SCTLs for residential land use. In this report, the individual exposed both as a child and an adult is termed the *aggregate resident*.

For generic SCTLs (i.e., SCTLs applicable and protective for a broad range of sites), default exposure assumptions are available from the USEPA for both residential and commercial/industrial land uses. These are listed in Table 2. Some

input parameters for the aggregate resident, such as inhalation rate and exposed dermal surface area, are not readily available from the USEPA and had to be developed from USEPA data sources. The values calculated for these parameters are also listed in Table 2, and the method of derivation is described in Appendix A.

In the case of the soil ingestion rate for the aggregate resident, the USEPA uses an age-adjusted soil ingestion rate of 114 mg-yr/kg-d in their SSG. This value is based on a 30-year exposure period being divided into 6 years of consumption of 200 mg of soil per day at a body weight of 15 kg, followed by 24 years of consumption of 100 mg of soil per day at a body weight of 70 kg (see USEPA, 1996b, for more information on the calculation of this value). While there is logic in this method of calculation, there is a potential problem in using this approach along with cancer slope factors in developing SCTLs based on carcinogenicity. Specifically, the problem involves the way the body weight is used in the averaging process. When cancer slope factors are developed, the typical approach in determining dose is to use an average intake rate of the chemical divided by an average body weight over the exposure period, usually a lifetime in the case of rodent bioassays. To be strictly comparable, a similar approach should be used in the development of the aggregate resident (time-weighted average) soil ingestion rate for use in calculating SCTLs. That is, a time-weighted average soil ingestion rate is calculated (e.g., 120 mg/day, based on 6 years at 200 mg/day and 24 years at 100 mg/day) and is then divided by a time-weighted average body weight (e.g., 59 kg, based on 6 years at 15 kg plus 24 years at 70 kg divided by an exposure duration of 30 years) to yield a time-weighted average soil ingestion rate, in mg soil/kg body weight/day. Aggregate resident values derived using this approach are employed in the calculation of SCTLs based on carcinogenicity. These values are listed in Table 2. The practical implications of this difference in time-weighted averaging is that, all other factors being equal, the SCTLs derived based on carcinogenicity are about two-fold higher than those calculated using the SSG

approach (e.g., the USEPA SSL for arsenic based on direct exposure is 0.4 mg/kg whereas the residential Florida SCTL for arsenic is 0.8 mg/kg).

One of the exposure variables, the particulate emission factor (PEF), is used to address intake from inhalation of contaminated soil-derived particulates. This value is a function both of site and local climatic conditions. The formula for calculating a PEF value is taken from the SSG (USEPA, 1996a) and appears in Figure 3. In calculating a PEF for Florida sites, default parameters from the SSG were used except for the Q/C term. The SSG selected as default a Q/C for 0.5 acres of contaminated soil in Los Angeles, CA. In order to make the default PEF more relevant to Florida climatic conditions, a Q/C for 0.5 acres in Miami[5] is used instead.

Another input parameter used to assess the soil-to-air pathway of exposure is the volatilization factor, VF. This term is used to define the relationship between the concentration of the chemical of concern in soil and the flux of the volatilized chemical of concern to air. The VF is calculated using an equation from the SSG as shown in Figure 4. Parameters related to characteristics of both the chemical and the soil are used in the calculation of a VF. For the purposes of establishing default SCTLs, default soil characteristics specified in the SSG have been adopted, although it is recognized that the relevant characteristics can vary widely in Florida soils. As discussed above, a Q/C for Miami is used rather than the default Q/C from the SSG, which is based on meteorological conditions in Southern California.

The default exposure assumptions identified in Table 2 are intended to be health protective under circumstances of chronic exposure. Site-specific conditions may restrict exposure to such an extent that the default assumptions are not valid, and the desired target risk goals can be achieved with higher SCTLs. On the other hand, there may be situations in which exposure exceeds the default assumptions

[5] The only city in Florida for which a modeled Q/C value is presented in the SSG.

employed in developing generic SCTLs, e.g., workers with extensive soil contact and opportunity for exposure, such as construction workers involved in excavation, or children with soil pica. For these sites, the SCTLs may not be sufficiently protective. Whenever generic SCTLs are used for site evaluation, it is important to verify, to the extent possible, that the default assumptions upon which they are based are neither greatly above nor below actual present and future exposure conditions. Approaches for developing site-specific exposure assumptions, when necessary, are discussed in Section II C, below.

Physical/chemical parameters. The equations for the calculation of SCTLs for direct contact require the input of several chemical-specific factors. These values, which include the organic carbon normalized soil-water partition coefficient for organic compounds (K_{oc}), Henry's Law constant (HLC), air diffusivity (D_i), and water diffusivity (D_w), are a function of the physical/chemical properties of each chemical of concern. It may be necessary sometimes to calculate values such as K_{oc} or HLCs when published values do not exist. In these cases, additional physical/chemical values such as the water solubility (S) or the octanol-water partition coefficient (K_{ow}) are needed. There are many sources for physical/chemical parameter values, but unfortunately the values listed in various sources can differ dramatically. In order to foster consistency in the development of SCTLs, it is important to have a designated hierarchy of sources for the selection of physical/chemical values.

In agreement with SSG, chemical-specific values for S, HLC, and K_{ow} are preferentially selected from the *Superfund Chemical Data Matrix* (SCDM) (EPA/540/R-96/028). This database is composed of carefully selected information taken from specified literature sources or other databases, or values are calculated. The SCDM then ranks those values which reasonably apply to the hazardous substance. K_{oc} values are from the *Soil Screening Guidance: Technical Background*

Document (SSG) (EPA/540/R-95/128). IRIS, ATSDR Toxicant Profiles and other reference sources (in that order of preference) are used when data are unavailable from the SCDM or SSG. For diffusivity values, the sources are the CHEMDAT 8 Database (EPA/453/C-94/080B) and the WATER 8 Model (EPA/453/C-94/080C). The physical/chemical parameters for chemicals specifically listed in Chapter 62-770, F.A.C., are provided in Tables 3a and 3b.

Toxicity values. The SCTL equations for direct exposure also require inputs in the form of chemical- and route-specific toxicity values. The USEPA provides such values for many chemicals, with preference given in the following order to: 1) IRIS; 2) HEAST; 3) USEPA-NCEA; and 4) Withdrawn values from IRIS or HEAST. When toxicity values are not available from the USEPA, alternative sources/approaches are available. Provisional toxicity values can be extrapolated from occupational exposure limits (see for example Williams et al., 1994), can be based on "surrogate values" (i.e., toxicity values for substances from the same chemical class and with similar toxicological properties), can be extrapolated from toxicity values available for other routes of exposure (i.e., route-to-route extrapolation), can be calculated using toxicity equivalency factors (TEFs), or developed from toxicological information in the primary literature. TEFs are commonly used when they are available. Beyond this step, there is no fixed hierarchy for these approaches, and preference should be given to the one that appears to be based on the best information. Each of these alternative approaches has strengths and weaknesses that must be kept in mind when evaluating their suitability for developing toxicity values for SCTL calculation:

- Occupational exposure limits are often based on relatively extensive study in humans, which is an advantage. Because they are intended for healthy adults, an adjustment must be made in order for them to be considered protective for a broader range of exposed individuals which may include some

with special sensitivity. By incorporating the appropriate "safety factor," toxicity values from occupational exposure limits can be, in general, conservative and health protective (Williams et al., 1994). There may be, however, some situations in which a chemical poses special toxicity to sensitive individuals not found in the workplace (e.g., lead in children), where any extrapolation from occupational limits may be troublesome.

- For chemicals with little or no toxicity information, the use of surrogate toxicity values from chemically-related compounds offers a means to provide some estimate of risk, and of acceptable soil concentrations. Small changes in chemical structure can produce profound differences in toxicity, however (compare CO and CO_2, acetate and fluoroacetate, ethanol and methanol, for example), and this approach carries with it significant uncertainty.

- Often, inhalation and dermal toxicity criteria are not available. In these cases, route-to-route extrapolation can be used to expand upon dose-toxicity relationships observed for one route of exposure to develop toxicity values for other routes. For example, the oral toxicity value can be used to derive corresponding inhalation or dermal values (see Appendix B). Intake from different routes is not necessarily equivalent, and information regarding toxicokinetics of the chemical (or assumptions in this regard) must be taken into account when performing route-to-route extrapolation. Further, route-to-route extrapolation is not appropriate when there is evidence that the toxicity value serving as the basis for extrapolation is likely to be route-specific. If a slope factor (SF) or a reference dose (RfD) is known or presumed to be route-specific, it should not be regarded as suitable for route-to-route extrapolation.[6]

[6] In the case of carcinogenic PAHs the toxic endpoint (cancer) occurs regardless of the route of exposure. This effect is clearly evidenced by the fact that while the OSF for benzo(a)pyrene is based on data in which oral dosing resulted in GI tract tumors in rodents, arguably a route-specific cancer,

While the USEPA originally recommended route-to-route extrapolation as a means of developing toxicity values (e.g., in USEPA, 1989a), more recently they have discouraged its use, citing the uncertainties involved (see for example the discussion in the USEPA, 1996b). While these uncertainties cannot be denied, when route-to-route extrapolation is performed with knowledge of the disposition and toxicity of the chemical, these uncertainties are hardly disproportionate to the uncertainties associated with other aspects in the calculation of SCTLs. Further, when the alternative is to omit a particular route of exposure from the SCTL calculation, in effect assuming that risk from this route is zero, this too is a source of uncertainty that is not well addressed by SSG methodology. In fact, for some chemicals, the absence of a toxicity value can mean that the dominant source of risk is ignored. In light of this discussion, the cause of minimizing uncertainty is arguably best served by judicial use of route-to-route extrapolation in SCTL development.

- Toxicity equivalency factors are numerical expressions of the relative potency of a series of compounds, with a reference compound assigned a value of one (1). For example, a chemical with a TEF of 0.5 would be only half as potent as the reference compound. Using the toxicity value for the reference compound and the TEFs, toxicity values for the series of compounds can be calculated. For a chemical with a TEF of 0.5, for example, a provisional RfD can be developed by dividing the RfD for the reference compound by 0.5. In the case of a cancer slope factor (CSF), the CSF for the reference compound would be multiplied by the TEF to derive a provisional CSF for the related

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benzo(a)pyrene has also been observed to produce other types of cancer in several species when administered by a variety of routes, including inhalation and dermal contact. Although no slope factor has yet been derived for these routes, the rather strong evidence that benzo(a)pyrene (and, by implication, other carcinogenic PAHs) is carcinogenic by a variety of routes, indicates that PAH induced cancer is not wholly route-specific. Because of this property, route-to-route extrapolation was performed to derive both inhalation and dermal slope factors from the OSF for this group of chemicals in developing SCTLs for Chapter 62-770, F.A.C.

compound. TEFs are based on comparative potency regarding some effect thought to be related to the toxicity of interest. The ability of this surrogate effect to accurately portray relative toxic potency is a source of uncertainty in this approach.

- Development of a toxicity value from the primary literature is labor-intensive and requires judgment of an experienced toxicologist. If a sufficient body of information regarding dose-response relationships for toxicity is available in the literature for a chemical, however, it represents an important and useful approach to developing a provisional toxicity value.

For Chapter 62-770, F.A.C., chemicals, many toxicity values were available from USEPA sources whereas others had to be extrapolated using a combination of the above approaches. To identify toxicity values needed for SCTL calculations, the TEF approach, surrogate values, and route-to-route extrapolation were used. The toxicity values and their sources/bases are provided in Table 4.

C. Developing site-specific direct contact SCTLs

While default SCTLs are useful tools in site evaluation and when formulating remediation strategies for a broad range of sites, there will be some sites for which default SCTL values are overly conservative or not conservative enough. That is, there will be some sites in which present and future site and exposure characteristics are so different from the assumptions used to calculate default SCTLs, that these SCTLs do not accurately correspond to the risk goals for that site. This section identifies variables in the SCTL equations for which site-specific information can be substituted in order to obtain a more accurate SCTL, as well as some considerations in making site-specific modifications.

Exposure variables. When evaluating whether to use alternative assumptions for exposure frequency and exposure duration, responsible risk management requires consideration of not only the present use of the site, but also the range of plausible future uses. If site use is unrestricted, or only broadly restricted (e.g., to residential or commercial use), this range will almost always include some uses or site conditions in which exposure to soil can be substantial. In these situations, the default assumptions will represent the best choice. If site management includes engineering and/or institutional controls, then exposure assumptions should be based on the upper limit of exposures possible within those controls. Deviation from the default assumptions should occur only in circumstances where it can be shown that the engineering and/or institutional controls proposed for the site will reliably restrict exposure frequency and duration. Also, caution must be exercised in proposing limited exposure frequencies and/or durations even if the effectiveness of engineering and institutional controls can be assured. The SCTL methodology described here is based on chronic exposure. When exposure is of short duration or intermittent, the SCTLs calculated with these exposure assumptions are <u>not</u> valid, and a very different type of toxicological analysis directed to this type of exposure must be conducted in order to establish limits of chemicals of concern in soil.

Under extraordinary circumstances, the exposed dermal surface area and inhalation rates could be modified (e.g., if protective clothing and/or a respirator is required while on site). There will be very few, if any, sites where the long term management involves such restrictions, however. The adherence factor (the amount of soil which adheres to skin, per unit of surface area) might conceivably be influenced by local soil conditions, but empirical data to support an alternative value would probably be required.

Site soil and weather characteristics. Site soil characteristics can influence the rate of volatilization of organic chemicals into air, and thus the level of chemical of concern that may be acceptable. Measuring appropriate soil characteristics in order to develop site-specific volatilization factors may be useful, particularly if risks from soil at a site are thought to be dominated by inhalation of volatile chemicals from soil. Parameters necessary for the determination of the VF include the average soil moisture content (w), the dry soil bulk density (ρ_b), fraction of organic carbon (f_{oc}), and soil pH (used to select pH-specific K_{oc} and K_d values). Methods for determining these site-specific measured values for the derivation of the VF are listed below and outlined in the SSG (USEPA, 1996a).

Soil Characteristic	Data Source	Method
Soil moisture content (w)	Lab measurement	ASTM D 2216
Dry soil bulk density (ρ_b)	Field measurement	All soils: ASTM D 2937; shallow soils: ASTM D 1556, ASTM D 2167, ASTM D 2922
Soil organic carbon (f_{oc})	Lab measurement	Nelson & Sommers (1982)
Soil texture	Lab measurement	Particle size analysis (Gee & Bauder, 1986) and USDA classification; used to estimate Θ_w & I
Soil pH	Field measurement	McLean (1982)

It is important to note that many site-specific values require data collected over a one-year period. Thus, while site-specific SCTLs may be desirable, the use of generic SCTLs may in fact be more cost-effective and less time-consuming. In addition to the time needed for the collection of soil-specific data, the investigator must be in strict accordance with the approved methods. This condition is particularly important because the collected data are also used for the derivation of other site-specific parameters. Values derived from site-specific data include Θ_w (water-filled soil porosity), Θ_a (air-filled soil porosity), total soil porosity (n) and soil-water organic partition coefficient (organics) (K_d). Therefore, errors in the collection of data would result not only in one incorrect value, but in several other

incorrectly derived values as well. For example Θ_w and Θ_a are derived from the soil moisture content (w). To adequately generate w, the soil moisture content must represent the *annual* average. The use of moisture content data from discrete soil samples which may be affected by preceding rainfall events would incorrectly represent the moisture content and therefore result in the incorrect derivation of Θ_w and Θ_a. Correctly deriving values such as Θ_a is of great significance, because other than the initial soil concentration, air-filled soil porosity (Θ_a) is the most significant soil parameter affecting the volatilization of chemicals of concern from soil. The higher the Θ_a, the greater the potential for emission of volatile chemicals of concern. The equations, sources, and methods for deriving soil characteristics using site-specific data are provided in the following table.

Soil Characteristic	Data Source	Method
Water-filled soil porosity (Θ_w) (Average soil moisture content)	$\Theta_w = n\,(I/K_s)^{1/(2b+3)}$ or $\Theta_w = w\rho_b$	Where, n = total soil porosity (L_{pore}/L_{soil}) I = infiltration rate (m/yr) K_s = saturated hydraulic conductivity (m/yr) b = soil-specific exponential parameter (unitless) w = soil moisture content (g_{water}/g_{soil}) ρ_b = dry soil bulk density (g/cm^3)
Total soil porosity (n)	$n = 1 - (\rho_b/\rho_s)$	Where, ρ_b = dry soil bulk density (g/cm^3) ρ_s = soil particle density = 2.65 kg/L
Infiltration rate (I)	HELP model; Regional estimates	HELP (Schroeder et al., 1984); may be used for site-specific infiltration estimates
Soil-specific exponential parameter (b) (Moisture retention component)	Look-up	Attachment A (USEPA, 1996a); used to calculate Θ_w
Saturated hydraulic conductivity (K_s)	Look-up	Attachment A (USEPA, 1996a); used to calculate Θ_w

Soil Characteristic	Data Source	Method
Air-filled soil porosity (Θ_a)	$\Theta_a = n - w\rho_b$ or $n - \Theta_w$	Where, n = total soil porosity (L_{pore}/L_{soil}) w = soil moisture content (g_{water}/g_{soil}) ρ_b = dry soil bulk density (g/cm^3) Θ_w = average soil moisture content (L_{water}/L_{soil})
Soil-water organic partition coefficient (organics) (K_d)	$K_d = K_{oc} \times f_{oc}$	Where, K_{oc} = chemical-specific soil-organic carbon partition coefficient (cm^3/g) f_{oc} = organic carbon content of soil (g/g)

VF is also a function of local climatic conditions and the size of contaminated area as expressed in the Q/C term. The USEPA (1996b) has tabulated Q/C values for contaminated areas ranging from 0.5 to 30 acres in size for selected cities around the U.S. These values are based on a modeling exercise which incorporated, among other things, meteorological data for these cities. The only city in Florida included in this exercise was Miami, and the next closest city was Atlanta. The default Q/C recommended in Figure 4 is based on Miami data and a 0.5 acre contaminated area. A site-specific Q/C term should be considered if the area of contaminated soil is significantly greater than 0.5 acres and inhalation exposure is a significant concern. Development of a site-specific Q/C term for a contaminated area outside the range presented by the SSG, or using meteorological data from a location in Florida other than Miami, is possible but would require a sophisticated and expensive analysis. In all but the most unusual circumstances, this level of effort to develop a site-specific Q/C term beyond the use of the SSG tabulated values would not be worthwhile.

The PEF term is also influenced by local meteorological conditions, as well as site characteristics. An important site characteristic influencing PEF is the percent of vegetative cover over the contaminated soil. The default assumption is that 50%

of the contaminated area has vegetative cover. This value can be adjusted for a specific site, but if a higher value is used some mechanism must be in place to insure that the vegetative cover remains in place in the future. Local wind conditions can also influence PEF and could conceivably be used to adjust the PEF in the development of site-specific SCTLs. A preliminary analysis of annual average meteorological data from cities around Florida found average windspeeds only slightly different from the default value, however (unpublished observations). Because PEF is a quantitatively important factor in the SCTL of only a very few chemicals, there is generally little incentive for developing site-specific PEF values. It is important to note that the PEF is applicable only for undisturbed soil. If there is significant soil disturbance at a site, such as from vehicular traffic, site-specific estimates of dust levels may have to be substituted for the PEF in deriving an SCTL.

Mass limits. The VF equation is based in part on the assumption of an infinite source. When the volume of contaminated soil is known (i.e., the area and depth), the VF equation can be modified to take mass of chemicals of concern into consideration. An alternative VF equation incorporating estimates of volume of contaminated soil is described in the SSG (USEPA, 1996a, 1996b).

Values that do not change from site to site. It is worth stating explicitly that there are some variables and assumptions that are unrelated to site conditions and circumstances and therefore should not be modified in deriving a site-specific SCTL. These parameters include toxicity values, absorption rates, fundamental physical/chemical properties of chemicals of concern, and the averaging time for carcinogenic effects. [Note: The averaging time for non-carcinogenic effects is a function of the exposure duration, which could be modified at a particular site.] Also, it is generally impractical to consider body weight as a site-specific variable

(except as it relates to the age of the exposed individuals, e.g., adults versus children).

D. Developing alternative direct contact SCTLs based on C_{sat}

To calculate the inhalation component of the SCTL for residential and industrial exposure to volatile carcinogens and non-carcinogens, a volatilization factor is used, as described in Section II B, Input values for direct exposure. The equation for the volatilization factor (Figure 4), which defines the relationship between the concentration of the chemical of concern in soil and the flux of the volatilized chemical of concern to air assumes an infinite source of the chemical of concern and only one mechanism of transport of the chemical of concern, vapor phase diffusion. With this model, other than the initial soil concentration, air-filled soil porosity is the most significant soil parameter affecting the final steady-state flux of volatile chemicals of concern. The higher the air-filled soil porosity, the greater the emission flux of volatile constituents. However, there are limits to this model. One limit of particular importance is the concentration at which the soil pore air and pore water are saturated with chemicals of concern and the adsorptive limits of the soil particles have been reached. At this point, the emission flux from soil to air for a chemical reaches a plateau and volatile emissions will not increase above this level no matter how much more chemical is added to the soil. This property is referred to as the soil saturation limit (C_{sat}) (Figure 6).

For chemicals of relatively low toxic potency, the use of the equations in Figures 1 and 2 to calculate SCTLs may result in soil concentrations that exceed C_{sat} for that chemical. This situation creates a problem in that the model used for the inhalation component of these equations is not predictive of air concentrations when the C_{sat} is exceeded, as discussed above. Also, for chemicals that are liquid at

ambient temperatures, soil concentrations above the saturation limit will be present as non-aqueous phase liquids (NAPLs), which may be undesirable at the site for a number of reasons. For these reasons, the C_{sat} is used by the USEPA as an upper limit for SCTLs in soil (USEPA, 1996a).

Among the chemicals listed in Chapter 62-770, F.A.C., this is an issue only for ethylbenzene and xylenes. That is, ethylbenzene and xylenes are the only chemicals for which the calculated risk-based value for the SCTL exceeds the calculated C_{sat} value. A comparison of the risk-based and the C_{sat} values for these two chemicals is provided below. For these chemicals [only], the FDEP has determined that the SCTL for direct contact for ethylbenzene and xylenes in Chapter 62-770, F.A.C., should be their respective C_{sat} values.

Chemical	Risk-Based Values		C_{sat}*
	Residential	Industrial	
ethylbenzene	940	6,800	240
xylenes	7,800	54,000	290

All values in mg/kg soil.
*C_{sat} value has been rounded to two significant figures. These C_{sat} values differ from those in the USEPA SSL because a K_{oc} based on the geometric mean of observed values was used rather than a calculated K_{oc} (please refer to section II B for preferences in selection of physical/chemical values).

E. Chemical Interactions for Chapter 62-770, F.A.C.

Exposure to combinations of chemicals may result in interactions leading to a significant increase or decrease in the overall toxicity of the mixture compared to the summation of the toxicity of the individual chemicals. As a result, the concept of toxic interactions from multiple chemical exposures is a subject of considerable interest and concern for hazardous waste sites where multiple chemical exposures are probable.

Toxic interactions may occur as a result of an alteration in the absorption, distribution, metabolism, and excretion of one chemical by another, modifying its toxicity. Studies in animals have reported the occurrence of such interactions among gaseous pollutants, pesticides, metals, and solvents. Interactions may also occur when one chemical alters the responsiveness of cells and target organs to the effects of other chemicals, such as through receptor up-regulation or altered cell signalling pathways. Very little information exists on toxic interactions in humans, and inferences must be made from studies of toxicant effects in laboratory animals. Even in circumstances where significant interactions have been observed in these studies, 1) the dosages at which the interaction occurs are usually not well characterized; 2) there is often uncertainty as to whether the mechanism for the interaction is relevant to humans, particularly at the comparatively low levels of exposure typically encountered from contaminated environmental media; and 3) most such studies involve exposure to two chemicals, whereas exposure at contaminated sites can involve several toxicants. For these reasons, the utility of these observations in evaluating the human health implications of multiple chemical exposures is limited, and it is extremely difficult to address chemical interactions in quantitative risk assessment other than on a rather simplistic level.

The standard approach taken in baseline risk assessments for contaminated sites is to assume that risks to the individual from multiple chemicals of concern are, at most, additive. The incremental excess cancer risk to the exposed individual is the sum of the cancer risks from individual carcinogenic site chemicals of concern. For non-carcinogens, hazard quotients for individual chemicals are summed only when there is evidence that the chemicals may have additive effects. The same mechanism of action or the same target organ for toxicity are usually taken as evidence for potential additivity.

SCTLs are derived for individual chemicals based on a specified target risk. In the case of petroleum products' chemicals of concern specified in Chapter 62-770, F.A.C., that means an excess cancer risk of 1×10^{-6} for carcinogens and a hazard index of 1 for non-carcinogens. If additivity of risk is assumed, that would mean that five carcinogens in soil at a site, each present at its SCTL, would collectively pose an excess cancer risk of 5×10^{-6}. Correspondingly, five non-carcinogens, each present at its SCTL, would result in a total hazard index of 5. Since most sites will have a number of petroleum-related chemicals of concern present, it is therefore possible to have a site that is considered "clean" (i.e., each of the chemicals is present in concentrations at or below their SCTLs) while having a total hazard index > 1. A hazard index > 1 does not necessarily mean that there are unacceptable non-cancer health risks, but it usually indicates that a closer examination of potential health risks is warranted. Accordingly, a brief analysis was conducted regarding the potential for additivity or other interaction among chemicals of concern listed in Chapter 62-770, F.A.C.

The first step in this analysis was to examine the bases for the reference doses and their implications in terms of additive risk. The following table lists each of the non-carcinogenic chemicals of concern for which an SCTL was derived for Chapter 62-770, F.A.C., the reference dose for that chemical, the toxic endpoint upon which the reference dose is based, and the uncertainty factor used in deriving the reference dose value. Collectively, the non-cancer risks posed by this suite of chemicals reflects an array of different target organs and toxicity endpoints. Even if most or all of these chemicals were present at a given site, it is unlikely that more than four or five would be considered to have additive toxicity potential based on target organ toxicity. That is, it is unlikely that more than four to five chemicals would be present which produce toxicity at the same target organ. As such, under a "worst-case" situation (i.e., four to five chemicals present, each at its SCTL and with the same target organ toxicity), the hazard index would not exceed 5. For most

sites with a hazard index > 1, the value would probably not be greater than 2 or 3. The metals listed in Chapter 62-770, F.A.C., each have rather characteristic toxicities that would not be considered additive based on target endpoints. There are some PAHs and BTEX which share target organs (primarily the liver and kidneys) and are therefore the most likely candidates for additive toxicity. The uncertainty factors for these chemicals range from 100 to 1,000. While the uncertainty factor is not intended to represent a numerical "margin of safety," it does indicate that the reference dose for these chemicals has been set 2-3 orders of magnitude below the lowest dosages observed to produce health effects. Under these circumstances, a marginally elevated hazard index (as might occur with a petroleum site with chemicals of concern at or below their SCTLs) should not be of significant concern.

Chemicals	RfD (mg/kg/day)	Uncertainty Factor	Current Reference	Target Organ/ Effect
METALS				
barium	0.07	3	IRIS (1994)	Increase BP
cadmium	0.0005	10	IRIS (1994)	Proteinuria
mercury	0.0003	30	HEAST (7/93)	Neurotoxicity
selenium	0.005	3	IRIS (1994)	Selenosis
silver	0.005	3	IRIS (1994)	Argyria
PAHs				
acenaphthene	0.06	300	IRIS (1994)	Hepatotoxicity
acenaphthylene	0.03	300	Surrogate	No data
anthracene	0.3	300	IRIS (1994)	None observed
benzo(g,h,i)perylene	0.3	300	Surrogate	No data
fluoranthene	0.04	300	IRIS (1994)	Nephrotoxicity
fluorene	0.04	300	IRIS (1994)	Decreased RBC counts/ increased liver/spleen/kidney weight
naphthalene	0.04	1000	HEAST WD	No data
phenanthrene	0.03	300	Surrogate	No data
pyrene	0.03	300	IRIS	Nephrotoxicity
BTEX				
toluene	0.2	100	IRIS	Altered liver/kidney weight
ethylbenzene	0.1	1000	IRIS	Histopath. changes in liver and kidney
xylenes, total	2.0	100	IRIS	Hyperactivity/ decreased weight

Chemicals	RfD (mg/kg/day)	Uncertainty Factor	Current Reference	Target Organ/ Effect
OTHER				
methyl tert-butyl ether	0.005	100	Region III RBC	Increased liver/kidney weight/renal lesions/ increased prostration/ swollen periocular tissue

The second step was to examine the toxicological literature for evidence of interactions (additive or otherwise) among the chemicals listed in Chapter 62-770, F.A.C. Several studies of potential interactions were identified, although their implications for exposures at petroleum sites are not always clear. For example, toluene has been reported to decrease the leucopenia induced by benzene in rats, probably due to a competitive inhibition of cytochrome P-450-mediated benzene metabolism. (See Krishnan & Pelekis, 1995, for review.) Inhibition of benzene metabolism by toluene has been observed in humans at occupational exposure levels (Inoue et al., 1988), but no information is available as to an effect on benzene toxicity in humans, nor is it clear that a similar inhibition might occur at lower, environmental levels of exposure. Despite these uncertainties, it appears that this interaction between benzene and toluene would reduce, rather than enhance, toxicity.

It is theoretically possible that some petroleum products' chemicals of concern might contain inducers of cytochrome P-450 (specifically, CYP 2E1), which would increase benzene bioactivation, and thus its toxicity. No demonstration of this was found in the literature, however, and Krishnan & Pelekis (1995) caution that this mechanism may not be relevant at low exposure levels [as might occur from petroleum contaminated soil]. It is also possible that petroleum products' chemicals of concern might compete for metabolizing enzymes, and that the presence of one chemical of concern might inhibit the metabolism and detoxification of another. This effect could result in greater-than-additive toxicity, and would seem to be particularly likely for the petroleum-related solvents (e.g., toluene,

ethylbenzene, and xylenes). Evidence of mutual inhibition of toluene and xylene metabolism has been observed in rats (Tardiff et al., 1989), but studies in humans have shown this effect only with relatively high levels of exposure (evidence of inhibition of metabolism was seen with inhalation exposure to 95 ppm toluene + 80 ppm xylene, but not 50 ppm toluene + 40 ppm xylene; Tardiff et al., 1991). Inhibition of metabolism of ethylbenzene and m-xylene during combined exposures of volunteers has also been reported (Engstrom et al., 1984), but the exposure levels (150 ppm ethylbenzene + 150 ppm m-xylene) were much greater than those that would result from contaminated soil at or near the SCTLs for these compounds.

With regard to the metals, there are numerous studies of interactions among toxic metals and between toxic metals and trace elements. Very little information is available, however, regarding interactions in humans which might affect toxicity. Selenium has been shown to reduce the toxicity of mercury in rats, and there are limited observations in humans which seem to support a protective role for selenium in mercury toxicity (Krishnan & Brodeur, 1994). No studies were identified which clearly indicate that exposures to metals, at environmentally relevant doses, are likely to result in significantly greater-than-additive toxicity.

In summary, the availability of information to assess the effects of co-exposures is limited. As a result, evaluating potential health risks associated with exposure to Chapter 62-770, F.A.C., chemicals in combination is difficult. A review of the toxicological literature found no basis to assume that exposures to the chemicals listed in Chapter 62-770, F.A.C., will produce supra-additive toxicity. If additivity of toxicity is assumed, the exposure to multiple petroleum products' chemicals of concern at some sites may result in a total hazard index > 1, even when individual chemicals of concern are at or below their SCTLs. Given the toxicological properties of the chemicals at issue, however, the marginally elevated

hazard index that may result from employing SCTLs individually based on a hazard index of 1 is not regarded as a health concern.

III. Development of SCTLs Based on Migration to Groundwater (Leaching)

A. Equation for calculating SCTLs based on leachability

The migration to groundwater pathway was developed to identify chemical concentrations in soil that have the potential to contaminate groundwater. The migration of chemicals of concern from soil to groundwater can be envisioned as a two-stage process: the release of chemicals of concern in soil into leachate, and the transport of chemicals of concern through the soil to and within an underlying aquifer. The method for calculating a leachability-based SCTL is taken from the SSG and incorporates a standard linear equilibrium soil/water partition equation to estimate release of chemicals of concern in soil leachate and a dilution factor to account for dilution of soil leachates in an aquifer. The SCTLs are then back-calculated from applicable groundwater cleanup target levels (GCTLs). In circumstances where contaminated soil is adjacent to surface water bodies, GCTLs based on protection of the surface water body can also be employed. The GCTL is multiplied by a dilution attenuation factor (DAF) to derive a target leachate concentration. The equation for calculating SCTLs based on migration of chemicals of concern from soil to groundwater is shown in Figure 5.

B. Input values for leachability

The equations for the calculation of SCTLs based on leachability require the input of several chemical-specific factors. These values include the organic carbon

normalized soil-water partition coefficient for organic compounds (K_{oc}) and the Henry's Law constant (HLC). For the development of leachability-based SCTLs for inorganics, K_d values (soil-water partition coefficient) for inorganic constituents are needed. While most of these values can be found in a variety of sources, sometimes it may be necessary to calculate values such as K_{oc} or HLCs when they are not otherwise available. In these cases, additional physical/chemical values such as the water solubility (S) or the octanol-water partition coefficient (K_{ow}) are needed. Different references for physical/chemical parameters can cite very different values and, as discussed in Section II B above, a hierarchy of sources for these values is recommended. Chemical-specific values for S, HLC, and K_{ow} are preferentially selected from the *Superfund Chemical Data Matrix* (SCDM) (EPA/540/R-96/028). K_{oc} values are from the *Soil Screening Guidance: Technical Background Document* (SSG) (EPA/540/R-95/128), and IRIS, ATSDR Toxicant Profiles and other reference sources (in that order of preference) are used when data are unavailable in the SCDM or SSG.

Currently, generating K_d values for metals is difficult. For this reason, the USEPA suggests using an equilibrium geochemical speciation model (MINTEQ) for estimating these values. However, modeled values may not accurately represent the potential for leachability because, unlike organic compounds, K_d values (soil/water partition) for metals are significantly affected by a variety of soil conditions. Iron oxide content, soil organic matter content, cation exchange capacity, pH, oxidation-reduction conditions, and major ion chemistry, are significant parameters that can affect the soil/water partition of metals and hence the leachability values. Therefore, in some instances, a leach test may be more useful than an SCTL based on a partitioning equation (see Section III C below).

C. Developing site-specific SCTLs based on leachability

In Florida, soil types vary significantly across the state, from quartz sand to muck, and leaching potential covers an extreme range. The default soil characteristics used to develop generic leachability-based SCTLs lie somewhere in the middle of this range. Development of site-specific leachability-based SCTLs can be quite important, because the soil characteristics at a given site may bear little resemblance to the default assumptions. It should be recognized, however, that site-specific SCTLs for leachability calculated using the equation in Figure 5 can be either higher or lower than the generic values because the default assumptions are not skewed toward the conservative end of the range of values possible in Florida. Site-specific characteristics important in calculating a leachability-based SCTL include the f_{oc}, Θ_w, Θ_a, n, and ρ_b, and procedures for developing site-specific SCTLs are described in the SSG (USEPA, 1996a).

Another parameter that is important in calculating leachability-based SCTLs is the dilution attenuation factor (DAF). The USEPA arrived at a default DAF using results from OSW's EPACMTP Model. This model utilized a Monte Carlo analysis with input parameters obtained from nationwide surveys of waste sites and from applying the SSL dilution model to 300 groundwater sites across the country. The model distributions were repeated 15,000 times for each scenario and a cumulative frequency distribution of DAF values was generated. The results of the accompanying sensitivity analysis indicated that climate, soil type, and size of the contaminated area have the greatest effect on the DAF. To gain further information on the national range and distribution of DAF values, the dilution model was applied to two large surveys of hydrogeologic site investigations. These were the American Petroleum Institute's hydrogeologic database (HGDB) and USEPA's database of conditions at DNAPL sites. DAF modeling information from a combination of 300 sites indicated that the geometric mean DAF of all sites

combined was 20 for a source area of 0.5 acre. This value was carefully selected using a "weight of evidence" approach which best represents a nationwide average and is therefore regarded as an acceptable default for use at most sites. In only special circumstances, such as very complex sites, a site-specific DAF can be calculated, but the aquifer hydraulic conductivity, the hydraulic gradient, the mixing zone depth, the infiltration rate, and the source length parallel to groundwater flow must be determined (USEPA, 1996a).

It has been demonstrated that the leachability-based SCTLs partition equation can be used to derive leaching based SCTLs for organic compounds. However, inorganics present at cleanup sites can also pose risks to an underlying aquifer. To derive leachability-based values for most metals is more complicated, however. Unlike organic compounds, K_d values (soil/water partition) for metals are significantly affected by a variety of soil conditions. In some instances, a leach test may be more useful than the partitioning method. Therefore, FDEP recommends the use of a leach test instead of the soil/water partition equation. At petroleum contaminated sites, metals are primarily of concern only when oily wastes, such as used oil, are present. In these cases, FDEP specifically requires the use of the Toxicity Characteristic Leaching Procedure (TCLP) for cleanup of these sites. While this procedure was developed to model leaching from the bottom of a landfill, it more closely estimates leaching from soil contaminated with oily constituents, such as used oil or similar petroleum products. In addition, consideration will be given for the use of the USEPA proposed leachability values for metals that were derived using the MINTEQ model. For determining site-specific leachate values for organics, the Synthetic Precipitation Leaching Procedure (SPLP), developed to model an acid rain leaching environment, can be used when there are no oily soil chemicals of concern.[7]

[7] Direct leachability testing should include a minimum of three representative soil samples, pursuant to USEPA Test Method 1312 (SPLP). Leachate concentrations from SPLP should not exceed the

IV. Development of SCTLs for Total Recoverable Petroleum Hydrocarbons (TRPHs)

The TRPH SCTLs were developed to be used in a two-tiered approach with a primary TRPH soil cleanup target level as the starting value. Primary TRPH values for direct exposure and leachability included in Table 1 are based on the assumption that the TRPHs consist exclusively of aromatic hydrocarbons in the $>C_8$-C_{10} range. While SCTLs derived for hydrocarbons in the C_5-C_7 range are the most restrictive (Table C4, Appendix C), these compounds are not detected using the Florida Petroleum Residual Organic (FL-PRO) analysis. Currently, the FL-PRO method of TRPH analysis is limited to measuring the concentration of mixed petroleum hydrocarbons in the range of C_8-C_{40}. While FL-PRO does not measure hydrocarbons in the C_5-C_7 range, the most toxic and prevalent COCs among these are addressed by other analyses and individual cleanup target levels. Therefore, the primary TRPH SCTL is based on the most conservative and health protective carbon range that can be detected by FL-PRO, the $>C_8$-C_{10} carbon range.

TRPH SCTLs are derived from chemical/physical parameters and toxicity values assigned to each carbon range as described in Appendix C. It should be noted, however, that while the $>C_8$-C_{10} aromatic fraction has the most restrictive inhalation RfD, the $>C_{16}$ aromatic fractions currently have the most restrictive oral RfD (TPHCWG, 1997b; Table C2, Appendix C). Therefore, under certain site-specific conditions in which there may be elevated soil moisture and fraction organic carbon, such that volatilization would not be a significant consideration relative to ingestion, the potential exists for the $>C_{16}$ aromatic hydrocarbon concentrations to pose the greater risk.

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applicable GCTLs. SPLP should not be used for chemicals of concern derived from used oil or similar petroleum products.

If the primary SCTL is exceeded, it is proposed that a second tier would be employed, such that each TRPH sub-classification would possess its own SCTL. However, individual SCTLs could not be set for each C-range because the current FL-PRO method of analysis cannot distinguish between aliphatics and aromatics. Additionally, the quantitation of individual compounds is difficult and not confirmative, as only "fresh" petroleum hydrocarbons provide distinct peaks in analysis by gas chromatography (GC). Weathered petroleum hydrocarbons such as those found at contaminated sites, produce "hills" not peaks when analyzed by GC. Therefore, one can only obtain an estimate over the entire C-range of the fraction of petroleum hydrocarbons that are present in the sample. While analytical methods for separating aliphatics and aromatics exist (i.e., Massachusetts Department of Environmental Protection), they are outside the current analytical capabilities of accepted methods employed in Florida. However, as modifications to FL-PRO are developed in the future, the second tier would allow differentiation based on site-specific analyses.

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VI. Figures & Tables

Figure 1. Model Equation for Developing Acceptable Risk-Based Concentrations in Soil

Acceptable Soil Cleanup Target Levels for Carcinogens

Using the slope factor:

$$SCTL = \frac{TR \times BW \times AT}{EF \times ED \times FC \times \left[\left(SF_o \times IR_o \times 10^{-6} kg/mg \right) + \left(SF_d \times SA \times AF \times DA \times 10^{-6} kg/mg \right) + \left(SF_i \times IR_i \times \left(\frac{1}{VF} + \frac{1}{PEF} \right) \right) \right]}$$

SCTL = Soil Cleanup Target Level
TR = Target Risk (unitless)
BW = body weight (kg)
AT = averaging time (days)
EF = exposure frequency (days/yr)
ED = exposure duration (years)
FC = fraction from contaminated source (unitless)

IR_O = ingestion rate, oral (mg/day)
SA = surface area of skin exposed (cm^2)
AF = adherence factor (mg/cm^2/day)
DA = dermal absorption (unitless)
IR_i = inhalation rate (m^3/day)
VF = volatilization factor (m^3/kg)
PEF = particulate emission factor (m^3/kg)

SF = slope factor $(mg/kg/day)^{-1}$
SF_O = oral
SF_d = dermal
SF_i = inhalation

Sample SCTL Calculation for Direct Exposure (Aggregate Resident): BENZENE

$$SCTL = \frac{0.000001 * 59kg * 25550days}{350d/yr * 30yr * 1 * \left[\left(0.029 \left(mg/kg/d \right)^{-1} * 120mg/d * 1x10^{-6} kg/mg \right) + \left(0.032 \left(mg/kg/d \right)^{-1} * 3674cm^2 * 0.2mg/cm^2 * 0.01 * 1x10^{-6} kg/mg \right) + \left(0.029 \left(mg/kg/d \right)^{-1} * 15m^3/d * \left(\frac{1}{3.40x10^3} + \frac{1}{1.24x10^9} \right) \right) \right]}$$

$$SCTL = \frac{1.51}{10500 * \left[\left(3.48x10^{-6} \right) + \left(2.35x10^{-7} \right) + \left(1.28x10^{-4} \right) \right]} = \frac{1.51}{10500 * 1.32x10^{-4}} = \frac{1.51}{1.38} = 1.1mg/kg \ ‡$$

Given: $Sf_o = 0.029$ $(mg/kg/day)^{-1}$
$Sf_d = 0.032$ $(mg/kg/day)^{-1}$
$Sf_i = 0.029$ $(mg/kg/day)^{-1}$
VF = 3.40×10^3 m^3/kg
PEF = 1.24×10^9 m^3/kg

‡All calculations carried out to 18 decimal places. For simplicity of demonstration, calculated values shown are to three significant figures.
Final SCTL value is rounded to two significant figures if >1 and to one significant figure if <1.

Figure 2. Model Equation for Developing Acceptable Risk-Based Concentrations in Soil

Acceptable Soil Cleanup Target Levels for Non-Carcinogens

Using the reference dose:

$$SCTL = \frac{THI \times BW \times AT}{EF \times ED \times FC \times \left[\left(\frac{1}{RfD_o} \times IR_o \times 10^{-6}\,kg/mg\right) + \left(\frac{1}{RfD_d} \times SA \times AF \times DA \times 10^{-6}\,kg/mg\right) + \left(\frac{1}{RfD_i} \times IR_i \times \left(\frac{1}{VF} + \frac{1}{PEF}\right)\right)\right]}$$

SCTL = Soil Cleanup Target Level
THI = Target Hazard Index (unitless)
BW = body weight (kg)
AT = averaging time (days)
EF = exposure frequency (days/yr)
ED = exposure duration (years)
FC = fraction from contaminated source (unitless)

IR_O = ingestion rate, oral (mg/day)
SA = surface area of skin exposed (cm^2)
AF = adherence factor (mg/cm^2/day)
DA = dermal absorption (unitless)
IR_i = inhalation rate (m^3/day)
VF = volatilization factor (m^3/kg)
PEF = particulate emission factor (m^3/kg)

RfD = reference dose (mg/kg/day)
RfD_O = oral
RfD_d = dermal
RfD_i = inhalation

Sample SCTL Calculation for Direct Exposure (Child Resident): FLUORENE

$$SCTL = \frac{1.00 * 15kg * 2190days}{350d/yr * 6yr * 1 * \left[\left(\frac{1}{0.04mg/kg/d} * 200mg/d * 1x10^{-6}kg/mg\right) + \left(\frac{1}{0.02\,mg/kg/d} * 1800cm^2 * 0.2mg/cm^2 * 0.01 * 1x10^{-6}kg/mg\right) + \left(\frac{1}{0.02mg/kg/d} * 10\,m^3/d * \left(\frac{1}{2.09 \times 10^5 m^3/kg} + \frac{1}{1.24 \times 10^9\,m^3/kg}\right)\right)\right]}$$

$$SCTL = \frac{3.29 \times 10^4}{2100 * \left[(5.00 \times 10^{-3}) + (1.80 \times 10^{-4}) + (2.39 \times 10^{-3})\right]} = \frac{3.29 \times 10^4}{2100 * 7.57 \times 10^{-3}} = \frac{3.29 \times 10^4}{15.9} = 2100mg/kg\ ‡$$

Given: RfD_o = 0.04 mg/kg/day
RfD_d = 0.02 mg/kg/day
RfD_i = 0.02 mg/kg/day
VF = 2.09×10^5 m^3/kg
PEF = 1.24×10^9 m^3/kg

‡All calculations carried out to 18 decimal places. For simplicity of demonstration, calculated values shown are to three significant figures. Final SCTL value is rounded to two significant figures if >1 and to one significant figure if <1.

Figure 3. Derivation of the Particulate Emission Factor[a]

$$PEF\ (m^3/kg) = Q/C * \frac{3600\ sec/hr}{0.036 * (1 - V) * (U_m/U_t)^3 * F(x)}$$

Parameter	Definition (units)	Default
PEF	particulate emission factor (m^3/kg)	1.241005×10^9
Q/C	inverse of mean conc. at center of a 0.5-acre-square source (g/m^2-s per kg/m^3)	85.61[b]
V	fraction of vegetative cover (unitless)	0.5 (50%)‡
U_m	mean annual windspeed (m/s)	4.69‡
U_t	equivalent threshold value of windspeed at 7m (m/s)	11.32
F(x)	function dependent on U_m/U_t, derived using Cowherd et al. (1985)[c] (unitless)	0.194

[a] Equation taken from USEPA *1996b Soil Screening Guidance: Technical Background Document.* EPA/540/R-95/128.

[b] Based on Q/C Value for Zone IX (Miami, FL) as listed in USEPA *Soil Screening Guidance.*

[c] Cowherd, C., Muleski, G., Engelhardt, P., and Gillette, D. (1985). *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination.* EPA/600/8-85/002.

‡ Value may be substituted with documented, FDEP accepted site-specific information.

** All calculations carried out to 18 decimal places. For simplicity of demonstration, calculated values shown are to seven significant figures.

Calculation of PEF based on Zone IX Q/C Value:**

$$PEF\ (m^3/kg) = 85.61\ g/m^2\text{-s per kg/m}^3 * \frac{3600\ sec/hr}{0.036 * (1 - 0.5) * (4.69\ m/s / 11.32\ m/s)^3 * 0.194} = 1.241005 \times 10^9\ (m^3/kg)$$

Figure 4. Equation Used for the Determination of the Volatilization Factor[a]

$$VF = Q/C \times CF \times \frac{(3.14 \times D_A \times T)^{1/2}}{2 \times \rho_b \times D_A}$$

WHERE:

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

Model Parameters (Units)		Default Value
VF:	Volatilization factor (m^3/kg)	-
D_A:	Apparent diffusivity (cm^2/s)	-
CF:	Conversion factor (m^2/cm^2)	10^{-4}
Q/C:	Inverse of the mean concentration[b] (g/m^2-s per kg/m^3)	85.61[c]
T:	Exposure interval (s)	ED ✱ 3.15×10^7 s/yr
ED:	Exposure duration (years)	Exposure-specific[e]
n:	Total soil porosity (L_{pore}/L_{soil})	1- (ρ_b/ρ_s)‡
w:	Average soil moisture content (g_{water}/g_{soil})	0.1 (10%)‡
ρ_b:	Dry soil bulk density (g/cm^3)	1.5‡
ρ_s:	Soil particle density (g/cm^3)	2.65
θ_a:	Air-filled soil porosity (L_{air}/L_{soil})	n - θ_w
θ_w:	Water-filled soil porosity (L_{water}/L_{soil})	0.15‡
K_d:	Soil-water partition coefficient (cm^3/g)	K_{oc} ✱ f_{oc}
D_i:	Diffusivity in air (cm^2/s)	Chemical-specific[d]
D_w:	Diffusivity in water (cm^2/s)	Chemical-specific[d]
H:	Henry's Law constant (atm-m^3/mol)	Chemical-specific[d]
H':	Dimensionless Henry's Law constant	H ✱ 41
K_{oc}:	Soil-organic carbon partition coefficient (cm^3/g)	Chemical-specific[d]
f_{oc}:	Organic carbon content of soil (g/g)	0.006 (0.6%)‡

[a] Model equation taken from USEPA 1996b *Soil Screening Guidance: Technical Background Document.* EPA/540/R-95/128.

[b] Assumes the center of a 0.5 acre plot.

[c] Based on Q/C Value for Zone IX (Miami, FL) as listed in EPA *Soil Screening Guidance.*

[d] Listed in Table 3a.

[e] Based on Aggregate Resident exposure for a duration of 30 years (ED).

‡Value may be substituted with documented, FDEP accepted site-specific information.

Sample VF Calculation for Benzene Exposure**

**All calculations carried out to 18 decimal places. For simplicity of demonstration, calculated values shown are to seven significant figures.

Given: $D_i = 0.088\ cm^2/s$
$D_w = 9.80 \times 10^{-6}\ cm^2/s$
$H' = 0.2296000$
$T = 9.460000 \times 10^8\ s$[e]
$K_{oc} = 62\ cm^3/g$
$K_d = 3.720000 \times 10^{-1}\ cm^3/g$

Then:

$$D_A = \frac{\left[(1.504996\times10^{-2} \times 0.088 \times 2.296000\times10^{-1}) + (1.793236\times10^{-3} \times 9.80\times10^{-6}) / 1.883232\times10^{-1}\right]}{(1.5 \times 3.720000\times10^{-1}) + (0.15) + (0.2839362 \times 0.2296000)}$$

$$= \frac{1.614772\times10^{-3}}{7.731977\times10^{-1}}\ cm^2/s = 2.088433\times10^{-3}\ cm^2/s$$

And:

$$VF = 85.61\left(\frac{g \bullet m^3}{m^2 \bullet s \bullet kg}\right) \times 1\times10^{-4}\left(\frac{m^2}{cm^2}\right) \times \frac{\left(3.14 \times 2.088433\times10^{-3}\left(\frac{cm^2}{s}\right) \times 9.460000\times10^8 (s)\right)^{\frac{1}{2}}}{2 \times 1.5 \times 2.088433\times10^{-3}\left(\frac{cm^2}{s}\right)}$$

$$= \frac{2.132285\times10^1}{6.265300\times10^{-3}} = \mathbf{3403.324}\left(\frac{m^3}{kg}\right)$$

Figure 5. Equation for the Determination of Soil Cleanup Target Levels (SCTLs) Based on Leachability

$$SCTL(mg/kg) = GCTL(\mu g/L) * CF(mg/\mu g) * DF * \left[K_{oc}(L/kg) * f_{oc}(g/g) + \frac{\Theta_w(L_{water}/L_{soil}) + \Theta_a(L_{air}/L_{soil}) * H'}{\rho_b(kg/L)} \right]$$

Parameter	Definition (units)	Variables and Default
GCTL	Groundwater cleanup target level (µg/L)	Table-Specific Value[1]
CF	Conversion factor (mg/µg)	0.001
DF	Dilution factor (unitless)	20
K_{oc}	Soil-organic carbon partition coefficient (L/kg)	Chemical-Specific Value[2]
f_{oc}	Fraction organic carbon in soil (g/g)	0.002‡
Θ_w	Water-filled soil porosity (L_{water}/L_{soil})	0.3 or $w\rho_b$‡
Θ_a	Air-filled soil porosity (L_{air}/L_{soil})	n - Θ_w
H	Henry's Law constant (atm-m^3/mol)	Chemical-Specific Value[2]
H'	Henry's Law constant (unitless)	H * 41
ρ_b	Dry soil bulk density (kg/L)	1.5 or (1-n) ρ_s‡
w	Average soil moisture content (kg_{water}/kg_{soil})	0.2 (20%)‡
n	Total soil porosity (L_{pore}/L_{soil})	1-(ρ_b/ρ_s) ‡
ρ_s	Soil particle density (kg/L)	2.65

[1] Groundwater Cleanup Target Levels (See Table 3b).

[2] Values selected (listed in Table 3a) as available in order of preference from:

1. Superfund Chemical Data Matrix (EPA/540/R-96/028).
2. USEPA *Soil Screening Guidance: Technical Background Document* (EPA/540/R-95/128).
3. USEPA Integrated Risk Information System (IRIS), May 96 Update.
4. Toxicological Profiles, Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services.

‡ Value may be substituted with documented, FDEP accepted site-specific information.

**All calculations carried out to 18 decimal places. For simplicity of demonstration, calculated values shown are to seven significant figures. Final SCTL is rounded to two significant figures if >1 and to one significant figure if <1.

Sample SCTL Calculation for Benzene Migration into Groundwater

Given: GCTL = 1 µg/L
K_{oc} = 62 L/kg
H' = 0.2296000

Then:

$$SCTL(mg/kg) = 1.0\ \mu g/L * 0.001\ mg/\mu g * 20 * \left[62\ L/kg * 0.002\ g/g + \frac{0.3\ L_{water}/L_{soil} + \left(1.339623x10^{-01}\ L_{air}/L_{soil} * 0.2296000\right)}{1.5\ kg/L} \right] =$$

SCTL = 0.0068901 mg/kg soil

SCTL = 0.007 mg/kg soil **

Figure 6. Equation[a] Used for the Determination of C_{sat}

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

Parameter	Definition (Units)	Default Value
C_{sat}	Soil saturation concentration (mg/kg)	-
S	Solubility in water (mg/L)	Chemical-specific[b]
ρ_s	Soil particle density (kg/L)	2.65
ρ_b	Dry soil bulk density (kg/L)	1.5‡
n	Total soil porosity (L_{pore}/L_{soil})	1 - (ρ_b/ρ_s) ‡
θ_a	Air-filled soil porosity (L_{air}/L_{soil})	n - wρ_b
θ_w	Water-filled soil porosity (L_{water}/L_{soil})	0.15‡
K_d	Soil-water partition coefficient (L/kg)	K_{oc} * f_{oc}
w	Average soil moisture content (kg_{water}/kg_{soil})	0.1 (10%)
H	Henry's Law constant (atm-m^3/mol)	Chemical-specific[b]
H'	Dimensionless Henry's Law constant	H * 41
K_{oc}	Soil-organic carbon partition coefficient (L/kg)	Chemical-specific[b]
f_{oc}	Fraction organic carbon in soil (g/g)	0.006 (0.6%)‡

[a] Model equation taken from USEPA 1996b *Soil Screening Guidance: Technical Background Document.* EPA/540/R-95/128.

[b] Listed in Table 3a.

‡ Value may be substituted with documented, FDEP accepted site-specific information.

**All calculations carried out to 18 decimal places. For simplicity of demonstration, calculated values shown are to seven significant figures. C_{sat} values used as SCTLs are rounded to two significant figures if >1 and to one significant figure if <1.

Sample C_{sat} Calculation for Ethylbenzene**

Given:

$S = 170$ mg/L

$K_d = 1.224000$ L/kg

$K_{oc} = 204$ L/kg

$H' = 3.239000 \times 10^{-1}$

Then:

$$C_{sat} = \frac{170\ mg/L}{1.5\ kg/L}\left(\left(1.224\ L/kg * 1.5kg/L\right) + \left(0.15\right) + \left(3.239x10^{-1} * 0.2839362\right)\right)$$

$C_{sat} = 113.3333$ mg/L * 2.077967 L/kg

$C_{sat} = 235.5029$ mg/kg

$C_{sat} = 240$ mg/kg

Table 1. *Table IV for Chapter 62-770, F.A.C.*

Soil Cleanup Target Levels (SCTLs)

Chemical Name	Direct Exposure (mg/kg)		Leachability Based on Table V[a]	Leachability Based on Table VI[b]	Leachability Based on Table VII[c]	Leachability Based on Table VIII[d]
	I*	II**	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
PAHs:						
acenaphthene	2300	22000	4.0	0.6	0.6	40
acenaphthylene	1100	11000	22	0.003*	0.003*	220
anthracene	19000	290000	2000	0.3	0.3	20000
benzo(a)anthracene	1.4	5.1	2.9	0.4	0.4	29
benzo(a)pyrene	0.1	0.5	7.8	1.2	1.2	78
benzo(b)fluoranthene	1.4	5.0	9.8	1.5	1.5	98
benzo(g,h,i)perylene	2300	45000	13000	2.0	2.0	130000
benzo(k)fluoranthene	15	52	25	1.5	1.5	250
chrysene	140	490	80	0.5	0.5	800
dibenzo(a,h)anthracene	0.1	0.5	14	2.2	2.2	140
fluoranthene	2800	45000	550	0.4	0.4	5500
fluorene	2100	24000	87	9.4	9.4	870
indeno(1,2,3-cd)pyrene	1.5	5.2	28	4.3	4.3	280
naphthalene	1000	8600	1.0	1.0	1.3	10
phenanthrene	1900	29000	120	0.02*	0.02*	1200
pyrene	2200	40000	570	0.8	0.8	5700
VOAs:						
benzene	1.1	1.5	0.007	0.007	0.5	0.07
ethylbenzene**	240	240	0.4	0.4	7.7	3.8
toluene	300	2000	0.4	0.4	4.8	4.0
xylenes**	290	290	0.3	0.3	5.3	2.9
OTHER:						
dichloroethane, 1,2-	0.6	0.9	0.02	0.02	0.7	0.2
methyl tert-butyl ether	350	6100	0.2	0.2	150	1.6
TRPHs	350	2500	340	340	340	3400
METALS:						
arsenic	0.8	3.7	TCLP	TCLP	TCLP	TCLP
barium	5200	87000	TCLP	TCLP	TCLP	TCLP
cadmium	75	1300	TCLP	TCLP	TCLP	TCLP
chromium	290	430	TCLP	TCLP	TCLP	TCLP
lead***	500	1000	TCLP	TCLP	TCLP	TCLP
mercury	3.7	28	TCLP	TCLP	TCLP	TCLP
selenium	390	10000	TCLP	TCLP	TCLP	TCLP
silver	390	9100	TCLP	TCLP	TCLP	TCLP

Values rounded to two significant figures if >1 and to one significant figure if <1.

TCLP= Toxicity Characteristic Leaching Procedure in mg/L. The analyses must be performed if the concentrations listed in Table II are exceeded, and need to pass test (see Table II of Chapter 62-770, F.A.C.).

*Unless the method detection limit (MDL) using the most sensitive and currently available technology is higher than the specified criterion.

**Direct exposure values based on soil saturation limit (C_{sat}).

***Direct exposure values from USEPA *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* OSWER Directive 9355.4-12 (1994). Residential value is the middle of the USEPA suggested range of 400-600 mg/kg.

*Values based on residential use assumptions.

**Values based on worker industrial exposure assumptions.

[a]Table V- Groundwater Cleanup Target Levels for Resource Protection/Recovery.

[b]TableVI - Lower of Table V and Freshwater Surface Water Criteria.

[c]Table VII - Surface Water Criteria for Resource Protection/Recovery.

[d]Table VIII - Low Yield/Poor Quality.

Table 2: Default Factors

Symbol	Definition (units)	Default	Reference
BW	body weight (kg) (aggregate resident)**	59	Derived from equation using child and adult body weights (See Appendix A)
	body weight (kg) (child)*	15	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
	body weight (kg) (adult/worker)	70	RAGS (part A), USEPA 1989a (EPA/540/1-89/002)
IRo	ingestion rate, oral (mg/day) (aggregate resident)	120	Derived from equation using child and adult ingestion rates (Technical Report, page 11)
	ingestion rate, oral (mg/day) (child)	200	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
	ingestion rate, oral (mg/day) (worker)	50	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
EF	exposure frequency (days/yr) (aggregate resident)	350	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
	exposure frequency (days/yr) (child)	350	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
	exposure frequency (days/yr) (worker)	250	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
ED	exposure duration (years) (aggregate resident)	30	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
	exposure duration (years) (child)	6	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
	exposure duration (years) (worker)	25	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
SA	surface area exposed (cm^2/day) (aggregate resident)	3674	Derived based on data from the Exposure Factors Handbook, USEPA 1989b (EPA/600/8-89/043) (See Appendix A)
	surface area exposed (cm^2/day) (child)	1800	Derived based on data from the Exposure Factors Handbook, USEPA 1989b (EPA/600/8-89/043) (See Appendix A)
	surface area exposed (cm^2/day) (worker)	2000	Derived based on data in Dermal Exposure Assessment: Principles and Applications, USEPA 1992 (EPA/600/8-91/011B)
AF	adherence factor (mg/cm^2) (aggregate resident and child)	0.2	Selected from range of values in Dermal Exposure Assessment: Principles and Applications, USEPA 1992 (EPA/600/8-91/011B)
	adherence factor (mg/cm^2) (worker)	0.6	Selected from range of values in Dermal Exposure Assessment: Principles and Applications, USEPA 1992 (EPA/600/8-91/011B)
AT	averaging time (days) (carcinogens)	25550 (70 years)	RAGS (part A), USEPA 1989a (EPA/540/1-89/002)
	averaging time (days) (non-carcinogens) (aggregate resident)	10950 (30 years)	RAGS (part A), USEPA 1989a (EPA/540/1-89/002) (AT=ED)
	averaging time (days) (non-carcinogens) (child)	2190 (6 years)	RAGS (part A), USEPA 1989a (EPA/540/1-89/002) (AT=ED)
	averaging time (days) (non-carcinogens) (worker)	9125 (25 years)	RAGS (part A), USEPA 1989a (EPA/540/1-89/002) (AT=ED)
DA	dermal absorption (unitless) (organics)	0.01	USEPA Region IV Guidance
	dermal absorption (unitless) (inorganics)	0.001	USEPA Region IV Guidance
IRi	inhalation rate (m^3/day) (aggregate resident)	15	Derived based on data from the Exposure Factors Handbook, USEPA 1989b (EPA/600/8-89/043) (See Appendix A)
	inhalation rate (m^3/day) (child)	10	RAGS (part A), USEPA 1989a (EPA/540/1-89/002)
	inhalation rate (m^3/day) (worker)	20	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
VF	volatilization factor (m^3/kg)	chemical-specific	Soil Screening Guidance, USEPA 1996b (EPA/540/R-95/128) (See Fig. 4)
PEF	particulate emission factor (m^3/kg)	1.24×10^9	Soil Screening Guidance, USEPA 1996b (EPA/540/R-95/128) (See Fig. 3)
TR	target cancer risk (unitless)	10^{-6}	Per Section 376.3071(5), F.S.
THI	target hazard index (unitless)	1	Per Section 376.3071(5), F.S.

*Child: Age 1-6 years **Aggregate Resident: Age 1-30 years

Table 3a. Chemical-Specific Values

Chemical Name	CAS #	Values from Reference Sources: Koc(L/kg)	H(atm-m3/mol)	Di (cm2/s)		Dw (cm2/s)		Calculated Values***: Da (cm2/s)	Volatilization Factors (m3/kg): Residential*	Industrial
METALS:										
arsenic	7440-38-2	n/a	n/a	n/a		n/a		n/a	n/a	n/a
barium	7440-39-3	n/a	n/a	n/a		n/a		n/a	n/a	n/a
cadmium	7440-43-9	n/a	n/a	n/a		n/a		n/a	n/a	n/a
chromium	18540-29-9	n/a	n/a	n/a		n/a		n/a	n/a	n/a
lead	7439-92-1	n/a	n/a	n/a		n/a		n/a	n/a	n/a
mercury	7438-97-6	n/a	n/a	0.031	E	6.30E-06	E	4.89490E-06	3.14396E+04	6.41757E+04
selenium	7782-49-2	n/a	n/a	n/a		n/a		n/a	n/a	n/a
silver	7440-22-4	n/a	n/a	n/a		n/a		n/a	n/a	n/a
PAHs:										
acenaphthene	83-32-9	4898	1.60E-04	0.042	E	7.69E-06	E	5.00612E-07	9.83097E+04	2.00674E+05
acenaphthylene	208-96-8	2500*	1.10E-04	0.067	I	7.44E-06	D	1.06969E-06	6.72541E+04	1.37282E+05
anthracene	120-12-7	23493	6.50E-05	0.032	E	7.74E-06	E	3.29608E-08	3.83132E+05	7.82065E+05
benzo(a)anthracene	56-55-3	357537	3.40E-06	0.051	E	9.00E-06	E	2.03187E-10	1.09115E+07	9.96079E+06
benzo(a)pyrene	50-32-8	968774	1.10E-06	0.043	E	9.00E-06	E	2.76040E-11	2.96039E+07	2.70245E+07
benzo(b)fluoranthene	205-99-2	1.23E+06	1.10E-04	0.023	E	5.56E-06	E	7.40588E-10	5.71536E+06	5.21739E+06
benzo(g,h,i)perylene	191-24-2	1600000*	1.40E-07	0.042	I	5.27E-06	W	4.82200E-12	3.16751E+07	6.46564E+07
benzo(k)fluoranthene	207-08-9	1.23E+06	8.30E-07	0.023	E	5.56E-06	E	1.03340E-11	4.83824E+07	4.41669E+07
chrysene	218-01-9	3.98E+05	9.50E-05	0.025	E	6.21E-06	E	2.17151E-09	3.33773E+15	3.04692E+06
dibenzo(a,h)anthracene	53-70-3	1789101	1.50E-08	0.020	E	5.18E-06	E	3.12500E-12	8.79860E+07	8.03199E+07
fluoranthene	206-44-0	49096	1.60E-05	0.030	E	6.35E-06	E	3.71863E-09	1.14066E+06	2.32836E+06
fluorene	86-73-7	7707	6.40E-05	0.036	E	7.88E-06	E	1.10584E-07	2.09171E+05	4.26968E+05
indeno(1,2,3-cd)pyrene	193-39-5	3.47E+06	1.60E-06	0.019	E	5.66E-06	E	4.91500E-12	7.01556E+07	6.40430E+07
naphthalene	91-20-3	1191	4.80E-04	0.059	E	7.50E-06	E	8.53945E-06	2.38030E+04	4.85877E+04
phenanthrene	85-01-8	14000*	2.30E-05	0.054	I	7.48E-06	W	3.30030E-08	3.82887E+05	7.81564E+05
pyrene	129-00-0	67992	1.10E-05	0.027	E	7.24E-06	E	1.71429E-09	1.67998E+06	3.42925E+06
BETX:										
benzene	71-43-2	62	5.60E-03	0.088	E	9.80E-06	E	2.08843E-03	3.40347E+03	3.10693E+03
ethylbenzene	100-41-4	204	7.90E-03	0.075	E	7.80E-06	E	9.34286E-04	2.27566E+03	4.64517E+03
toluene	108-88-3	140	6.60E-03	0.087	E	8.70E-06	E	1.26542E-03	1.95538E+03	3.99139E+03
xylenes	1330-20-7	249	6.70E-03	0.078	E	8.75E-06	E	6.93560E-04	2.64122E+03	5.39137E+03
OTHER:	See Appendix C							See Appendix C:		
TRPHs	Technical Basis for the TRPH SCTLs			0.100	C	1.00E-05	C	Technical Basis for the TRPH SCTLs		
dichloroethane, 1,2-	107-06-2	38	9.79E-04	0.104	E	9.90E-06	E	6.63553E-04	6.03801E+03	5.51193E+03
methyl tert-butyl ether	1634-04-4	11.2**	5.87E-04	0.103	D	1.05E-05	D	7.72153E-04	2.50320E+03	5.10963E+03

*Koc Values from EHRAV: Electronic Handbook of Risk Assessment Values.

**Koc and H values from ATSDR Profile 1995.

***All Calculations are carried out to 18 decimal places, values have been rounded to six significant figures for presentation in this table.

D = CHEMDAT8 (EPA/453/C-94/080B) I = IRIS

W = WATER8 Model (EPA/453/C-94/080C)

E = USEPA 1996 Soil Screening Guidance (EPA/540/R-95/128)

C = See Appendix C: Technical Basis for the TRPH SCTLs

Notes:

Except as noted otherwise, H values are from SCDM: Superfund Chemical Data Matrix (EPA/540/R-96/028), June 1996, selected in the same order of preference as outlined in the SCDM.

Koc geometric mean values are from EPA Soil Screening Guidance: Technical Background Document (EPA/540/R-95/128), May 1996. Values selected from Tables 38 and 39 with preference for the geometric mean over the calculated value.

*VFs for residential SCTLs based on exposure duration of 30 years for carcinogens and 6 years for non-carcinogens.

Table 3b. Groundwater Cleanup Target Levels

Chemical Name	CAS #	Carcinogen	Groundwater Target Levels GCTL (ug/L)		Freshwater Surface Water GCTL (ug/L)	Marine Surface Water Protection GCTL (ug/L)	Low Yield/Poor Quality Aquifer GCTL (ug/L)
METALS:							
arsenic	7440-38-2	yes	50	S	50	50	500
barium	7440-39-3		2000	S	2000	*b*	20000
cadmium*	7440-43-9	yes	5	S	*a*	0.3	515
chromium	18540-29-9	yes	100	S	*a*	50	1000
lead	7439-92-1		15	S	*a*	5.6	150
mercury	7438-97-6		2	S	0.012	0.025	20
selenium	7782-49-2		50	S	5	71	500
silver	7440-22-4		100	S	0.07	0.35	1000
PAHs:							
acenaphthene	83-32-9		20	G	3	3	200
acenaphthylene	208-96-8		210	A	0.031	0.031	2100
anthracene	120-12-7		2100	G	0.3	0.3	21000
benzo(a)anthracene	56-55-3	yes	0.2	A	0.031	0.031	2
benzo(a)pyrene	50-32-8	yes	0.2	S	0.031	0.031	2
benzo(b)fluoranthene	205-99-2	yes	0.2	A	0.031	0.031	2
benzo(g,h,i)perylene	191-24-2		210	A	0.031	0.031	2100
benzo(k)fluoranthene	207-08-9	yes	0.5	A	0.031	0.031	5
chrysene	218-01-9	yes	5	G	0.031	0.031	50
dibenzo(a,h)anthracene	53-70-3	yes	0.2	A	0.031	0.031	2
fluoranthene	206-44-0		280	G	0.2	0.2	2800
fluorene	86-73-7		280	G	30	30	2800
indeno(1,2,3-cd)pyrene	193-39-5	yes	0.2	A	0.031	0.031	2
naphthalene	91-20-3		20	A	20	26	200
phenanthrene	85-01-8		210	A	0.031	0.031	2100
pyrene	129-00-0		210	G	0.3	0.3	2100
BETX:							
benzene	71-43-2	yes	1	S	1	71	10
ethylbenzene	100-41-4		30	S*	30	605	300
toluene	108-88-3		40	S*	40	475	400
xylenes	1330-20-7		20	S*	20	370	200
OTHER:							
TRPHs			5000	☆	5000	5000	50000
dichloroethane, 1,2-	107-06-2	yes	3	S	3	127	30
methyl tert-butyl ether	1634-04-4		35	A	35	33600	350

GCTLs for other chemicals can be found in Chapters 62-550 and 62-520, F.A.C.

* Although cadmium is a carcinogen the Florida SCTL is based on the more conservative non-carcinogen endpoint.

a = Hardness-dependent per Chapter 62-302, F.A.C. **b** = Not greater than 10% above background.

G = Florida Department of Environmental Protection Groundwater Guidance Concentration.

S = Florida Department of Environmental Protection Groundwater Standard.

S* = Florida Department of Environmental Protection Secondary Groundwater Standard.

A = Alternative value (based on additional toxicity information, analytical capabilities, or organoleptic properties; see Table 5).

☆ = Value set by Florida Department of Environmental Protection for use in Chapter 62-770, F.A.C.

Table 4. Sources and Derivation of Toxicity Values Used in Calculations

Chemical Name	GI Absorption	SFo (mg/kg/day)$^{-1}$	Tox Value Source	SFi (mg/kg/day)$^{-1}$	Tox Value Source	SFd (mg/kg/day)$^{-1}$	Tox Value Source
arsenic	0.95	1.5E+00	IRIS	1.5E+01	REG III	1.6E+00	extrapolated
benzene	0.9	2.9E-02	IRIS	2.9E-02	IRIS	3.2E-02	extrapolated
benzo(a)anthracene	0.5	7.3E-01	USEPA 93 TEF	6.1E-01	REG III	1.5E+00	extrapolated
benzo(a)pyrene	0.5	7.3E+00	IRIS	6.1E+00	REG III (WD)	1.5E+01	extrapolated
benzo(b)fluoranthene	0.5	7.3E-01	USEPA 93 TEF	6.1E-01	REG III	1.5E+00	extrapolated
benzo(k)fluoranthene	0.5	7.3E-02	USEPA 93 TEF	6.1E-02	REG III	1.5E-01	extrapolated
chromium (hexavalent)	0.013	n/a		4.2E+01	IRIS	n/a	
chrysene	0.5	7.3E-03	USEPA 93 TEF	6.1E-03	REG III	1.5E-02	extrapolated
dibenzo(a,h)anthracene	0.5	7.3E+00	USEPA 93 TEF	6.1E+00	REG III	1.5E+01	extrapolated
dichloroethane, 1,2-	1.0	9.1E-02	IRIS	9.1E-02	IRIS	9.1E-02	extrapolated
indeno(1,2,3-cd)pyrene	0.5	7.3E-01	USEPA 93 TEF	6.1E-01	REG III	1.5E+00	extrapolated

Chemical Name	GI Absorption	RfDo (mg/kg/day)	Tox Value Source	RfDi (mg/kg/day)	Tox Value Source	RfDd (mg/kg/day)	Tox Value Source
acenaphthene	0.5	6.0E-02	IRIS	3.0E-02	extrapolated	3.0E-02	extrapolated
acenaphthylene	0.5	3.0E-02	Surrogate	1.5E-02	extrapolated	1.5E-02	extrapolated
anthracene	0.5	3.0E-01	IRIS	1.5E-01	extrapolated	1.5E-01	extrapolated
arsenic	0.95	3.0E-04	IRIS	2.9E-04	extrapolated	2.9E-04	extrapolated
barium	0.05	7.0E-02	IRIS	1.4E-04	extrapolated*	3.5E-03	extrapolated
				RfC 5.0E-04 (HEAST)			
benzene	0.9	n/a		1.7E-03	REG III	n/a	
benzo(g,h,i)perylene	0.5	3.0E-02	Surrogate	1.5E-02	extrapolated	1.5E-02	extrapolated
cadmium	0.044	1.0E-03	IRIS	5.7E-05	REG III (WD)	4.4E-05	extrapolated
chromium (hexavalent)	0.013	5.0E-03	IRIS	6.5E-05	extrapolated	6.5E-05	extrapolated
dichloroethane, 1,2-	1	n/a		2.9E-03	REG III	n/a	
ethylbenzene	1.0	1.0E-01	IRIS	2.9E-01	extrapolated*	1.0E-01	extrapolated
				RfC 1.0 (HEAST)			
fluoranthene	0.5	4.0E-02	IRIS	2.0E-02	extrapolated	2.0E-02	extrapolated
fluorene	0.5	4.0E-02	IRIS	2.0E-02	extrapolated	2.0E-02	extrapolated
lead	n/a	n/a	n/a	n/a	n/a	n/a	n/a
mercury	0.1	3.0E-04	IRIS	8.6E-05	extrapolated*	3.0E-05	extrapolated
				RfC 3.0E-04 (HEAST)			
methyl tert-butyl ether	1.0	5.0E-03	REG III	8.6E-01	REG III	5.0E-03	extrapolated
naphthalene	1.0	4.0E-02	HEAST (WD)	4.0E-02	extrapolated	4.0E-02	extrapolated
phenanthrene	0.5	3.0E-02	Surrogate	1.5E-02	extrapolated	1.5E-02	extrapolated
pyrene	0.5	3.0E-02	IRIS	1.5E-02	extrapolated	1.5E-02	extrapolated
selenium	0.97	5.0E-03	IRIS	4.9E-03	extrapolated	4.9E-03	extrapolated
silver	0.2	5.0E-03	IRIS	1.0E-03	extrapolated	1.0E-03	extrapolated
toluene	1.0	2.0E-01	IRIS	1.1E-01	extrapolated*	2.0E-01	extrapolated
				RfC 0.4 (HEAST)			
TRPHs	0.5	(See Appendix C: Technical Basis for the TRPH Soil Cleanup Target Levels)					
xylenes, total	0.895	2.0E+00	IRIS	1.8E+00	extrapolated	1.8E+00	extrapolated

*These values were extrapolated from inhalation reference concentrations.
HEAST: Health Effects Assessment Summary Tables.
IRIS: Integrated Risk Information System.
REG III: USEPA Region III Risk-Based Concentration Table.
Surrogate: Surrogate RfD based on other non-carcinogenic PAHs (e.g., pyrene).
USEPA 93 TEF: USEPA *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons* (EPA/600/R-93/089).
n/a: not applicable
WD = withdrawn

Table 5. Basis for Groundwater Cleanup Target Levels

Chemical	Class	GCTL (µg/L)	PQL (µg/L)	Support for Groundwater Cleanup Target Levels	Reference
acenaphthylene	systemic toxicant (D)	210	4.0	Value reflects RfD of 0.03 mg/kg/day, calculated GCTL = 210	Surrogate
benzo(a)anthracene	carcinogen (B2)	0.2	0.2	Based on carcinogenicity; currently, the best available PQL is 0.2, and therefore the GCTL is 0.2	FDEP
benzo(b)fluoranthene	carcinogen (B2)	0.2	0.2	Based on carcinogenicity; currently, the best available PQL is 0.2, and therefore the GCTL is 0.2	FDEP
benzo(g,h,i)perylene	systemic toxicant (D)	210	0.2	Value reflects RfD of 0.03 mg/kg/day, calculated GCTL = 210	Surrogate
benzo(k)fluoranthene	carcinogen (B2)	0.5	0.2	Based on carcinogenicity, using an oral SF of 0.073 mg/kg/day^{-1}, the GCTL = 0.5 and currently the best available PQL is 0.2	USEPA 93 TEF
dibenzo(a,h)anthracene	carcinogen (B2)	0.2	0.2	Based on carcinogenicity; currently, the best available PQL is 0.2, and therefore the GCTL is 0.2	FDEP
indeno(1,2,3-cd)pyrene	carcinogen (B2)	0.2	0.2	Based on carcinogenicity; currently, the best available PQL is 0.2, and therefore the GCTL is 0.2	FDEP
naphthalene	organoleptic (D)	20	0.2	Value based on organoleptic criteria	Amoore & Hautala, 1983
phenanthrene	systemic toxicant (D)	210	4.0	Value reflects RfD of 0.03 mg/kg/day, calculated GCTL = 210	Surrogate
methyl tert-butyl ether	systemic toxicant[a]	35	10	Value reflects RfD of 0.005 mg/kg/day, calculated GCTL = 35	REG III
ethylbenzene	secondary standard[b]	30	4.0	GCTL value based on Secondary Standard	GWGC
toluene	secondary standard[b]	40	4.0	GCTL value based on Secondary Standard	GWGC
xylenes, total	secondary standard[b]	20	4.0	GCTL value based on Secondary Standard	GWGC

[a] No IRIS-designated carcinogenicity class.
[b] Chapter 62-520, F.A.C., Ground Water Classes, Standards, and Exemptions, designates the primary and secondary drinking water standards as enforceable groundwater standards with secondary standards relating to the organoleptic or other undesirable properties of groundwater.

References:

Amoore, J. and Hautala, E. (1983). Odor as an Aid to Chemical Safety: Odor thresholds compared with threshold limit values and volatilities for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology 3:272-279.

FDEP: Florida Department of Environmental Protection, Bureau of Petroleum Storage Systems, Tallahassee, Florida.

GWGC: Florida Department of Environmental Protection, Bureau of Drinking Water and Ground Water Resources, Ground Water Guidance Concentrations, June 1994.

REG III: USEPA Region III Risked-Based Concentration Table, April 1996.

Surrogate: Surrogate RfD based on other non-carcinogenic PAH's RfDs (i.e., pyrene).

USEPA 93 TEF: USEPA Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons (EPA/600/R-93/089).

Appendix A

Derivation of Inhalation Rates and

Dermal Surface Areas

A. Derivation of an Inhalation Rate (m^3/day) for an Aggregate Resident

The Exposure Factors Handbook (USEPA, 1989b) provided inhalation rates (L/min) for all activity levels listed in the following categories: 6, 10, and 13 year old males, an adult female and an adult male (Table A1) and provided the amount of time spent at each activity level (found on pages 3-8 of USEPA, 1989b) (Table A2).

Table A1:
Minute Inhalation (L/min) by Activity Level

Activity Level	Infant	Male 6yr	Male 10yr	Male 13yr	Female Adult	Male Adult
Resting	0.84	6.5	7.1	8.9	5.7	12.2
Light	-	13.9	17.2	16.4	8.1	13.8
Moderate	-	33.3	53.4	32.8	26.5	40.9
Heavy	-	40.3	70.5	57.9	47.9	80.0

Table A2:
Percent Time at Activity Level

	Outdoor		*Indoor*	
Activity Level	**Average**	**RME**	**Average**	**RME**
Resting	.28	0	.48	.25
Light	.28	0	.48	.60
Moderate	.37	.50	.03	.10
Heavy	.07	.50	.01	.05

RME = Reasonable Maximum Exposure

Using the values above, minute inhalation rates (L/min) were converted to daily inhalation rates (m^3/day) with the equation below. These values are listed in Table 3.

$$m^3/day = L/min * 60\ min/hr * 24\ hr/day * 1\ cm^3/mL * 1000\ mL/L * 1E\text{-}06\ m^3/cm^3$$

Table A3:
Inhalation Rates (m^3/day)

Activity Level	Infant	Male 6yr	Male 10yr	Male 13yr	Female Adult	Male Adult
Resting	1.21	9.36	10.22	12.82	8.21	17.57
Light	-	20.02	24.77	23.62	11.66	19.87
Moderate	-	47.95	76.90	47.23	38.16	58.90
Heavy	-	58.03	101.52	83.38	68.98	115.20

Indoor and outdoor daily inhalation rates (presented in Table A4) were calculated for each receptor using the average values for percent of time spent at each activity level (Table A2).

Daily Inhalation Rate (m^3/day) = (% of time spent resting*resting inhalation rate) +
+ (% of time spent in light activity*light inhalation rate) +
+ (% of time spent in moderate activity*moderate inhalation rate) +
+ (% of time spent in heavy activity*heavy inhalation rate)

Table A4:
Daily Inhalation Rates (m^3/day) for Each Age Level

	Infant	Male 6yr	Male 10yr	Male 13yr	Female Adult	Male Adult
Average						
Outdoor	0.34	30.03	45.36	33.51	24.51	40.34
Indoor	0.58	16.12	20.12	19.74	11.37	20.89
RME						
Outdoor	0.51*	52.99	89.21	65.30	53.57	87.05
Indoor	1*	22.05	30.18	26.26	16.32	27.96

* Information is not presented in the Exposure Factors Handbook for light, moderate, or heavy inhalation rates for infants. Using only the resting inhalation rate of 1.21 m^3/day (Table A3) to calculate the outdoor and indoor RME inhalation rates results in "worst case" values that are less than "average" values. Therefore, an alternative method was used to calculate the infant indoor and outdoor RME inhalation rates. The ratio between the "average outdoor" and the "RME outdoor" for each of the other age groups was calculated and then the mean of these ratios was multiplied by the infant outdoor "average" inhalation rate to derive an estimated outdoor "RME" inhalation rate. For example, the mean ratio of RME/average for outdoor values is 1.5, so 0.34 x 1.5 = 0.51 is the estimated RME outdoor-infant daily inhalation rate. The same method was used with the indoor values to derive an estimated indoor "RME" inhalation rate.

To calculate an inhalation rate for an aggregate resident, an exposure duration of 30 years was assumed. Due to the limited data, it was assumed that a person spends four years each at the infant, 6 year old, 10 year old, and 13 year old inhalation rates. The remaining 14 years are spent at the adult inhalation rate. Indoor and outdoor average inhalation rates for an aggregate resident (Table A5) were calculated using the following equation:

$$\text{Indoor or Outdoor Inhalation Rate } (m^3/day) =$$

$$= [(4\ yr * \text{Infant IR } (m^3/day)) + (4\ yr * \text{6 yr old IR } (m^3/day)) +$$
$$+ (4\ yr * \text{10 yr old IR } (m^3/day)) + (4\ yr * \text{13 yr old IR } (m^3/day)) +$$
$$+ (14\ yr * \{(\text{Adult Male IR } (m^3/day) + \text{Adult Female IR } (m^3/day))/2\})]/30\ yrs$$

The average person is estimated to spend 3.07 hours per week outside (page 1-21, USEPA, 1989b). This value is equal to 0.44 hours per day. Therefore, the average time spent inside is 23.56 hours per day. Using these assumptions, total (includes indoor and outdoor) average inhalation rates for the aggregate resident (Table A5) were calculated using the following equation:

$$\text{Aggregate Resident Total Inhalation Rate } (m^3/day) =$$

$$= \frac{[(\text{Outdoor IR } m^3/day * 0.44\ hr/day) + (\text{Indoor IR } m^3/day * 23.56\ hr/day)]}{24\ hr/day}$$

Table A5:
Inhalation Rates for an Aggregate Resident

	Inhalation Rate (m^3/day)
AVERAGE	
Outdoor	29.70
Indoor	15.07
Total (In + Out)	15.34*
RME	
Outdoor	60.54
Indoor	20.93
Total (In + Out)	21.66

*The aggregate resident inhalation rate used to calculate the SCTL is rounded to 15 m^3/day.

B. Derivation of a Dermal Surface Area for the Aggregate Resident

Values presented in the Exposure Factors Handbook (USEPA, 1989b) were used to calculate the surface area available for dermal exposure of an aggregate resident. Median total body surface areas for children are presented in Table A6, with the exception for children under two, for which values are unavailable. The percentage of total body surface area by part for children is presented in Table A7.

Table A6:
Median Total Body Surface Area (cm^2)

Surface Area (cm^2)			
Age (yr)	Male	Female	Average
2 < 3	6030	5790	5910
3 < 6	7280	7110	7195
6 < 9	9310	9190	9250
9 < 12	11600	11600	11600
12 < 15	14900	14800	14850
15 < 18	17500	16000	16750

Table A7:
Percentage of Total Body Surface Area by Part for Children

Percent of Total Body Surface Area (%)						
Age	Head	Trunk	Arms	Hands	Legs	Feet
< 1	18.20	35.70	13.70	5.30	20.60	6.54
1 < 2	16.50	35.50	13.00	5.68	23.10	6.27
2 < 3	14.20	38.50	11.80	5.30	23.20	7.07
3 < 4	13.60	31.90	14.40	6.07	26.80	7.21
4 < 5	13.80	31.50	14.00	5.70	27.80	7.29
6 < 7	13.10	35.10	13.10	4.71	27.10	6.90
9 < 10	12.00	34.20	12.30	5.30	28.70	7.58
12 < 13	8.74	34.70	13.70	5.39	30.50	7.03
13 < 14	9.97	32.70	12.10	5.11	32.00	8.02
16 < 17	7.96	32.70	13.10	5.68	33.60	6.93
17 < 18	7.58	31.70	17.50	5.13	30.80	7.28

Body surface areas by part for children (Table A8) were calculated using the following equation:

Surface Area (cm^2) = Total body surface area (cm^2) x
x % of Total body surface area for the body part

It was assumed that an aggregate resident would have his hands, half of his arms, and half of his legs available for dermal exposure. Using this assumption, a total surface area was calculated for each age group using the following equation (Table A8):

Total Surface Area (cm^2) = Hands SA (cm^2) + [(Arms SA + Legs SA (cm^2))/2]

Table A8:
Body Surface Area by Part for Children

	Body Surface Area (cm^2)						
Age	**Head**	**Trunk**	**Arms**	**Hands**	**Legs**	**Feet**	**Available SA***
2 < 3	839	2275	697	313	1371	418	1347
3 < 4	979	2295	1036	437	1928	519	1919
4 < 5	993	2266	1007	410	2000	525	1914
6 < 7	1212	3247	1212	436	2507	638	2295
9 < 10	1392	3967	1427	615	3329	879	2993
12 < 13	1298	5153	2034	800	4529	1044	4082
13 < 14	1481	4856	1797	759	4752	1191	4034
16 < 17	1333	5477	2194	951	5628	1161	4862
17 < 18	1270	5310	2931	859	5159	1219	4904

*Assume exposed surface area of 1/2 of arms, 1/2 of legs, and hands

Available Child (age 1-6) SA* (cm^2) = 1789 = 1800**

**Child Surface Area rounded to two significant figures

Surface area by body part and total surface areas for adults are presented in Table A9. The adult surface area available for dermal exposure was calculated using the same equation used for the child.

Table A9: Surface Area by Body Part for Adults

	Surface Area (cm^2)		
Body Part	Men	Women	Average
Head	1180	1100	1140
Trunk	5690	5420	5555
Upper Extremities	3190	2760	2975
Arms	2280	2100	2190
Upper Arms	1430	-	1430
Forearms	1140	-	1140
Hands	840	746	793
Lower Extremities	6360	6260	6310
Legs	5050	4880	4965
Thighs	1980	2580	2280
Lower Legs	2070	1940	2005
Feet	1120	975	1048
Total	**19400**	**16900**	**18150**

Available Adult SA* (cm^2) = 4371

*Assume exposed surface area of 1/2 of arms, 1/2 of legs, and hands

The aggregate resident surface area available for dermal exposure was calculated using the following equation:

$$\text{Aggregate Resident Surface Area } (cm^2) =$$
$$= [(2 \text{ yr} * 2<3 \text{ yr old SA } cm^2) + (1 \text{ yr} * 3<4 \text{ yr old SA } cm^2) +$$
$$+ (2 \text{ yr} * 4<5 \text{ yr old SA } cm^2) + (2 \text{ yr} * 6<7 \text{ yr old SA } cm^2) +$$
$$+ (3 \text{ yr} * 9<10 \text{ yr old SA } cm^2) + (2 \text{ yr} * 12<13 \text{ yr old SA } cm^2) +$$
$$+ (2 \text{ yr} * 13<14 \text{ yr old SA } cm^2) + (2 \text{ yr} * 16<17 \text{ yr old SA } cm^2) +$$
$$+ (2 \text{ yr} * 17<18 \text{ yr old SA } cm^2) + (12 \text{ yr} * \text{Adult SA } cm^2)] * 1/30 \text{ yr}$$

No specific age group data are presented in the Exposure Factors Handbook for children at ages 1, 5, 7, 8, 10, 11, 14, 15, and 18 years. Therefore, the surface area information for these ages was alternately taken from either the next previous or following age group. The age ranges applied as factors in the above equation are shown in the table below. The numbers in parentheses under the "age" column represents the age of a person with a particular surface area. The age range in each group corresponds to years spent with a specific surface area ("years" column), which is then multiplied by the corresponding available surface area. For example, there is no information for 1 yr-olds, so the SA value for 2 yr-olds from the Exposure Factors Handbook is assumed to apply to both 1 and 2 year-olds. Since this value is applicable for two years (out of 30 total), the SA value of 2186 is multiplied by 2. The alternate assignment of ages without SA values to higher and lower age groups is intended to minimize biasing the surface area estimate either high or low.

Table A10:
Aggregate Surface Area

Age	Years	Available SA (cm^2)*
2 < 3 (1-2)	2	1347
3 < 4 (3)	1	1919
4 < 5 (4-5)	2	1914
6 < 7 (6-7)	2	2295
9 < 10 (8-10)	3	2993
12 < 13 (11-12)	2	4082
13 < 14 (13-14)	2	4034
16 < 17 (15-16)	2	4862
17 < 18 (17-18)	2	4904
Adult: 19 < 30 (19 - 30)	12	4371

Aggregate SA =	3674

*Assume exposed surface area of

Appendix B

Derivation of Inhalation and Dermal Toxicity Values

A. Inhalation Toxicity Values

For evaluating hazard from the inhalation of a chemical of concern, the USEPA develops toxicity values in the form of Reference Doses (RfDs) or Reference Concentrations (RfCs). While the USEPA has recently shown preference for RfCs, the equations for the methods described in this report use RfDs exclusively. The reason for this decision is that it is well recognized that children have much higher ventilation rates relative to body weight than adults. Consequently, they will receive a higher dosage of a chemical of concern from air than an adult at the same air concentration. The use of RfDs allows this difference to be taken into consideration, whereas the use of RfCs involves the implicit assumption that adults and children are equally sensitive to contamination in air. For the same reason, the equation for carcinogenicity utilizes Inhalation Slope Factors (ISFs) rather than Inhalation Unit Risk (IUR) values (which are expressed as recognized air concentrations).

1.) Reference Dose (RfD)

The first choice, when an inhalation RfD was not available, was to develop one from the RfC for that chemical. The conversion from RfC to inhalation RfD assumed a 70 kg individual breathing 20 m^3/day. Thus, the RfC was multiplied by 20 m^3/day and divided by 70 kg to obtain a value with the units mg/kg/day.

e.g., Methyl *tert*-butyl ether: Inhalation RfC = 3 mg/m^3

thus, (3 mg/m^3 x 20 m^3/day) / 70 kg = 8.6×10^{-1} mg/kg/day = RfD_i

When an RfC was not available, the second choice was to develop an inhalation RfD from the oral RfD using route-to-route extrapolation. Such extrapolation was only done when the toxic endpoint being addressed was systemic in nature. Oral RfDs that were known or likely to be route-specific (e.g., where the toxic endpoint involved the gastrointestinal tract) were not extrapolated.

The formula for converting an oral RfD to an inhalation RfD was as follows:

$$RfD_i = RfD_o \times GI\ Absorption$$

e.g., Anthracene: $RfD_o = 3.0 \times 10^{-1}$ mg/kg/day
GI Abs = 0.5

thus, (3.0×10^{-1} mg/kg/day) x (0.5) = 1.5×10^{-1} mg/kg/day

2.) Slope Factor (SF)

When a carcinogen had an inhalation unit risk (IUR) value, but not an inhalation slope factor (ISF), the IUR value was converted to an ISF for the calculation of a soil target level. The conversion assumes a 70 kg individual breathing 20 m^3/day. Thus, the IUR (Unit Risk/µg/m^3) is divided by 20 m^3/day and multiplied by 70 kg and a conversion factor of 1000 µg/mg to obtain a value with the units $(mg/kg/day)^{-1}$.

e.g., Benzene: IUR = 8.3×10^{-6} UR/µg/m^3

thus, [((8.3×10^{-6} UR/µg/m^3) / 20m^3/day) x 70 kg x 1000 µg/mg] =
= 2.9×10^{-2} $(mg/kg/day)^{-1}$= ISF

If an IUR was not available and the chemical was regarded as likely producing carcinogenicity via a systemic effect, an ISF was derived from the oral slope factor (OSF), if available. This route-to-route extrapolation was accomplished by using the following formula:

ISF = OSF / GI Absorption

In general, route-to-route extrapolation from the OSF was not performed if the OSF was known or presumed to reflect route-specific toxicity. When a chemical exhibits route-specific toxicity, it exerts its toxic effect (i.e., cancer) only by a specific exposure route. For example, chromium only causes lung cancer if it is inhaled, thus the toxic effect (lung cancer) is route-specific and target organ-specific. No other exposure route for chromium has been shown to cause cancer.

B. Dermal Toxicity Values

1.) Reference Dose (RfD)

Dermal RfDs were derived from either the oral or inhalation RfD (if both were available and suitable, preference was given to the oral RfD). The following formula was used:

$$RfD_d = RfD_o \times GI\ Absorption$$

If an RfD (either oral or inhalation) was known or presumed to be route-specific, it was not regarded as suitable for route-to-route extrapolation.

2.) Slope Factor (SF)

Dermal slope factors (DSFs) were derived from OSFs using route-to-route extrapolation:

$$DSF = OSF \,/\, GI\ Absorption$$

e.g., Benzene: OSF = 2.9×10^{-2} $(mg/kg/day)^{-1}$
GI Abs = 0.9

thus, $(2.9 \times 10^{-2}\ (mg/kg/day)^{-1}) \div (0.9) =$
$= 3.2 \times 10^{-2}\ (mg/kg/day)^{-1} = DSF$

In general, OSFs were not extrapolated to produce DSFs if they were thought to reflect route-specific toxicity.*

* In the case of carcinogenic PAHs the toxic endpoint (cancer) occurs regardless of the route of exposure. This effect is clearly evidenced by the fact that while the OSF for benzo(a)pyrene is based on data in which oral dosing resulted in GI tract tumors in rodents, arguably a route-specific cancer, benzo(a)pyrene has also been observed to produce other types of cancer in several species when administered by a variety of routes, including inhalation and dermal contact. Although no slope factor has yet been derived for these routes, the rather strong evidence that benzo(a)pyrene (and, by implication, other carcinogenic PAHs) is carcinogenic by a variety of routes, indicates that PAH induced cancer is not wholly route-specific. Because of this property, route-to-route extrapolation was performed to derive both inhalation and dermal slope factors from the OSF for this group of chemicals.

Appendix C

Technical Basis for the TRPH

Soil Cleanup Target Levels

Technical Basis for the TRPH Soil Cleanup Target Levels

The following calculations for total petroleum hydrocarbon (TRPH) values were adopted essentially as described in the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG, 1997a, 1997b, and 1997c; Volumes III and IV, and the Technical Overview).

The application of a general standard for TRPHs is difficult because of the variation in mobility and toxicity of the chemicals included. To overcome this problem, TPHCWG (1997a) suggests a sub-classification methodology in which aromatics and aliphatics are considered separately because these groups vary considerably in their environmental behavior. Each of these groups was then further subdivided on the basis of equivalent carbon number index (EC). The EC is a function of the molecular weight (MW) and boiling point (BP) of a chemical normalized to the BP of the n-alkanes, or its retention time in a BP gas chromatographic column. This approach is used since it is consistent with methods routinely used in the petroleum industry for separating complex mixtures and is a more appropriate differentiation technique than the actual carbon number of the chemical.

Range of Equivalent Carbon Number, EC	EC	Classification
C_5-C_7	6.5	Aromatic
>C_7-C_8	7.5	Aromatic
>C_8-C_{10}	9.0	Aromatic
>C_{10}-C_{12}	11	Aromatic
>C_{12}-C_{16}	14	Aromatic
>C_{16}-C_{21}	18.5	Aromatic
>C_{21}-C_{35}	28	Aromatic
C_5-C_6	5.5	Aliphatic
>C_6-C_8	7.0	Aliphatic
>C_8-C_{10}	9.0	Aliphatic
>C_{10}- C_{12}	11	Aliphatic
>C_{12}- C_{16}	14	Aliphatic
>C_{16}- C_{35}	18.5	Aliphatic

Calculation of TRPH Fraction-Specific Physical Properties

Several alternatives for estimating representative physical/chemical properties for each fraction were reviewed by the TPHCWG. They included simple averaging of all available property data, composition-based averaging in which a weighted average of the available property data was computed based on the relative mass of each component in gasoline, and correlation to relative boiling point index in which the properties were developed based on EC values. While all of the approaches had similar results, it was determined that the correlations approach was most useful, because if the definition of the fractions change, new properties can be easily computed.

Utilizing the values correlations approach, the TRPHs are grouped into EC fractions, a method which allows for the calculation of the fate and transport characteristics of solubility (S), organic carbon partition coefficient (Koc) and vapor pressure (atm). While Henry's Law constant (HLC) could also be estimated from a similar type of equation, TPHCWG determined that using the estimated molecular weights, solubilities and vapor pressures to calculate HLC allowed for internal consistency with the other estimated values. The formulas provided by TPHCWG (1997a) are as follows:

Aromatics:

$$\text{Log S} = (-0.21 \times \text{EC}) + 3.7$$
$$\text{Log Koc} = (0.10 \times \text{EC}) + 2.3$$

Aliphatics:

$$\text{Log S} = (-0.55 \times \text{EC}) + 4.58$$
$$\text{Log Koc} = (0.45 \times \text{EC}) + 0.43$$

Aliphatics and Aromatics

$$\text{Log VP} = (-0.5 \times \text{EC}) + 2.3, \text{ for EC} \leq 12$$
$$\text{Log VP} = (-0.36 \times \text{EC}) + 0.72, \text{ for EC} > 12$$

$$\text{H (unitless)}^* = \frac{\text{Vapor Pressure (atm)} \times \text{Molecular Weight (g/mol)}}{\text{Solubility (mg/L)} \times 8.2\text{x}10^{-5}\ (\text{atm-m}^3/\text{mol-K}) \times 293\text{K}}$$

H (unitless)/41 = Henry's Law constant (atm-m^3/mol)*
(*rounded to two significant figures)

When diffusivity in air or water was plotted as a function of equivalent carbon number, TPHCWG found that the values did not vary significantly from compound to compound. Thus, a conservative, reasonable assumption was to set $D_{air} = 10^{-1}$ cm^2/sec and $D_{water} = 10^{-5}$ cm^2/sec for all fractions.

Using the above models, the following chemical values for the TRPH classes have been assigned:

Table C1:
Assigned chemical properties of TRPH classes based on an Equivalent Carbon Number[a]

TRPH Class	Ave. EC	Proposed Value					
		H(atm-m^3/mol)[b]	H'	MW(g)	K_{oc} (mL/g)	S (mg/L)	VP(atm)
C_5-C_7 Aromatic	6.5	5.6E-3	NC	NC	NC	NC	NC
>C_7-C_8 Aromatic	7.5	6.6E-3	NC	NC	NC	NC	NC
>C_8-C_{10} Aromatic	9.0	1.2E-2	4.8E-1	1.2E+2	1.6E+3	6.5E+1	6.3E-3
>C_{10}-C_{12} Aromatic	11	3.3E-3	1.4E-1	1.3E+2	2.5E+3	2.5E+1	6.3E-4
>C_{12}-C_{16} Aromatic	14	1.3E-3	5.2E-2	1.5E+2	5.0E+3	5.8E00	4.8E-5
>C_{16}-C_{21} Aromatic	18.5	3.2E-4	1.3E-2	1.8E+2	1.4E+4	6.5E-1	1.1E-6
>C_{21}-C_{35} Aromatic	28	1.6E-5	6.7E-4	2.4E+2	1.3E+5	6.6E-3	4.4E-10

TRPH Class	Ave. EC	Proposed Value					
		H(atm-m^3/mol)[b]	H'	MW(g)	K_{oc} (mL/g)	S (mg/L)	VP(atm)
C_5-C_6 Aliphatic	5.5	8.0E-1	3.3E+1	8.1E+1	8.0E+2	3.6E+1	3.5E-1
>C_6-C_8 Aliphatic	7.0	1.2E00	4.9E+1	1.0E+2	3.8E+3	5.4E00	6.3E-2
>C_8-C_{10} Aliphatic	9.0	1.9E00	7.9E+1	1.3E+2	3.0E+4	4.3E-1	6.3E-3
>C_{10}-C_{12} Aliphatic	11	3.0E00	1.2E+2	1.6E+2	2.4E+5	3.4E-2	6.3E-4
>C_{12}-C_{16} Aliphatic	14	1.3E+1	5.3E+2	2.0E+2	5.4E+6	7.6E-4	4.8E-5
>C_{16}-C_{35} Aliphatic	18.5	1.2E+2	4.9E+3	2.7E+2	5.7E+8	2.5E-6	1.1E-6

NC: Values for the C_5-C_7 and >C_7-C_8 aromatics, which correspond to benzene and toluene, were not calculated according to the TPHCWG methods. Chemical-specific values for these fractions were assumed to be equal to those of benzene and toluene, thus the K_{oc} and H values from Table 3a of the Technical Report were used.

[a] Solubility (mg/L), Vapor Pressure (atm), and K_{oc} (mL/g) values calculated according to formulas in Tables 7, 9, and 12 of TPHCWG 1997a. H' (unitless) was calculated according to the formula presented above.

[b] Henry's Law constant calculated using methods described above. Final values rounded to two significant figures.

Table C2:
Calculated chemical properties of TRPH classes

TRPH Class	Calculated Fraction-Specific Values*		
	D_a (cm^2/sec)	Volatilization Factor** (m^3/kg)	
		Residential	Industrial
C_5-C_7 Aromatic	2.373206E-3	1.427839E+3	2.914565E+3
>C_7-C_8 Aromatic	1.454501E-3	1.823853E+3	3.722925E+3
>C_8-C_{10} Aromatic	2.676664E-4	4.251577E+3	8.678495E+3
>C_{10}-C_{12} Aromatic	4.766102E-5	1.007547E+4	2.056647E+4
>C_{12}-C_{16} Aromatic	9.433057E-6	2.264753E+4	4.622907E+4
>C_{16}-C_{21} Aromatic	8.318777E-7	7.626359E+4	1.556724E+5
>C_{21}-C_{35} Aromatic	4.561537E-9	1.029891E+6	2.102257E+6
C_5-C_6 Aliphatic	1.572995E-2	5.546045E+2	1.132082E+3
>C_6-C_8 Aliphatic	8.136944E-3	7.711100E+2	1.574022E+3
>C_8-C_{10} Aliphatic	2.136944E-3	1.507145E+3	3.076447E+3
>C_{10}-C_{12} Aliphatic	4.478028E-4	3.287029E+3	6.709621E+3
>C_{12}-C_{16} Aliphatic	8.737169E-5	7.441520E+3	1.518994E+4
>C_{16}-C_{35} Aliphatic	7.662332E-6	2.512850E+4	5.129333E+4

*All calculations carried out to 18 decimal places. Values provided have been rounded to seven significant figures for presentation in this table.

**For residential exposure to non-carcinogens, VFs are based on an exposure duration of six years. Industrial exposure duration is 25 years.

Derivation of TRPH Fraction Toxicological Values

The toxicity values for the various TRPH fractions were obtained from TPHCWG (1997c) and are as follows:

Table C3:
Toxicity Values of TRPH Classes[a]

TRPH Class	RfD_o (mg/kg-day)	RfD_d (mg/kg-day)[b]	RfC_i (mg/m^3)	RfD_i (mg/kg-day)[c]
C_5-C_7 Aromatic	0.2	0.1	0.4	0.1
>C_7-C_8 Aromatic	0.2	0.1	0.4	0.1
>C_8-C_{10} Aromatic	0.04	0.02	0.2	0.06
>C_{10}-C_{12} Aromatic	0.04	0.02	0.2	0.06
>C_{12}-C_{16} Aromatic	0.04	0.02	0.2	0.06
>C_{16}-C_{21} Aromatic	0.03	0.02	not available	0.02[d]
>C_{21}-C_{35} Aromatic	0.03	0.02	not available	0.02[d]
C_5-C_6 Aliphatic	5.0	3.0	18.4	5.0
>C_6-C_8 Aliphatic	5.0	3.0	18.4	5.0
>C_8-C_{10} Aliphatic	0.1	0.05	1.0	0.3
>C_{10}-C_{12} Aliphatic	0.1	0.05	1.0	0.3
>C_{12}-C_{16} Aliphatic	0.1	0.05	1.0	0.3
>C_{16}-C_{35} Aliphatic	2.0	1.0	not available	1.0[d]

[a] Toxicity Values from TPHCWG 1997c.
[b] RfDd values extrapolated, GI absorption assumed to be 0.5 (see Appendix B).
[c] RfDi values extrapolated from RfCi values when available, GI absorption assumed to be 0.5 (see Appendix B).
[d] RfDi values extrapolated, GI absorption assumed to be 0.5 (see Appendix B).

Derivation of TRPH SCTLs

The Florida TRPH SCTLs will be based on a 2-tiered approach. First, there will be a primary TRPH soil cleanup target level (SCTL). This SCTL is based on the assumption that the TRPHs consist exclusively of aromatic hydrocarbons in the >C_8-C_{10} range. Second, if the primary SCTL is exceeded, then the TRPHs may be sub-classified with each class possessing its own SCTL.

The primary TRPH SCTL is based on the >C_8-C_{10} carbon range as a result of two factors. First, the analytical method identified by the Florida Department of Environmental Protection for the purpose of measuring petroleum hydrocarbons in water and soil is limited to the detection of products within a carbon chain range of C_8-C_{40}. This method, the Florida Petroleum Residual Organic (FL-PRO) — Alternative Method to Total Recoverable Petroleum Hydrocarbons, 418.1 or 9073 — combines several of the commonly used methods so that the targeted range of petroleum hydrocarbons can be analyzed in a single step. However, because of its limitations, the smallest detectable C-range using the FL-PRO Method is the >C_8-C_{10} grouping. [This method is available for immediate use and may be obtained by calling the FDEP Quality Assurance Section at (904) 488-2796.] Secondly, the TRPH SCTL value was selected based on the identification of the most conservative values. The calculation of

the SCTLs (listed below) using standard FDEP and USEPA protocols results in the most conservative values for the C_5-C_7 aromatics. However, due to the limitations of the TRPH Method of Analysis, and since the most toxic and prevalent COCs within this range are addressed by other analyses and individual cleanup target levels, the values in this group are not used as TRPH SCTLs. The next most conservative values for residential and industrial direct exposure that occur within a carbon range that can be analyzed by FL-PRO are found in the >C_8-C_{10} aromatics grouping. Therefore, the TRPH SCTL values are based on this group of total petroleum hydrocarbons.

Calculation of the SCTLs

With the assignment of the above chemical and toxicological values, the determination of risk-based SCTLs follows the same methodology as that used for individual compounds.

Table C4: Calculated SCTLs for TRPH Classes

TRPH Class	SCTL (mg/kg_{soil})		
	Residential	Industrial	Leachability[a]
C_5-C_7 Aromatic	220	1500	34
>C_7-C_8 Aromatic	280	1900	50
>C_8-C_{10} Aromatic	**350**	**2500**	**340**
>C_{10}-C_{12} Aromatic	720	5700	520
>C_{12}-C_{16} Aromatic	1200	11000	1000
>C_{16}-C_{21} Aromatic	1200	12000	2800
>C_{21}-C_{35} Aromatic	2100	37000	26000
C_5-C_6 Aliphatic	4300	29000	470
>C_6-C_8 Aliphatic	5900	40000	1200
>C_8-C_{10} Aliphatic	650	4600	6700
>C_{10}-C_{12} Aliphatic	1300	9600	49000
>C_{12}-C_{16} Aliphatic	2400	20000	1100000
>C_{16}-C_{35} Aliphatic	31000	240000	110000000

[a]Based on an acceptable groundwater concentration of 5000 µg/L.