



Tiered Development of Human Health PCLs

Overview of this Document

- Objectives:** This guidance document discusses and illustrates the process of establishing Protective Concentration Levels (PCLs) in accordance with the various tiers set forth in §350.75 of the Texas Risk Reduction Program (TRRP) rule.
- Audience:** Regulated Community, TCEQ Project Managers and Environmental Professionals
- References:** The Texas Risk Reduction Program (TRRP) rule is contained in Title 30 Texas Administrative Code (TAC) Chapter 350. The TRRP rule, together with conforming changes to related rules, was initially published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). The rule was amended in 2007 (effective March 19, 2007; 32 TexReg 1526-1579) and 2009 (effective March 19, 2009; 34 TexReg 1861-1872)
- Find links for the TRRP rule and preamble, Tier 1 PCL tables, and other TRRP information at < www.tceq.texas.gov/remediation/trrp/>.
- TRRP guidance documents undergo periodic revision and are subject to change. Referenced TRRP guidance documents may be in development. Links to current versions are at: <www.tceq.texas.gov/remediation/trrp/guidance.html>.
- Contact:** TCEQ Remediation Division, Technical Support Section, 512-239-2200 or techsup@tceq.texas.gov.

For mailing addresses, refer to: www.tceq.texas.gov/about/directory/

General Overview of the Tiered Process

The Texas Risk Reduction Program (TRRP) establishes tiered processes for determining human health and ecological protective concentration levels (PCLs) for chemicals of concern (COCs). The focus of this document is the human health PCL calculation process and this guidance is appropriate for use at an affected property where ecological PCL development is unwarranted because ecological exclusion criteria are met, or to develop human health PCLs for comparison to ecological PCLs to determine the critical PCL. Ecological PCL development is not the subject of this document, but it is important to consider it during the PCL development process. The process for establishing ecological PCLs is covered in a separate ecological risk assessment guidance document that can be downloaded from the TRRP Web page shown above (*Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas* (RG-263 (revised))).

The TRRP PCL development process is patterned after the American Society for Testing and Materials risk-based corrective action process (*ASTM Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, E-1739*). A PCL is the regulatory standard for a concentration of a COC that must be achieved in the source medium (e.g., soil, groundwater, sediment) in order to protect a receptor at the point(s) of exposure to that COC. A PCL can be thought of as the “cleanup level.” PCLs are set by first establishing the health protective level that must be met at the point of exposure, referred to as the risk-based exposure limit (RBEL), considering the toxicity of the COC, exposure dose of the COC, and acceptable risk and hazard levels. Then if the source area and point of exposure are in different locations within an environmental medium or within different environmental media, the concentration that must be met in the source area (PCL) is back-calculated considering the mobility of the COC in the environment. The mobility of the COC in the environment is considered in terms of a natural attenuation factor (NAF), which accounts for the chemical and physical properties of the COC, affected property characteristics and physical processes associated with mobility. In short, the $PCL = RBEL \times NAF$. In the example of the soil-to-groundwater pathway, the $^{GW}Soil\ PCL = groundwater\ PCL \times NAF$.

Box 1. Don't Forget Ecological PCLs!

To avoid project delays and repeating work, be sure to complete an ecological Tier 1 Exclusion Criteria Checklist early in the assessment process to determine if ecological PCLs may need to be established.

The PCL development process is different from a conventional baseline risk assessment process that starts with a known concentration in a source area and assesses the risk to the receptor at a point of exposure. The TRRP rule sets forth a systematic tiered process to establish PCLs that follows the principle of start simple and increase complexity only when warranted (Figure 1). Tiers are essentially defined levels of effort or sophistication that progressively factor in greater site-specificity into establishing PCLs by allowing modifications of the NAF and associated affected property parameters. Specifically, a three-tiered system for human health PCL development is detailed in §350.75(a)-(d).

Tier 1 PCLs are established using equations and input parameters set in the rule resulting in non-unique or “generic” PCLs for each COC for each exposure pathway. For Tier 1, the NAF equals one. Tier 1 assumes the source and receptor are located at the same point. Tier 2 PCLs are established using equations set in rule and guidance, but allow for use of site-specific input parameters. Tier 3 covers any evaluation method that deviates from the prescribed requirements of Tiers 1 and 2, and allows user-defined PCL equations and input variables. Tier 3 provides the greatest amount of site-specific considerations, and accommodates both equivalent and higher degrees of sophistication. Therefore, the PCL values are likely to be higher numeric values under Tier 3 than those established under Tier 1 or 2. That is not to say, however, that Tier 2 or 3 PCLs are less protective of human health. The tiered process allows site-specific information to be substituted for conservative Tier 1 assumptions to calculate PCLs that are higher than Tier 1,

yet are still protective of human health to the same level of risk and hazard as Tier 1 PCLs. Differences between the three tiers are listed in Table 1.

Table 1. Comparison of Tiers 1, 2, and 3.

Characteristic	Tier 1	Tier 2	Tier 3
Site-specific	No	Yes	Yes, more than Tier 2
Exposure factors	No modifications	Some modifications	Same as Tier 2
COC properties	No modifications	Some modifications	Same as Tier 2
Toxicity factors	No modifications	Some modifications	Same as Tier 2
Affected property parameters	No modifications	Site-specific	Site-specific
RBEL equations	Set in rule	Set in rule ¹	Set in rule ¹
Natural attenuation factors (NAF) models	Set in rule	Set in rule and guidance ²	User determined (e.g., site-specific K_d ³)
PCL equations	Set in rule	Set in rule and guidance ²	User proposed ⁴

1. RBELs needed for other exposure pathways are not set in rule and are established in conjunction with TCEQ under Tiers 2 and 3.

2. See www.tceq.texas.gov/assets/public/remediation/trrp/tier2.pdf.

3. K_d – soil-water partition coefficient of inorganic compounds

4. PCL equations can be modified to the extent the RBEL and NAF can be modified in accordance with the rule.

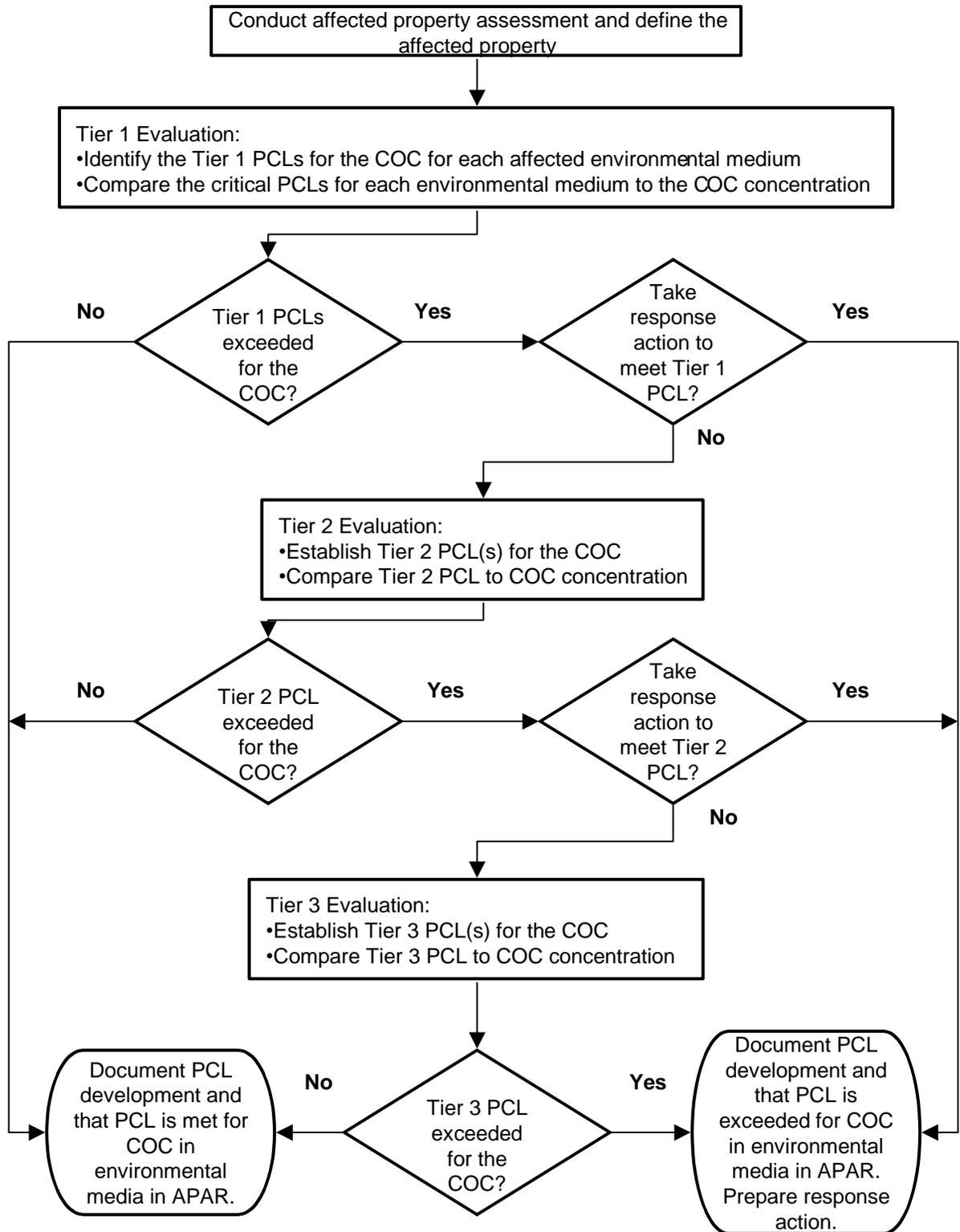
How far into the tiered process one proceeds is up to the person undertaking the action (Figure 1). However, the logic process of Figure 1 needs to be followed for each COC for each environmental medium. The tiered process is intended to aid people in identifying the exposure pathways and COCs that pose the greatest threat to receptors so that response actions can be focused on addressing those pathways and COCs. The tiered process procedure is to start with Tier 1 and then progress into Tier 2 for only those COCs and exposure pathways that do not meet Tier 1 criteria, and then into Tier 3 for only those COCs and exposure pathways that do not meet Tier 2 criteria. Alternatively, the tiered PCL development can start and stop at any tier, but a response action must be taken when a PCL is exceeded (Figure 1).

The different tiers can be applied to different COCs acting through the same exposure pathway, to different exposure pathways within the same environmental medium, and to different environmental media. However, there are no requirements to use any particular tier for PCL development, unless a PCL calculated under a given tier is not protective or an exposure pathway is unaddressed by Tier 1 or Tier 2 (e.g., dairy uptake). Tier 3 may be applied to

Box 2. Critical PCL.

A critical PCL is the lowest of all applicable human health and ecological PCLs for a COC in an environmental medium. See TCEQ guidance document *Critical PCLs* (RG-366/TRRP-25) for more information on critical PCLs.

the latter situation. As an example of a PCL that may not be protective, assume the Tier 1 soil leachate PCL (i.e., ^{GW}Soil) is met, but groundwater-monitoring data indicate that COC concentrations in the groundwater source area are worsening. Unless there is another source of the groundwater contamination, the leaching of COCs from the original affected soil is the likely cause. In this instance, the soil PCL is either not protective or the soil PCL is exceeded by remaining COC concentrations. Either the adequacy of the soil PCL or the soil needs to be further evaluated to determine if the PCL actually is exceeded in the soil. If the Tier 1 PCL is determined not to be protective of groundwater, then development of a sufficiently site-specific PCL under Tier 2 or Tier 3 is an available option.



(APAR – Affected Property Assessment Report)

Figure 1. Overview of Tiered Human Health PCL Development Process.

In deciding which tier(s) to apply for a given situation, evaluate the data needed to support PCL development at a higher tier, and the likelihood that developing PCLs under a higher tier will modify the PCL such that reduced remedial costs or remedial timeframes will yield savings that exceed the cost of establishing PCLs at the higher tier. Situations such as a small volume of shallow soil affected with low mobility COCs may be quickly and effectively addressed under Tier 1 while a large contamination problem involving multiple COCs and affected environmental media may be more effectively addressed under a higher tier.

There is no need to calculate Tier 1 PCLs. TCEQ has already calculated and published Tier 1 PCLs for over 675 COCs. Download Tier 1 PCL Tables from the TRRP Web page listed at the beginning of this document. See guidance document *Tier 1 PCL Tables* (RG-366/TRRP-23) for instructions on using the tables and an explanation of the information that can be obtained from those tables. In the event a Tier 1 PCL is not available, a Tier 1 PCL can be requested from TCEQ. Additionally, the Tier 1 PCLs are updated each year. For more information on requesting Tier 1 PCLs and the annual update, see TCEQ guidance document *Toxicity Factors and Chemical/Physical Parameters* (RG-366/TRRP-19).

Flexibility of the Tiered Human Health PCL Development Process

A PCL is a numeric value that is either calculated from a mathematical equation or based on a policy, such as a federal maximum contaminant level (MCL). The PCL equations have two parts: RBEL and natural attenuation factor (NAF). The relationship between the two is shown in Table 2. The RBEL is the exposure medium COC concentration which is protective of human health at the point of exposure. See Figure: 30 TAC §350.74(a) in the TRRP rule for the RBEL equations. The NAF is based on fate and transport modeling of the COC. See Figure: 30 TAC §350.75(b)(1) in the TRRP rule for the Tier 1 NAF equations.

Table 2 lists the potential modifications under Tier 2 and 3 for each exposure pathway. Where tiered modifications are allowed for a given exposure pathway, the modifications may be to the RBEL, NAF, or both. However, there is minimal flexibility to modify residential RBELs. More flexibility is provided for modification of commercial/industrial RBELs, but adjustments are strictly controlled by the requirements of §350.74(j)(2). The greatest flexibility is the ability to modify site-specific information in the calculation of NAFs.

Table 2. Factors Used to Modify PCLs at Tier 2 and 3.

PCL ^{1, 2}	RBEL ¹ Residential	RBEL ¹ Commercial/Industrial	NAF ¹ (C _s /C _{P_{OE}}) Affected Property Parameters
Air _{Inh-V} Soil	N/A	Limited to EF, OCC	All parameters
Tot _{Comb} Soil Air _{Inh-VP} Soil	N/A	Limited to EF, OCC	All parameters
Tot _{Comb} Soil Soil _{Ing}	RBAF	Limited to EF, RBAF	N/A
Tot _{Comb} Soil Soil _{Derm}	Limited to ABS _d , ABS _{GI}	Limited to ABS _d , ABS _{GI}	N/A
Tot _{Comb} Soil Veg _{Ing} Soil	N/A	N/A	All parameters
GW _{Ing} Soil	N/A	N/A	All parameters
GW _{Class 3} Soil	N/A	N/A	All parameters
GW _{Ing} GW	N/A	Limited to EF if no MCL	N/A
GW _{Class 3} GW	N/A	N/A	N/A
Air _{Inh-V} GW	N/A	Limited to EF, OCC	All parameters

1. PCL = RBEL x NAF; Tier 1 NAF = 1.
 2. See Table 5 for PCL definitions.
 EF-exposure factors (only: non-carcinogenic averaging time, exposure duration, exposure frequency for workers), N/A – not applicable, OCC – occupational inhalation criteria, RBAF – relative bioavailability factor; ABS_d – dermal absorption fraction, ABS_{GI} – gastrointestinal absorption fraction, C_s – concentration at source, C_{P_{OE}} – concentration at point of exposure.

This section lists the primary factors that need to be considered in working the tiered process.

RBEL Modifications

There is limited flexibility to modify default RBEL exposure factors under Tier 2 or 3. In short, only the factors listed in Table 3 can be modified.

Table 3. Allowable Modifications to Default RBEL Exposure Factors.

Rule Citation	§350.74(j)(1)	§350.74(j)(2)*
Exposure Factors	Gastrointestinal absorption fraction (ABS _{GI})	Non-carcinogenic averaging time (At _w)
	Dermal absorption fraction (ABS _d)	Exposure duration (ED _w)
	Relative bioavailability factor (RBAF)	Exposure frequency (EF _w)

*For commercial/industrial land use only.

Consult the rule directly to identify the requirements for modifying the RBEL exposure factors of Table 3, as no further explanation is offered in this guidance. However, because the nature of methods, data and documentation needed to support agency approval may be somewhat site specific for adjusting the §350.74(j)(1) factors, contact a TCEQ toxicologist prior to expending effort to adjust these RBEL parameters.

With regard to adjustments to the §350.74(j)(2) exposure factors, review the requirements listed in the rule and consider the level of effort involved relative to the level of likely relief in PCL values and required response actions before proceeding. Public notice, approval by the Executive Director of the TCEQ (not TCEQ staff), and legal and physical controls on property use and access are required.

Natural Attenuation Factors

Under Tiers 1 and 2, NAFs are estimated by means of analytical models specified by the TCEQ in rule or guidance. For a detailed explanation of the Tier 1 and 2 NAFs, refer to TCEQ guidance document *Development of Natural Attenuation Factors for PCLs* (RG-366/TRRP-26). In Tier 3, the NAF may be estimated by means of an appropriate analytical model, numerical model, or simulation selected by the person.

Sections §350.75(e) - (h) list requirements that must be satisfied to use NAFs. For Tiers 1 and 2, those requirements are generally presumed to be satisfied, except for §350.75(g), which pertains to verification of NAF estimations with actual field evidence (verification data). However, with regard to Tier 3 NAF models, the following should be considered.

A Tier 3 NAF model may be used when *any* of the following situations exist:

- Site conditions are too complex for the use of Tier 2 PCL model;
- Tier 2 PCL NAF model does not exist for specific exposure pathway;
- Tier 2 PCL NAF model cannot provide the necessary accuracy for site conditions;
- Tier 2 PCL NAF model cannot be used to perform the desired simulation.

Development of human health PCLs with Tier 3 NAF models must meet *all* of the following criteria:

- Physical property input parameters must use TRRP Tier 1 default or site-specific values as allowed by TRRP; literature values generally are not acceptable, unless they can be shown to have particular relevance to the affected property;
- Base predictive simulations on fully calibrated models;
- Run predictive simulations for a period greater than the “reasonable timeframe.” (For an explanation of reasonable timeframe, see TCEQ

guidance document *Application of Remedy Standards A and B* (RG-366/TRRP-28).

Include the following in Tier 3 NAF model submittals:

- Description of the precise *intent* of the Tier 3 model simulation or calculation (purpose);
- Description of the Tier 3 *physical* model (physical, chemical, hydraulic, etc.) with references;
- Description of the Tier 3 *mathematical* model (derivation of equations, etc.) with references;
- Description of any commercial or proprietary *software* product used to determine Tier 3 PCLs;
- Descriptions of *standard methods* by which empirical or site-specific data are determined (laboratory methods, field methods, etc.);
- Analysis of site *calibration* statistics for predictive simulation models (hydraulic, chemical, etc.);
- Discussion of simulation prediction *results* for period up to and beyond the reasonable timeframe;
- Appendices for all input and output *data* associated with model calculations and/or simulations;
- CD-ROM or other electronic file containing all set-up and input *data files* associated with model simulations that allow TCEQ to review simulations directly.

With regard to providing documentation for the model, the person can provide a reference to publicly available literature or a Web page address where the information can be readily accessed at no charge to TCEQ.

Key Considerations in Human Health PCL Development

Before developing PCLs, some critical information about the affected property must be determined. Table 4 references key TRRP guidance documents that will facilitate appropriate PCL development. Some of the more basic considerations are highlighted in the following text.

Table 4. Key Supporting TRRP Guidance Documents.

TRRP Guidance	Critical Content for TRRP-22
TRRP-18	Guides PCL adjustments for cumulative risk and hazard
TRRP-19	Guides use of toxicity factors and COC chemical/physical properties for RBEL and NAF equations
TRRP-21	Guides setting points of exposure
TRRP-23	Explains RBEL and PCL nomenclature, Tier 1 PCL Table format and purpose, and how to use the Tier 1 PCL Tables
TRRP-24	Guides development of human health surface water and sediment PCLs
TRRP-25	Explains critical PCLs and guides selection of critical PCLs
TRRP-26	Provides overview of Tier 1 and 2 NAF equations and guides their use
TRRP-27	Guides development of PCLs for TPH
Tier 2 PCL Equations	Provides the TCEQ Tier 2 PCL equations for use in Tier 2 evaluations < www.tceq.texas.gov/assets/public/remediation/trrp/tier2.pdf >
NAF – natural attenuation factor, TPH – total petroleum hydrocarbons. All guidance documents available at < www.tceq.texas.gov/remediation/trrp/guidance.html >.	

Target COCs

Determine the relevant COCs so that an appropriate sampling strategy can be designed and applicable PCLs can be established. Target COCs are not established by the TRRP. Target COCs are set by the person and/or TCEQ program area in consideration of historical practices at the affected property and the purpose of the assessment. Target COCs may only be dropped from PCL development when the screening criteria established under §350.71(k) of the TRRP rule are met. For further information, see TCEQ guidance document *Selecting Target Chemicals of Concern* (RG-366/TRRP-10) and *Screening Target Chemicals of Concern from PCL Development* (RG-366/TRRP-14).

Source Medium Characterization

Adequately characterize the source medium so that the affected environmental media are identified (surface soil, subsurface soil, groundwater). This is important because the minimum set of exposure pathways that must be evaluated for PCL development are defined for each affected environmental medium. Further, conduct sufficient characterization of the subsurface geology and hydrogeology as necessary to yield critical information to support PCL development. Critical geology and hydrogeology information can include soil types and properties such as porosity, air and water content, organic carbon content, depth to groundwater, groundwater

flow gradients, and the thickness of the groundwater-bearing unit, for example.

At a minimum, establish PCLs for all “complete or reasonably anticipated to be completed” exposure pathways [§350.71(c)]. See Table 5 for the minimum exposure pathways that apply for the different environmental media. As indicated in Table 5, land use and groundwater classification control the applicability of certain exposure pathways. Because no Tier 1 or 2 procedures are provided for them, PCLs for “other complete or reasonably anticipated to be completed” exposure pathways are established under Tier 3.

Table 5. Source Medium, Mandatory Exposure Pathways and PCLs.

Source Medium	Complete or Reasonably Anticipated to Be Completed Exposure Pathways	PCL
Surface Soil	<i>Residential:</i> Combined ingestion, dermal contact, inhalation of volatiles and particulates, and ingestion of above-ground and below-ground vegetables with COCs in soil. <i>Commercial/Industrial:</i> Combined ingestion, dermal contact, and inhalation of volatiles and particulates of COCs in soil.	^{Tot} Soil _{Comb}
Subsurface Soil	Inhalation of volatile COCs from soil.	^{Air} Soil _{Inh-V}
Surface and Subsurface Soil	Soil-to-groundwater leaching of COCs to Class 1 and 2 groundwater.	^{GW} Soil _{ing} or ^{GW} Soil _{Secondary MCL}
Surface and Subsurface Soils	Soil-to-groundwater leaching of COCs to Class 3 groundwater.	^{GW} Soil _{Class 3}
Class 1 Groundwater	Ingestion of COCs in Class 1 groundwater.	^{GW} GW _{ing} or ^{GW} GW _{Secondary MCL}
Class 2 Groundwater	Ingestion of COCs in Class 2 groundwater.	^{GW} GW _{ing} or ^{GW} GW _{Secondary MCL*}
Class 3 Groundwater	COCs in Class 3 groundwater.	^{GW} GW _{Class 3}
Class 1, 2 and 3 Groundwater	Inhalation of volatile COCs from Class 1, 2 or 3 groundwater.	^{Air} GW _{Inh-V}
All environmental media	Other complete or reasonably anticipated to be completed exposure pathways.	Other
*For Class 2 groundwater, secondary MCLs only apply if a potable water well is impacted or threatened, or if the Class 2 groundwater is the only water supply source [§350.74(f)(3)(B) and (C)].		

Land Use Classification

Human health PCLs are either based on residential or commercial/industrial land use scenarios as defined in §350.4(a). Determine the land use for each tract of land within the affected property in advance of PCL development, but residential land use is the default and can be assumed for any property. See TCEQ guidance documents *Land Use Classification* (RG-366/TRRP-7) and *Institutional Controls* (RG-366/TRRP-16) for further information and requirements regarding commercial/industrial land use.

Groundwater Classification

Groundwater classification defines the applicable PCLs (Table 5) and therefore, must be determined in advance of PCL development. Unless the groundwater is determined to be Class 2 or 3, or only “saturated soil,” set PCLs based on Class 1 groundwater classification. See TCEQ guidance document *Groundwater Classification* (RG-366/TRRP-8) for further information.

Point of Exposure

A point of exposure (POE) is a location in the environment where the human or ecological receptor is assumed to encounter the COC. Generally speaking, the applicable RBEL is met at that location, although there are considerations for cumulative effects (see TCEQ guidance document *Risk Levels, Hazard Indices, and Cumulative Adjustments* (RG-366/TRRP-18)). For consistency, TRRP defines human health POE locations for each of the exposure pathways listed in Table 5. See TCEQ guidance document *Human Health Points of Exposure* (RG-366/TRRP-21) for further information on POE locations.

Toxicity Effects and Adjustments to PCLs to Account for Cumulative Effects from Multiple COCs

PCLs consider both carcinogenic and non-carcinogenic effects. A given COC may produce both carcinogenic and non-carcinogenic effects. If such is the case, then develop PCLs for both types of effects.

Further, as discussed in §350.72(b), when there are more than 10 carcinogenic COCs and/or 10 non-carcinogenic COCs present in a single environmental medium, address the impact of multiple COCs and if necessary, lower the individual PCLs to meet the target cumulative risk level and hazard index. For example, if there are 12 carcinogenic COCs and 9 non-carcinogenic COCs present in surface soil, a cumulative evaluation is needed for the carcinogens. See TCEQ guidance document *Risk Levels, Hazard Indices, and Cumulative Adjustments* (RG-366/TRRP-18) for detailed information and guidance regarding this subject matter.

Considerations for Progressing to Higher Tiers

Factors to consider when determining how far into the tiered process to proceed include:

- *The real need for a higher PCL.* If the measured COC concentrations at the affected property do not exceed the PCLs for a particular tier, Tier 1 PCLs for example, there is no reason to proceed further into the tiered

process for that COC. Proceed to a higher tier only when there is a need to do so.

- *Impact of ecological PCLs.* If ecological PCLs will be lower than the Tier 1 or Tier 2 human health PCLs for an affected property, it may not be necessary to continue the human health PCL development because the ecological PCL will be the critical (lowest) PCL. One exception to this will be if an ecological services analysis (ESA) is pursued and the results indicate that no response action is required at the property for ecological purposes. See §350.33(a)(3) and (b) and TCEQ guidance document *Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas* (RG-263 (revised)) for information on the ESA.
- *The COC and exposure pathway.* Verify if PCL modification is allowed under Tier 2 or 3 for the particular exposure pathway and/or COC. For example, for the groundwater ingestion exposure pathway, the ^{GW}GW_{Ing} PCL is set equivalent to the federally promulgated MCL when an MCL is available for the COC. The PCL in this instance is the same for the COC at all three tiers and adjustment under a higher tier is not allowed. See Tables 2 and 6 for a listing of exposure pathways and COCs, respectively, which have constraints on their modification under the tiered process.
- *The potential for a significant benefit from further PCL development.* Verify if a significant change in the PCL value is likely. For example, the PCL may adjust sufficiently upward under Tier 2 or 3 such that less of a response action or no response action is required. However, if there is little potential for the PCL to increase sufficiently such that the scale of the response action is lessened, there is likely no real benefit to adjusting PCLs under Tier 2 or 3.
- *Availability of data to support further PCL development.* Specific types of affected property data may be needed to support further PCL development that are not already available. This will represent additional expenditures. However, proper planning of an assessment by anticipating the data needed to support PCL development will minimize the chance of this situation. See TCEQ guidance document *Planning and Assessment Surveys* (RG-366/TRRP-6) for guidance on proper planning for a TRRP assessment.
- *Certainty of TCEQ acceptance and project schedule.* If there is a particularly urgent need to expedite a remediation project, then the need for TCEQ approval of alternative PCLs will slow the project, especially if TCEQ does not concur with the modifications.
- *Availability of a Tier 1 PCL.* If the source area size for a COC in an environmental medium is larger than 30 acres using the source area determination method prescribed by §350.75(b)(2), then a Tier 1 PCL is not available. The PCL must be developed under Tier 2 or 3 based on a site-specific source area determination. See TCEQ guidance document *Affected Property Assessment Requirements* (RG-366/TRRP-12) for a more thorough discussion of source area size. Also, unless a Tier 1 or 2

PCL equation is provided in rule or guidance for a particular exposure pathway, PCLs must be established for that exposure pathway under Tier 3.

- *Impact of the affected property ownership in the event an institutional control is required.* In general, using Tier 2 or 3 to establish PCLs does not trigger any requirement to file an institutional control. However, in situations where exposure factors are modified, occupational inhalation criteria are used, or a plume management zone is used, an institutional control is required. In some instances, the third party issues may dictate tiered PCL selection to some extent. For more information, see TCEQ guidance document *Institutional Controls* (RG-366/TRRP-16).

Specific Considerations in Setting PCLs

This section provides guidance for some situations that are likely to be frequently encountered when setting PCLs.

^{GW}GW_{Ing} and Land Use

When the COC has a federally promulgated MCL, that MCL becomes the groundwater ingestion PCL (^{GW}GW_{Ing}). In this situation, the PCL is the same for residential and commercial/industrial land use. Therefore, before filing an institutional control for commercial/industrial land use, ensure that the commercial/industrial land use will result in a different PCL.

Setting ^{GW}GW_{Ing}

If the class of the affected or threatened groundwater is either unknown or known to be Class 1 or 2 groundwater, then the ^{GW}GW_{Ing} PCL applies. In setting ^{GW}GW_{Ing}, there are several variables that need to be considered. The following steps are recommended to guide setting ^{GW}GW_{Ing}.

Step 1. Set the Health-Based PCL. Determine if there is flexibility to adjust the ^{GW}GW_{Ing} PCL under Tier 2 and then decide whether a Tier 2 adjustment will be pursued.

This PCL can only be adjusted under Tier 2 when *all* of the following conditions are met.

- There is not a federally promulgated primary MCL for the COC. To determine this use the "^{GW}GW_{Ing}" column of Table 3 of the Tier 1 PCL Tables. If the letter descriptor in the column to the right of the numeric ^{GW}GW_{Ing} value is "m", then ^{GW}GW_{Ing} is based on an MCL.
- Land use is commercial/industrial where the adjusted PCL is to be applied.

- Permission is obtained from the TCEQ Executive Director (not staff) to adjust exposure factors, after all requirements of §350.74(j)(2) are met.

If no adjustment will be made under Tier 2, use the “ $^{GW}GW_{Ing}$ ” column in Table 3 of the Tier 1 PCL Tables to identify the residential or commercial /industrial $^{GW}GW_{Ing}$ PCL value applicable for the COC and land use.

Step 2. Determine Whether a Secondary MCL and Aesthetic Criteria Are Applicable.

Determine if *any* of the three following affected property conditions are applicable.

- 1) The COC is in Class 1 groundwater.
- 2) The COC is in Class 2 groundwater, within 0.5 miles of a public or private drinking water supply well, and within or likely to migrate into the groundwater production zone for that well. The *groundwater production zone* is each groundwater-bearing unit that contributes water to the well.
- 3) The COC is Class 2 groundwater and that groundwater is the only drinking water source (i.e., no alternative drinking water sources exist).

If none of the conditions are applicable, then secondary MCLs or aesthetic criteria do not need to be considered in setting the PCL. Skip Step 3 and proceed to Step 4.

Step 3. Identify Secondary MCL or Aesthetic Criteria. If *any* of the three conditions in Step 2 are met, then secondary MCLs and scientifically valid published aesthetic criteria are applicable if available for the COC. To determine if they are available, use the *Secondary MCL* column in Table 3 of the Tier 1 PCL Tables. If a value is provided, then use it in Step 4. If no value is provided, proceed to Step 4 without a numeric value for this step.

Step 4. Set the $^{GW}GW_{Ing}$ PCL.

Select the lower of the two values from Step 1 and Step 3 (if Step 3 is applicable) and compare it to:

- the representative background groundwater concentration for the COC (see TCEQ guidance document *Determining Representative Concentrations* (RG-366/TRRP-15) for information regarding defining the background COC concentration in groundwater); and
- The MQL for the standard available analytical method that provides the lowest MQL for that COC.

The PCL is the highest of the three values (i.e., health-based PCL, background concentration, MQL).

Occupational Inhalation Criteria

Often times, TRRP is applied to commercial and industrial facilities that have worker protection programs in place to safeguard against occupational inhalation exposures. In such instances, the $^{Air}Soil_{Inh-VP}$, $^{Air}Soil_{Inh-V}$, and $^{Air}GW_{Inh-V}$ can be adjusted under Tier 2 or 3 to apply an eight-hour time-weighted average occupational inhalation criterion (Occupational Safety and Health Administration Permissible Exposure Limits (PELs) or American Conference of Governmental Industrial Hygienists Threshold Limit Values (TLVs)). In this instance, the lower of the PEL or TLV is substituted for the inhalation RBEL ($^{Air}RBEL_{Inh}$). This adjustment is *only* allowed for:

- Commercial/industrial land use;
- The limits of the affected property;
- Property with a health and safety plan that is documented to the agency and certified by the person (the one who is responsible for complying with TRRP at the affected property) that the plan is followed; designed to ensure compliance with the occupational inhalation criteria for the COC(s); requires monitoring of the COC concentrations in the working air environment; and specifies actions to be taken if criteria are exceeded.

To provide some assurance the health and safety plan will be accepted by the TCEQ, it is recommended to have an industrial hygienist or other appropriate professional certify that the plan is appropriate for the COC(s) and site conditions.

Also note that COC concentrations must meet the standard commercial/industrial or residential air RBELs, as applicable, at and beyond the area of applicability of the health and safety plan.

Other applicable state and federal air standards cannot be exceeded. Finally, an institutional control is required. See TCEQ guidance document *Institutional Controls* (RG-366/TRRP-16) for further information.

Setting Human Health PCLs for Surface Water and Sediment

When surface water and sediment are affected, human health PCLs may need to be set. See Sections 3.3 and 5.0 of TCEQ guidance document *Determining PCLs for Surface Water and Sediment* (RG-366/TRRP-24) for guidance on when and for what exposure pathways human health PCLs must be established.

Aesthetic Considerations

The Tier 2 or 3 PCL adjustments typically provide a health risk basis to allow higher COC concentrations to remain at the affected property. However, if the risk-based concentration results in the COC creating or continuing to represent a nuisance condition, adjust the PCL concentration downward to abate the nuisance. Typically, adjustments to PCLs to address aesthetic considerations will not be directed by the TCEQ unless complaints are received about the nuisance, except as discussed earlier in Step 2 of the *Setting GW_{Ing}* section of this guide, for Class 1 and 2 groundwater.

COCs with Special Considerations

COC-specific approaches are established for the COCs listed in Table 6. No additional guidance is offered here and the person should consult the TRRP rule when developing PCLs for any of these COCs.

Table 6. COCs with Specific PCL Development Requirements.

COC	Rule Citation and TRRP Guidance
Cadmium	§350.76(b)
Lead	§350.76(c)
Polychlorinated biphenyls (PCBs)	§350.76(d)
Polychlorinated dibenzodioxins and dibenzofurans	§350.76(e)
Polycyclic aromatic hydrocarbons	§350.76(f)
Total Petroleum Hydrocarbons	§350.76(g) and TRRP-27

The Role of C_{sat}

The theoretical soil saturation limit concentration (C_{sat}) is the minimum soil COC concentration at which non-aqueous phase liquid (NAPL) exists for a COC and soil condition. In other words, C_{sat} is a value at and above which the COC is present in soil water at its aqueous solubility limit and is present in soil pore air at its saturated vapor concentration. At C_{sat} the soil vapor is maximally saturated, which means that as COC concentrations increase above C_{sat} , the soil vapor concentration for the COC will not increase. The benefit of C_{sat} is that it can be used as a theoretical concentration ceiling for the $AirSoil_{Inh-V}$ exposure pathway. If C_{sat} is a lower concentration than the $AirSoil_{Inh-V}$ PCL for a COC and soil condition, then the $AirRBEL_{Inh-V}$ exposure pathway cannot be exceeded and the exposure pathway can be eliminated from further evaluation for that COC at that affected property. However, as discussed earlier, when there are more than 10 carcinogenic or noncarcinogenic COCs in the subsurface soil, then conduct a check to determine if the PCLs need to be downwardly adjusted to meet the target cumulative risk level and hazard index. If such an adjustment needs to be made to $AirSoil_{Inh-V}$ for a COC, make it before doing the C_{sat} comparison.

The C_{sat} comparison is a Tier 2 or 3 evaluation. To set C_{sat} and appropriately compare C_{sat} and $AirSoil_{Inh-V}$, base both values on the same site-specific data. In other words, it is not allowable to compare C_{sat} to a Tier 1 $AirSoil_{Inh-V}$ PCL. The C_{sat} equation can be found in the Tier 2 PCL document www.tceq.state.tx.us/assets/public/remediation/trrp/tier2.pdf.

The Role of Solubility (S)

Solubility is the theoretical maximum dissolved-phase concentration above which a COC will either precipitate out of solution or exist as NAPL. Effective solubility (S_e) is the same concept for mixtures of COCs. See TCEQ guidance *NAPL Assessment Requirements* (Draft) for more details on mixtures. Similar to C_{sat} , solubility (reported in units of mg/L) can be used as a theoretical ceiling for the $AirGW_{Inh-V}$ pathway for volatile COCs. Unlike C_{sat} , solubility is not calculated for each COC. Rather, values of solubility are chemical specific. As such, solubility is fixed for each COC and is not modified for Tier 2 or Tier 3 calculations [§350.73(f)]. Compare solubility to Tier 1, Tier 2 or Tier 3 $AirGW_{Inh-V}$ PCLs. If the critical PCL is greater than the aqueous solubility limit for that COC, then the $AirGW_{Inh-V}$ exposure pathway can be eliminated from further evaluation for that COC at that affected property. As is the case for the C_{sat} , address any needs to make adjustment for cumulative COCs before comparing solubility to the groundwater PCL. See TCEQ guidance document *Toxicity Factors and COC Chemical/Physical Parameters* (RG-366/TRRP-19) for additional information. Download chemical property tables containing allowable values of solubility with the Tier 1 PCL Tables from the TRRP Web page.

Tiered PCL Development: An Example Case

In order to demonstrate several important aspects of the tiered PCL development process, this guidance document will use an example case study to develop human health PCLs. In the example case study for a property near Houston, Texas, three environmental media are impacted (surface soils, subsurface soils and groundwater), and there are two independent source areas (See Figure 2). In source Area A, the only COC is lead and it is only impacting surface soils. In source Area B, benzene and naphthalene are the two COCs present in surface soil, subsurface soil and groundwater. The affected groundwater is Class 2. All impacted groundwater is onsite and surface water pathways are absent. The references to Tier 1, 2 and 3 in Table 7 denote which tier the person used to establish PCLs for the COC and environmental medium.

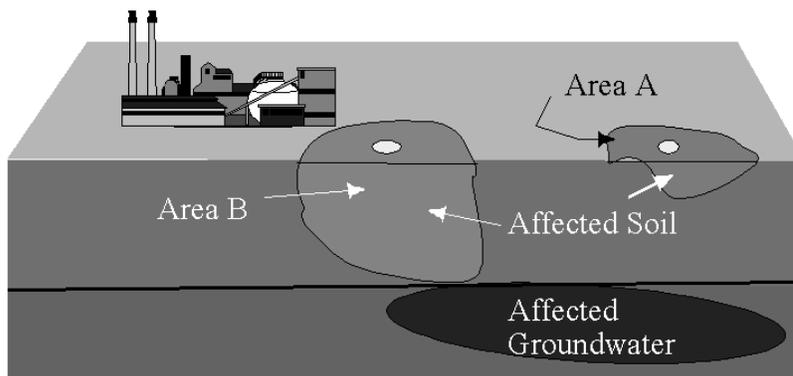


Figure 2. Example Application of the Tiered PCL Development Process.

Table 7. Affected Soil – Example Application.

COC	Surface Soil $^{Tot}Soil_{Comb}$	Surface Soil $^{GW}Soil$	Subsurface Soil $^{Air}Soil_{Inh-v}$	Subsurface Soil $^{GW}Soil$
Area A				
Lead	Tier 1	Tier 2	NA	NA
Area B				
Benzene	Tier 2	Tier 3	Tier 2	Tier 3
Naphthalene	Tier 1	Tier 1	Tier 1	Tier 1
Affected Class 2 Groundwater				
	$^{GW}GW_{Ing}$	$^{Air}GW_{Inh-v}$		
Benzene	Tier 1	Tier 2		
Naphthalene	Tier 2	Tier 1		
NA – not applicable, subsurface soils not affected.				

Case Study #1: Area A—Lead In Surface Soils

Target COCs

Area A represents surface soils containing lead related to the storage of batteries. No other chemicals were released in Area A. Therefore, the target COC for this example is lead.

Source Medium Characterization

As indicated in Figure 1, the tiered PCL development process begins with affected property assessment and delineation of affected soils to residential assessment levels (typically Tier 1 PCLs or background levels). In this example, the affected property was delineated laterally to concentrations below 15 mg/kg (i.e., the Texas-specific median background value for lead from Figure: 30 TAC §350.51(m)) in a 100 ft by 150 ft area. Vertical assessment to background (15 mg/kg) was achieved through the collection of samples at 0.25-foot depth intervals to a depth of 3 feet below ground surface (bgs) at each boring location. This detailed sampling frequency was used because, based on the site conceptual model, it was anticipated that the lead impact would have vertically penetrated the soil to only a minor extent. The more detailed assessment data should significantly help in evaluating the soil-to-groundwater exposure pathway. Soil analytical results revealed concentrations decreasing from a maximum concentration of 982 mg/kg in the upper 0.25 foot soil interval to concentrations below 15 mg/kg in the 1.75 foot to 2.0 foot depth interval.

In anticipation of exceeding the Texas-specific median background value for lead (15 mg/kg), which is the critical PCL for groundwater protection as it is a greater value than the Tier 1 $^{GW}Soil_{Ing}$ PCL, and the release resulting in a soils-only impact, it was decided to install monitoring wells to determine the groundwater depth, gradient and velocity. Depth-to-groundwater is critical information in setting the $^{GW}Soil$ PCL under Tier 2 or 3 (i.e., L_2/L_1 in the Tier 2 $^{GW}Soil_{Ing}$ PCL equation).

The vertical soil assessment was complete in this example once the background concentration for lead was reached at 2 feet ($L_1 = 2$ feet). Groundwater is encountered at 30 feet below ground surface ($L_2 = 30$ feet). Even if the person decides to assume affected soil is in direct contact with groundwater ($L_1=L_2$), they can still use other affected property parameters (e.g., soil pH, soil composition – sandy, loamy, clayey, etc.) to adjust the K_d value and set a Tier 2 $^{GW}Soil_{Ing}$ PCL value using the equation found at: www.tceq.state.tx.us/assets/public/remediation/trrp/tier2.pdf.

Land Use Classification

The property is intended for redevelopment for mixed-use purposes; however, the landowner is willing to file a deed notice to limit use of the affected property for commercial/industrial purposes if the cost to clean up to residential levels is too high. Consequently, PCLs will be developed for both commercial/industrial and residential land use considerations.

Classify Groundwater

In this example, the groundwater is not anticipated to be Class 3. Because the groundwater PCLs are the same for Class 1 and 2 groundwater, and based on the site conceptual model it was anticipated that groundwater is not affected, the person could just presume the groundwater is Class 1. Sampling the monitor wells confirmed that lead had not affected the groundwater. However, appropriate information was collected from the monitor wells and the groundwater classification was determined to be Class 2.

Identify Exposure Pathways and Applicable POEs

Based on the results of the source medium characterization and the information summarized in Table 5, the applicable PCLs addressing exposure pathways for lead contamination in surface soil are $^{Tot}Soil_{Comb}$ and $^{GW}Soil_{Ing}$. The corresponding POEs are located within the footprint of affected soil for the surface soil exposure pathways covered by $^{Tot}Soil_{Comb}$ and throughout the groundwater for the cross-media exposure pathway covered by $^{GW}Soil_{Ing}$. In the absence of ecological receptors, affected subsurface soil, or affected groundwater, no other exposure pathways require further evaluation.

Identify Tier 1 PCLs for Applicable Exposure Pathways

The pertinent PCLs for surface soils are $^{Tot}Soil_{Comb}$ and $^{GW}Soil_{Ing}$. A summary of the Tier 1 PCLs, including the Texas-specific median background concentration for lead (15 mg/kg), is provided in Table 8. Bolded values in Table 8 identify the Tier 1 PCLs that are exceeded. The affected property, as defined during the affected property assessment using the Texas-specific median background concentration as the surface soil assessment level, is comprised of a 1/3-acre area of surface soils extending to a depth of about 2 feet bgs.

Compare COC Concentrations to Critical PCL

The maximum measured concentration is below the Tier 1 $^{Tot}Soil_{Comb}$ PCL protective of commercial/industrial exposure to lead in surface soils. However, the maximum concentration of lead in the affected property exceeds both the residential Tier 1 $^{Tot}Soil_{Comb}$ and $^{GW}Soil_{Ing}$ PCLs. For residential land

use, the Texas-specific median background concentration is the critical PCL. See TCEQ guidance document *Critical PCLs* (RG-366/TRRP-25) for more detailed guidance on determining the critical PCL and *Determining Representative Concentrations* (RG-366/TRRP-15) for further discussion of comparing critical PCLs to representative COC concentrations from the affected property.

Table 8. Comparison of Site Lead Data with Tiered PCLs

PCL	Tier 1	Tier 2	Maximum Concentration
^{Tot} Soil _{Comb} (Com/Ind)	1,600 mg/kg		982 mg/kg
^{Tot} Soil _{Comb} (Residential)	500 mg/kg		982 mg/kg
^{GW} Soil _{Ing}	3 mg/kg	1051 mg/kg	982 mg/kg
Texas-specific median background	15 mg/kg		982 mg/kg

Consider Progressing to Tier 2

Since soil lead concentrations exceed the residential critical PCL, the person may decide to either apply the Tier 1 PCL as a remedy objective, or develop a Tier 2 PCL based on site-specific data. In this case study, the following site-specific data were collected during the affected property assessment and installation of monitor wells for use in Tier 2.

The results of pH and textural analysis of soils revealed a site-specific soil pH of 7.4 to 7.6 for loamy soils. Soils contain concentrations exceeding the Texas-specific median background concentration of lead to a depth of 2 feet bgs. The depth to groundwater is 30 feet. The person can choose to use these data as site-specific affected property parameters to calculate a Tier 2 ^{GW}Soil_{Ing} PCL. Therefore, since some of the data pertinent to Tier 2 PCL development were collected during the affected property assessment, a Tier 2 PCL can now be developed with minimal additional cost to the person performing the response action.

Tier 2 calculations for Residential ^{Tot}Soil_{Comb}. Per §350.76(c) that is specific for lead, the Tier 1 residential ^{Tot}Soil_{Comb} PCL for lead is 500 mg/kg. However, the data needs for Tier 2 are extensive so the tiered process does not provide flexibility for lead for this exposure pathway.

Tier 2 calculations for ^{GW}Soil_{Ing}. Since the POE for potential groundwater ingestion is located below the affected soil, the Tier 2 ^{GW}Soil_{Ing} PCL is calculated using the following equation:

$${}^{GW}Soil_{Ing} = \frac{{}^{GW}RBEL_{Ing} \cdot LDF}{K_{SW}} \cdot \frac{L_2}{L_1}$$

Per §350.74(f)(2), the ^{GW}RBEL_{Ing} for lead in Class 1 and 2 groundwater is the most currently available federal action level for drinking water (i.e., 0.015

mg/L). Consequently, the $^{GW}RBEL_{Ing}$ is the same for both residential and commercial/industrial land use considerations.

Pertinent site-specific inputs for the Tier 2 $^{GW}Soil_{Ing}$ calculation are provided in Table 9. The Tier 2 Leachate Dilution Factor (LDF) was calculated for loamy soils with $5 < pH < 9$ and with L_1 (thickness of affected soil) = 2 ft and $L_2 = 30$ ft (Table 9). The pH data are used to determine a more appropriate soil-water partition coefficient (K_d) using Figure: 30 TAC §350.73(f)(1)(A) of the rule. The Tier 1 default values for air and water-filled porosity and soil bulk density are assumed for calculating K_{sw} . The LDF value for the Tier 2 $^{GW}Soil_{Ing}$ PCL was calculated using the LDF equation presented in: www.tceq.state.tx.us/assets/public/remediation/trrp/tier2.pdf, and site-specific soil and groundwater information in Table 9. The LDF was calculated to be 7.826.

Table 9. Site-Specific Data and LDF Calculation for Case Study Area A

Soil pH	Soil Texture	L_1	L_2	K_d	K_{sw}
7.5	Loam	2 feet	30 feet	597	0.001675
I_r	U_{gw}	W_s	b_{gw}	Calculated LDF	
14.5 cm/yr *	800 cm/yr	14.3 m	10 m	7.826	

* I_r , net infiltration rate of water through soil, based on 50 inches per year and a factor of 0.0009 for silt.

The Tier 2 PCL calculation is completed as follows (Table 10):

Table 10. $^{GW}Soil_{Ing}$ PCL Calculation Inputs for Lead.

$^{GW}Soil_{Ing} PCL = [GW PCL \times LDF / K_{sw}] \times L_2 / L_1$		
$^{GW}GW_{Ing}$ (mg/L)	Tier 2 LDF	Tier 2 $^{GW}Soil_{Ing}$ (mg/kg)
0.015	7.826	1051

The corresponding Tier 2 PCL value is 1051 mg/kg. As shown in Table 8, the maximum concentration of lead detected at the affected property (982 mg/kg) is below the Tier 2 $^{GW}Soil_{Ing}$ PCL. In this instance, the critical PCL remains $^{Tot}Soil_{Comb}$ PCL for residential land use, however, $^{GW}Soil_{Ing}$ is the critical PCL for commercial/industrial land use. Since the maximum concentration of lead is below the commercial/industrial critical PCL, no further action is required, pending execution of an appropriate institutional control to document commercial/industrial land use as the basis for the PCLs.

Case Study #2: Area B—Benzene and Naphthalene in Surface Soils and Subsurface Soils

Target COCs

Area B in Figure 2 represents a release of benzene and naphthalene. For purposes of this example, benzene and naphthalene are the only COCs. Refer to TRRP guidance document *Selecting Target COCs* (RG-366/TRRP-10) for further information regarding selection of COCs.

Source Medium Characterization

The affected soil was delineated laterally to benzene concentrations below 0.026 mg/kg (i.e. the residential assessment level based on the Tier 1 ^{GWSoil_{ing}} PCL) and naphthalene concentrations coincidentally below the MQL in a 140 ft by 140 ft area. Vertical assessment was achieved through the collection of samples at 5-foot depth intervals to the MQL for benzene and naphthalene at each boring location. There should not be a background concentration for organic COCs such as benzene and naphthalene since they are not naturally occurring. Soil analytical results revealed benzene concentrations decreasing from a maximum concentration of 200 mg/kg in the 0 to 5 foot soil interval to minimum concentrations still above the Tier 1 PCL of 0.026 mg/kg at 30 feet bgs. Naphthalene was detected at a maximum concentration of 50 mg/kg in soil with concentrations decreasing to below 1 mg/kg at the groundwater table. Based on the vertical assessment, the release reached groundwater which is present at 30 feet bgs. Monitoring wells were installed.

Land Use Classification

The landowner is willing to file a deed notice to limit use of the affected property for commercial/industrial purposes. Consequently, PCLs will be developed for commercial/industrial land use considerations. Note, however, since benzene has a federally promulgated maximum contaminant level (MCL), the ^{GWSoil_{ing}} PCL for benzene will be the same regardless of land-use considerations and will vary only based on site-specific affected property parameter values.

Classify Groundwater

In this example, the affected property is situated over a minor aquifer and a water well survey reveals no water wells within a ½ mile radius of the site. Potentially, the groundwater-bearing unit could be Class 1. The groundwater classification is significant because it determines the applicable groundwater PCL and as a result, it determines the ^{GWSoil} PCL value. Therefore, it is decided to classify the groundwater to verify the groundwater is not Class 1. A plume

management zone (PMZ) is a potential response action to address the exceedence of a groundwater PCL in Class 2 and 3 groundwater. If a PMZ can be established, then the PMZ will allow a higher $^{GW}Soil_{Ing}$ PCL to be justified. A groundwater aquifer test performed in monitor wells installed at the site revealed a well yield of 300 gallons per day. Therefore, the groundwater-bearing unit beneath the site is classified as Class 2. See TCEQ guidance documents *Application of Remedy Standards A and B* (RG-366/TRRP-28), *Soil and Groundwater Response Objectives* (RG-366/TRRP-29) and *Groundwater Classification* (RG-366/TRRP-8) for more information.

Identify Exposure Pathways and Applicable POEs

Based on the results of the source medium characterization and the information summarized in Table 5, the applicable pathways requiring PCLs for benzene and naphthalene contamination in surface soil are $^{Tot}Soil_{Comb}$ and $^{GW}Soil_{Ing}$. For subsurface soil, the applicable PCLs are $^{Air}Soil_{Inh-V}$ and $^{GW}Soil_{Ing}$. The corresponding POEs are located within the footprint of affected soil for the $^{Tot}Soil_{Comb}$ exposure pathway and at ground surface to 2 meters height above ground surface (the breathing zone) for the $^{Air}Soil_{Inh-V}$ exposure pathway and in groundwater directly below affected soil for the $^{GW}Soil_{Ing}$ exposure pathway.

Identify Tier 1 PCLs for Applicable Pathways

The affected property, as described above, is comprised of an approximate 0.5-acre area of soils containing elevated levels of benzene and naphthalene. Surface soil, subsurface soil and groundwater are affected. Surface water pathways are incomplete. Site assessment data are compared with Tier 1 PCLs for 0.5-acre source area in Table 11. Bolded values indicate which Tier 1 PCLs are exceeded.

Table 11. Comparison of COC Concentrations in Soil with Tier 1 PCLs.

PCL	Tier 1 (Commercial/Industrial)	Maximum COC Concentration
$^{Tot}Soil_{Comb}$ (benzene)	180 mg/kg	200 mg/kg
$^{Air}Soil_{Inh-V}$ (benzene)	270 mg/kg	50 mg/kg
$^{GW}Soil_{Ing}$ (benzene)	0.026 mg/kg	200 mg/kg ⁽¹⁾ 50 mg/kg ⁽²⁾
$^{Tot}Soil_{Comb}$ (naphthalene)	360 mg/kg	50 mg/kg
$^{Air}Soil_{Inh-V}$ (naphthalene)	370 mg/kg	30 mg/kg
$^{GW}Soil_{Ing}$ (naphthalene)	93 mg/kg	50 mg/kg ⁽¹⁾ 30 mg/kg ⁽²⁾
(1) Maximum Concentration in Surface Soils.		
(2) Maximum Concentration in Subsurface Soils.		

At Tier 1, the maximum concentrations of naphthalene do not exceed the critical PCL for naphthalene (93 mg/kg). Therefore, naphthalene in soil will not be evaluated further in the tiered PCL process as part of this case study. In contrast, the maximum concentration of benzene in the affected property exceeds the Tier 1 $^{GW}Soil_{Ing}$ and $^{Tot}Soil_{Comb}$ values. Therefore, based on site-specific data collected during the affected property assessment, Tier 2 $^{GW}Soil_{Ing}$ and $^{Tot}Soil_{Comb}$ PCLs are calculated as shown below.

Tier 2 Calculations for $^{GW}Soil_{Ing}$

Since the POE for potential groundwater ingestion is located below the affected soil, the Tier 2 $^{GW}Soil_{Ing}$ PCL is calculated using the following equation:

$$^{GW}Soil_{Ing} = \frac{\text{Groundwater PCL} \times \text{LDF}}{K_{sw}} \cdot \frac{L_2}{L_1}$$

(from: www.tceq.state.tx.us/assets/public/remediation/trrp/tier2.pdf)

Per §350.74(f)(2), the $^{GW}GW_{Ing}$ for benzene in Class 2 groundwater is the federally promulgated MCL for benzene in drinking water (i.e., 0.005 mg/L). Consequently, the $^{GW}GW_{Ing}$ is the same for both residential and commercial/industrial land use considerations, as well as under all three tiers. For Class 2 groundwater, the tiered process does not provide flexibility for COCs with an MCL, except in the context of setting a PMZ. Even then $^{GW}GW_{Ing}$ PCL itself is not changed, it is just applied to an alternate POE location.

Pertinent inputs for the Tier 2 $^{GW}Soil_{Ing}$ calculation are provided in Table 12. Refer to TCEQ guidance document *Development of Natural Attenuation Factors for PCLs* (RG-366/TRRP-26) for details regarding the Tier 2 NAF calculation procedures.

The results of analysis of soils using the Walkley-Black method revealed a site-specific fraction organic carbon (f_{oc}) of 2 percent (i.e., 0.02 g/g). Additional geotechnical analysis reveals a site-specific volumetric water content of 31 percent of soil with total porosity of 38 percent. Soils are impacted with benzene concentrations at or exceeding the Tier 1 $^{GW}Soil_{Ing}$ PCL to the depth of groundwater at 30 feet. These data may be used as site-specific inputs along with other groundwater data in Table 12 to calculate a Tier 2 $^{GW}Soil_{Ing}$ PCL. The resulting LDF and PCL calculation inputs for benzene are presented in Table 13. The corresponding benzene Tier 2 $^{GW}Soil_{Ing}$ value is 0.059 mg/kg.

Table 12. Site-Specific Data for Case Study #2 Area B.

Term	Definition	Units	Tier 1 Default	Tier 2 Site-specific Value
f_{oc}	Fraction Organic Carbon	g-carbon/g-soil	0.002	0.02
K_{oc}	Benzene	cm ³ -H ₂ O /cm ³ -soil	66	66
K_d	Soil-water partition coefficient = $K_{oc} \times f_{oc}$	cm ³ -water/ g-soil	0.132	1.32
K_{sw}	Soil-leachate partition factor for COC	mg/L-water/ mg/kg-soil	Calculated	Calculated
L_1	Thickness of affected soil	cm	$L_2 = L_1$	914
L_2	Depth from top of affected soil to water-bearing unit	cm	$L_2 = L_1$	914
θ_{as}	Volumetric air content of vadose zone soils	cm ³ -air/ cm ³ -soil	0.21	0.07
θ_{ws}	Volumetric water content of vadose zone soils	cm ³ -water /cm ³ -soil	0.16	0.31
U_{gw}	Groundwater Darcy velocity	cm/yr	-	800
H'	Henry's Law constant	cm ³ -water /cm ³ -air	0.227	0.227
W_s	Width of soil source area parallel to flow	m	-	14.30

Table 13. ^{GW}Soil_{Ing} LDF and PCL Calculation Inputs for Benzene.

^{GW} GW _{Ing} (mg/L)	Tier 2 LDF	K_{sw} (L/kg)	L_2/L_1	Tier 2 ^{GW} Soil _{Ing} (mg/kg)
0.005	7.826	0.6594	1	0.059

Tier 2 Calculation for ^{Tot}Soil_{Comb}

The equations for the ^{Tot}Soil_{Comb} PCL for commercial/industrial land use are shown below:

$${}^{Tot}Soil_{Comb} = \frac{1}{\left[\left(\frac{1}{Air\ Soil_{Inh-VP}} \right) + \left(\frac{1}{Soil\ Soil_{Ing}} \right) + \left(\frac{1}{Soil\ Soil_{Derm}} \right) \right]} \text{ where:}$$

$Soil\ Soil_{Derm} = Soil\ RBEL_{Derm}$ (note: this RBEL is not calculated for benzene since its vapor pressure is greater than 1 mm Hg; see §350.74(c))

$Soil\ Soil_{Ing} = Soil\ RBEL_{Ing}$

$Air\ Soil_{Inh-VP} = Air\ RBEL_{Inh-VP} \times NAF$

It is apparent from the equations above that two of the pathway specific PCLs (i.e., dermal and ingestion) are equal to their corresponding RBELs since there is no cross-media transfer associated with the ingestion and dermal exposure pathway, hence $NAF = 1$. Consequently, the $Soil_{Soil_{Derm}}$ and $Soil_{Soil_{Ing}}$ PCLs typically do not change as a result of the Tier 2 evaluation. However, the $Air_{Soil_{Inh-VP}}$ PCL will change in the Tier 2 evaluation as a consequence of calculating a site-specific Tier 2 NAF.

Using the site-specific data provided in Table 12 and the methodology described in TCEQ guidance document *Development of Natural Attenuation Factors for PCLs* (RG-366/TRRP-26), the Tier 2 NAF is $46,200 \text{ m}^3/\text{kg}$. The Tier 2 PCLs are calculated as shown below:

$$^{Air}Soil_{Inh-VP} = ^{Air}RBEL_{Inh-VP} \left[\text{mg}/\text{m}^3 \right] \times NAF \left[\text{mg}/\text{kg} - \text{soil} \div \text{mg}/\text{m}^3 - \text{air} \right] =$$

$$0.019 \text{ mg}/\text{m}^3 \times 46,200 \text{ m}^3/\text{kg} = 878 \text{ mg}/\text{kg}$$

Calculate $^{Tot}Soil_{Comb}$

$$^{Tot}Soil_{Comb} = \frac{1}{\left[\left(\frac{1}{^{Air}Soil_{Inh-VP}} \right) + \left(\frac{1}{Soil_{Soil_{Ing}}} \right) + \left(\frac{1}{Soil_{Soil_{Derm}}} \right) \right]} =$$

$$\frac{1}{\left[\left(\frac{1}{878 \text{ mg}/\text{kg}} \right) + \left(\frac{1}{520 \text{ mg}/\text{kg}} \right) + 0 \right]} = 327 \text{ mg}/\text{kg}$$

The pertinent Tier 2 PCLs for benzene are summarized in Table 14.

Table 14. Summary of Tier 2 PCLs for Benzene.

Pathway	Tier 2 PCL for Benzene (mg/kg)
Inhalation: $^{Air}Soil_{Inh-VP}$	878
Ingestion: $Soil_{Soil_{Ing}}$	520
Dermal: $Soil_{Soil_{Derm}}$	N/A
Combined: $^{Tot}Soil_{Comb}$	327
Soil to Groundwater: $^{GW}Soil_{Ing}$	0.059

The maximum benzene concentrations of 200 mg/kg (surface soil) and 50 mg/kg (subsurface soil) are then compared with the calculated Tier 2 PCLs in Table 14. These benzene concentrations are below the Tier 2 $^{Air}Soil_{Inh-VP}$ and $^{Tot}Soil_{Comb}$ PCLs, but exceed the Tier 2 $^{GW}Soil_{Ing}$ PCL.

Tier 3 Approach for ^{GW}Soil_{Ing}

Since the maximum concentration in the soil exceeded the Tier 2 ^{GW}Soil_{Ing} PCL, the USEPA Synthetic Precipitation Leaching Procedure (SPLP) was conducted on soil samples having high concentrations of benzene to confirm if the soil leachate is a true concern. The SPLP results can be directly compared to the applicable groundwater PCL. If the SPLP result does not exceed the groundwater PCL, then soil leachate is protective and no ^{GW}Soil_{Ing} PCL needs to be established.

Box 3. SPLP Data.

It is not appropriate to couple the synthetic precipitation leaching procedure (SPLP) result with an LDF or L_2/L_1 ratio in the ^{GW}Soil PCL equation. Also, SPLP results cannot be used in response to §350.73(f)(1) to determine a site-specific K_d , as is further explained on Table 1 of *Toxicity Factors and Chemical/ Physical Parameters (RG-366/TRRP-19)*. See also the preamble to the 2007 TRRP rule amendment (32 TexReg 1526-1579).

In this example, the SPLP result is 0.06 mg/L, which is greater than the 0.005 mg/L ^{GW}GW_{Ing} PCL. The SPLP results indicate the soil benzene concentrations are not protective of groundwater. Therefore, a response action is warranted unless the person finds additional flexibility using a different PCL development approach under Tier 3.

Case Study #2 Continued: Area B—Benzene and Naphthalene in Groundwater

This example is a continuation of Case Study #2 and illustrates Tier 2 modification to the groundwater volatilization NAF for benzene and, in the case of naphthalene, the potential flexibility of Tier 2 for setting the ^{GW}GW_{Ing} PCL for a COC where there is no federal MCL or action level. For naphthalene, this example presents the case where the exposure factors for commercial/industrial land use are modified in accordance with §350.74(j)(2) that involves public notice and approval by the sitting executive director.

Target COCs

Area B represents a release of benzene and naphthalene that has affected surface soils, subsurface soils and groundwater at a depth of 30 feet bgs. For purposes of this example, benzene and naphthalene are the only COCs.

Source Medium Characterization

In this case, groundwater was encountered in monitoring wells at 30 feet bgs. Benzene was detected in groundwater with a concentration of 50 mg/L beneath the source area (i.e., the affected soil described in the previous example) and 1 mg/L at a distance of approximately 50 feet downgradient from the source. The extent of benzene in groundwater was delineated to below 0.005 mg/L (the groundwater assessment level was based on ^{GW}GW_{Ing})

at a distance of about 150 feet from the source area and to a width perpendicular to groundwater transport of about 115 feet. Naphthalene was detected with a maximum concentration of 10 mg/L in the source area. The naphthalene was delineated in groundwater to 1.5 mg/L, (the groundwater assessment level was based on $^{GW}GW_{Ing}$), at a distance of 45 feet downgradient of the source area and to a width perpendicular to groundwater transport of 25 feet.

Land Use Classification

Where groundwater is concerned, land use considerations are PCL specific. Since benzene has a federally promulgated MCL, the groundwater ingestion-based PCL ($^{GW}GW_{Ing}$) will be the same for benzene regardless of intended land use. Since the landowner is willing to file a deed notice to limit use of the affected property for commercial/industrial purposes, the $^{GW}GW_{Ing}$ PCL for naphthalene and the $^{Air}GW_{Inh-v}$ PCLs for naphthalene and benzene will be developed for commercial/industrial land use considerations.

Classify Groundwater

As stated in the previous example, the groundwater-bearing unit is classified as Class 2 groundwater.

Identify Exposure Pathways and Applicable POEs

The applicable pathways requiring PCLs for benzene and naphthalene in Class 2 groundwater are $^{GW}GW_{Ing}$ and $^{Air}GW_{Inh-v}$. There is not a single POE for $^{GW}GW_{Ing}$, rather the POE for $^{GW}GW_{Ing}$ is located throughout the uppermost groundwater-bearing unit. The POE for $^{Air}GW_{Inh-v}$ is located at the ground surface to 2 meters height above ground surface (the breathing zone) directly above the affected groundwater. Surface water bodies are not present in the area.

Identify Tier 1 PCLs for Applicable Pathways

The groundwater source area size for $^{Air}GW_{Inh-v}$ for benzene is greater than 0.5 acres. Source area size is only relevant to the $^{Air}GW_{Inh-v}$ exposure pathway, and not $^{GW}GW_{Ing}$ exposure pathway, because only the $^{Air}GW_{Inh-v}$ pathway has a $NAF > 1$. Source area size is specific for each COC for each NAF-based exposure pathway in each environmental medium. Therefore, under Tier 1 in this example, the 30-acre source area $^{Air}GW_{Inh-v}$ PCL, and the $^{GW}GW_{Ing}$ PCL are applicable for benzene. For naphthalene, the 0.5-acre source area $^{Air}GW_{Inh-v}$ PCL is applicable because the groundwater source area size for naphthalene does not exceed 0.5 acres. Therefore, the 0.5-acre $^{Air}GW_{Inh-v}$ PCL and $^{GW}GW_{Ing}$ PCL are applicable for naphthalene.

Compare COC Concentrations to Critical PCL

A summary of COC concentration data compared with Tier 1 commercial/industrial PCLs is shown in Table 15. Bolded values indicate which Tier 1 PCLs are exceeded. The maximum concentration of benzene in groundwater exceeds both the Tier 1 $^{GW}GW_{Ing}$ and $^{Air}GW_{Inh-V}$ PCLs. The maximum concentration of naphthalene exceeds the Tier 1 $^{GW}GW_{Ing}$ PCL. See TCEQ guidance documents *Critical PCLs* (RG-366/TRRP-25) and *Determining Representative Concentrations* (RG-366/TRRP-15) for further discussion on comparing critical PCLs with representative concentrations.

Table 15. Comparison of COC Concentrations with Tier 1 Commercial/Industrial PCLs.

PCL	Tier 1 PCL value	Maximum Concentration
$^{Air}GW_{Inh-V}$ (benzene 30 acres)	39 mg/L	50 mg/L
$^{GW}GW_{Ing}$ (benzene)	0.005 mg/L	50 mg/L
$^{Air}GW_{Inh-V}$ (naphthalene 0.5 acre)	440 mg/L	10 mg/L
$^{GW}GW_{Ing}$ (naphthalene)	1.5 mg/L	10 mg/L

Consider Progressing to Tier 2

For naphthalene, the critical Tier 1 PCL is the $^{GW}GW_{Ing}$ value. In the case of naphthalene, this value is a risk-based exposure limit (RBEL) that, for commercial-industrial land use considerations, can only be modified under Tier 2 in accordance with §350.74(j)(2).

The critical Tier 1 PCL for benzene is also the $^{GW}GW_{Ing}$ value. However, in the case of benzene, this value is based on the MCL and therefore cannot be adjusted via §350.74(j)(2). However, since groundwater at this affected property is Class 2, the POE could be moved to an alternate (downgradient) location, provided that appropriate controls are established as part of a Remedy Standard B response action involving a PMZ. See TCEQ guidance document *Human Health Points of Exposure* (RG-366/TRRP-21) for guidance on setting groundwater POEs in the context of a PMZ. Using a PMZ under Tier 2 involves calculating an attenuation action level at the point of interest which is protective of groundwater ingestion at the alternate downgradient POE. This can be done using the lateral groundwater transport model described in the Tier 2 equations (www.tceq.state.tx.us/assets/public/remediation/trrp/tier2.pdf) or methods described in the TCEQ guidance document *Monitored Natural Attenuation Demonstrations* (RG-366/TRRP-33) for a plume that is stable or decreasing in size due to natural attenuation processes. Alternatively, a Tier 3 method can be employed to determine the attenuation action level. However, for Class 2 groundwater cases, if the calculated attenuation action level for the groundwater source area exceeds the maximum measured groundwater concentration in the source area at the time of Response Action Plan (RAP) submittal, then the maximum measured groundwater concentration will be

the attenuation action level in the groundwater source area (see §350.33(a)(2)). The concentration of benzene in this example, measured in the source area at the time of submitting the RAP, can be used as an attenuation action level for the groundwater source area. The Tier 2 evaluation for benzene will then focus on calculating a Tier 2 PCL for the groundwater-to-ambient air pathway for the PMZ to determine if maximum groundwater concentrations exceed the $AirGW_{Inh-v}$ PCL.

Calculate Tier 2 $AirGW_{Inh-v}$ PCL for Benzene

Some pertinent site-specific inputs for the Tier 2 $AirGW_{Inh-v}$ calculation are provided in Table 16. The results of geotechnical analysis of soils revealed a site-specific volumetric water content of 31 percent with total porosity of 38 percent. Depth to groundwater is 30 feet, and the average wind speed above ground surface in the area is 358 cm/sec. These data may be used as site-specific inputs to calculate a Tier 2 $AirGW_{Inh-v}$.

Table 16. Site-Specific Data for Case Study Area B.

Term	Definition	Units	Tier 1 Default	Tier 2 Value
U_{air}	Windspeed above ground surface	cm/sec	240	358
h_v	Thickness of vadose zone soil	cm	300	909
L_{gw}	Depth to groundwater	cm	305	914
θ_{as}	Volumetric air content of vadose zone soils	cm^3 -air/ cm^3 -soil	0.21	0.07
θ_{ws}	Volumetric water content of vadose zone soils	cm^3 -water/ cm^3 -soil	0.16	0.31

The calculation of Tier 2 NAF for the $AirGW_{Inh-v}$ PCL is described in further detail in *Development of Natural Attenuation Factors for PCLs* (RG-366/TRRP-26). Using the site-specific data provided in Table 16 and the methodology described in RG-366/TRRP-26, the Tier 2 NAF is 709,000 m^3/L . The Tier 2 PCL is calculated as shown below.

Calculate $AirGW_{Inh-v}$

$$AirGW_{Inh-v} = AirRBEL_{Inh-v} \left[mg/m^3 \right] \times NAF \left[(mg/L - water) \div (mg/m^3 - air) \right] = 0.019 \text{ mg}/m^3 \times 709,000 \text{ m}^3/L = 13,471 \text{ mg}/L$$

The Tier 2 $AirGW_{Inh-v}$ PCL for benzene exceeds the chemical-specific aqueous solubility of benzene in water; therefore, the solubility of benzene in water (1,770 mg/L) can be used as a theoretical ceiling for $AirGW_{Inh-v}$. Thus, the maximum groundwater concentration (50 mg/L) is below the Tier 2 $AirGW_{Inh-v}$

PCL based on solubility. Though not discussed further in this case study, in situations when the measured concentration of a COC exceeds one percent (1%) of its aqueous solubility, determine if the COC is present as NAPL. Address this concern by evaluating the NAPL occurrence matrix and response action triggers described in the TCEQ guidance document *Risk-Based NAPL Management* (RG-366/TRRP-32). §350.78(b) could also apply.

As discussed previously in this example, given a successful monitored natural attenuation demonstration, the maximum concentration of benzene detected in groundwater at the source (50 mg/L) at the time of submitting the RAP which contains the PMZ proposal becomes the attenuation action level to be met in groundwater at the source area. Since the maximum detected concentration is lower than the calculated Tier 2 $^{Air}GW_{Inh-V}$ PCL, the PMZ will also be protective of the ambient air inhalation pathway. In this case, the critical PCL for benzene is still 0.005 mg/L, but it now applies at alternate POEs situated at the limits of the PMZ. Therefore, further response actions could focus on managing the PMZ so that the critical PCL is not exceeded at the alternate POEs.

Calculate Tier 2 $^{GW}GW_{Ing}$ PCL for Naphthalene

This example is designed to illustrate potential adjustment to a RBEL based on use of exposure factors associated with commercial/industrial land use. Also, this example illustrates the potential flexibility of Tier 2 for setting the $^{GW}GW_{Ing}$ PCL for a COC where there is no federal MCL or action level. The Tier 1 PCL for naphthalene and the maximum groundwater concentration were shown in Table 15.

Under Tier 2 and in accordance with §350.74(j)(2), the exposure duration, exposure frequency, and averaging time potentially could be adjusted but will require public notice and approval *by the sitting Executive Director*. TCEQ staff will not be able to “pre-approve” the proposed adjustments for the person prior to the person conducting the public notice as required by the rule, or prior to them being taken to the Executive Director for consideration, but TCEQ staff can verify the information is administratively complete in advance of the public notice or Executive Director consideration. For this example, we will presume that the person is considering the advantage of pursuing RBEL adjustments.

The $^{GW}GW_{Ing}$ PCL is equal to $^{GW}RBEL_{Ing} \times NAF$ where $NAF = 1$. The $^{GW}RBEL_{Ing}$ has the following equation:

$$^{GW}RBEL_{Ing} = \frac{RfD_o \times HQ \times BW.A \times AT.w \times 365 \text{ days/yr}}{IR.w \times EF.w \times ED.w}$$

where,

- RfD_o = Reference dose, oral, 0.02 mg/kg-day
HQ = Hazard Quotient, 1 unitless
BW.A = Adult body weight, 70 Kg
AT.w = Averaging Time, workers, 25 years
IRw.w = Water Ingestion Rate, workers, 1.4 L/day
EF.w = Exposure Frequency, workers, 250 modified to 5 days/year
ED.w = Exposure Duration, workers, 25 years

Since the property is designated for commercial/industrial land use, the person elects to modify the exposure frequency (EF.w) under Tier 2 from 250 days/year to 5 days/yr and will document this in a deed notice for the on-site property in accordance with the rule. The 5-days/yr modification is extreme and substantial documentation must be provided that the property is only used at that frequency. Assuming Tier 1 default RBEL values for all other factors (NAF remains unchanged at 1), the ^{GW}GW_{Ing} PCL is 73 mg/L. For this example, the PCL is a higher concentration than the maximum measured groundwater concentration. Therefore, a groundwater response action is not required. As a consequence of the ^{GW}GW_{Ing} PCL adjustment, the Tier 1 ^{GW}Soil_{Ing} PCL will increase proportionally (approximately 50 times higher).