

Risk assessment is an important tool in engineering, esp. environmental engineering.

Risk assessment essentially tries to answer the following question

What is the probability that an undesirable consequence will occur as a result of exposure to some situation.

Coin toss

- 2 players, "public" & "corporation" each put a dollar into a "reward." Flip a coin once, "public" = heads "corporation" = tails.

If heads public takes all, tails corporation takes all.

$$\text{Expected gain} = 2^{00} \times 0.5 = 1^{00}$$

$$\text{Actual loss} = 1^{00}, \text{ Net expected benefit} = \text{gain} - \text{loss} = 0^{00} \quad (\text{Zero-sum})$$

- Now flip a coin, if it comes up "heads" corporation pays public 1^{00} , if tails corporation pays nothing.

In this example the corporation must play;

$$\text{Actual gain} = 0^{00}$$

$$\text{Expected loss} = (1^{00}) \times 0.5 = \$0.50 \leftarrow \underline{\text{Risk}}$$

Risk management

- Techniques employed to make the loss bearable (insurance).
- Techniques employed to make the dose smaller (pollution treatment; discharge limits)
- Techniques employed to reduce exposure (limited access; cyclone fencing; vector control).

chemicals in the environment

Hazardous chemicals

Ignitability, Corrosivity, Reactivity, Toxicity. - properties that cause a consequence.

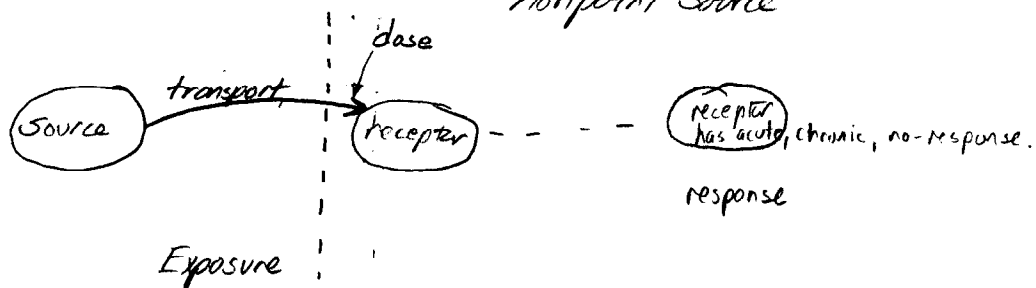
Effects

Acute - immediate

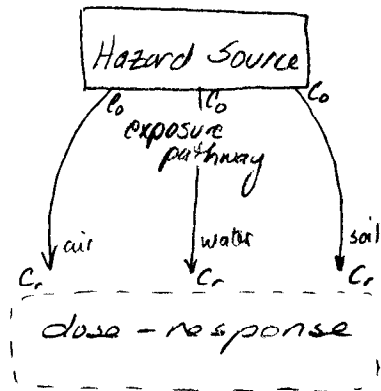
Chronic - long term; delayed.

Transport from source to receptor.

Sources of materials - Biological cycles
domestic waste
industrial waste
nonpoint source



What is the risk associated with the assimilation of a certain compound at a certain concentration over short (acute) and long (chronic) exposure?



$$\frac{C_r}{C_0} \approx \frac{1}{DAF} \quad \text{DAF "dilution attenuation factor"}$$

Exposure concentration

- source, production rate, release rates
- transformation during transport
- Estimate population at risk
 - occupation, medical surveillance; socioeconomic use habits

Dose response

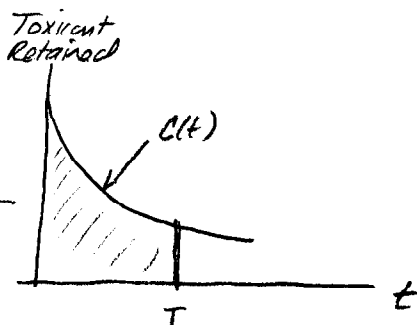
For response material must cause a consequence and receptor must be exposed

- very toxic, no exposure - not a hazard
- slightly toxic, high exposure - could be very hazardous

- Amount of toxicant absorbed is decreased by metabolic activity if exposure is terminated

Retenhuin Dase

$$\int_0^T C(t) dt = \text{retention dose}$$



Lifetime (70yrs) is called dose commitment

Typ. formula

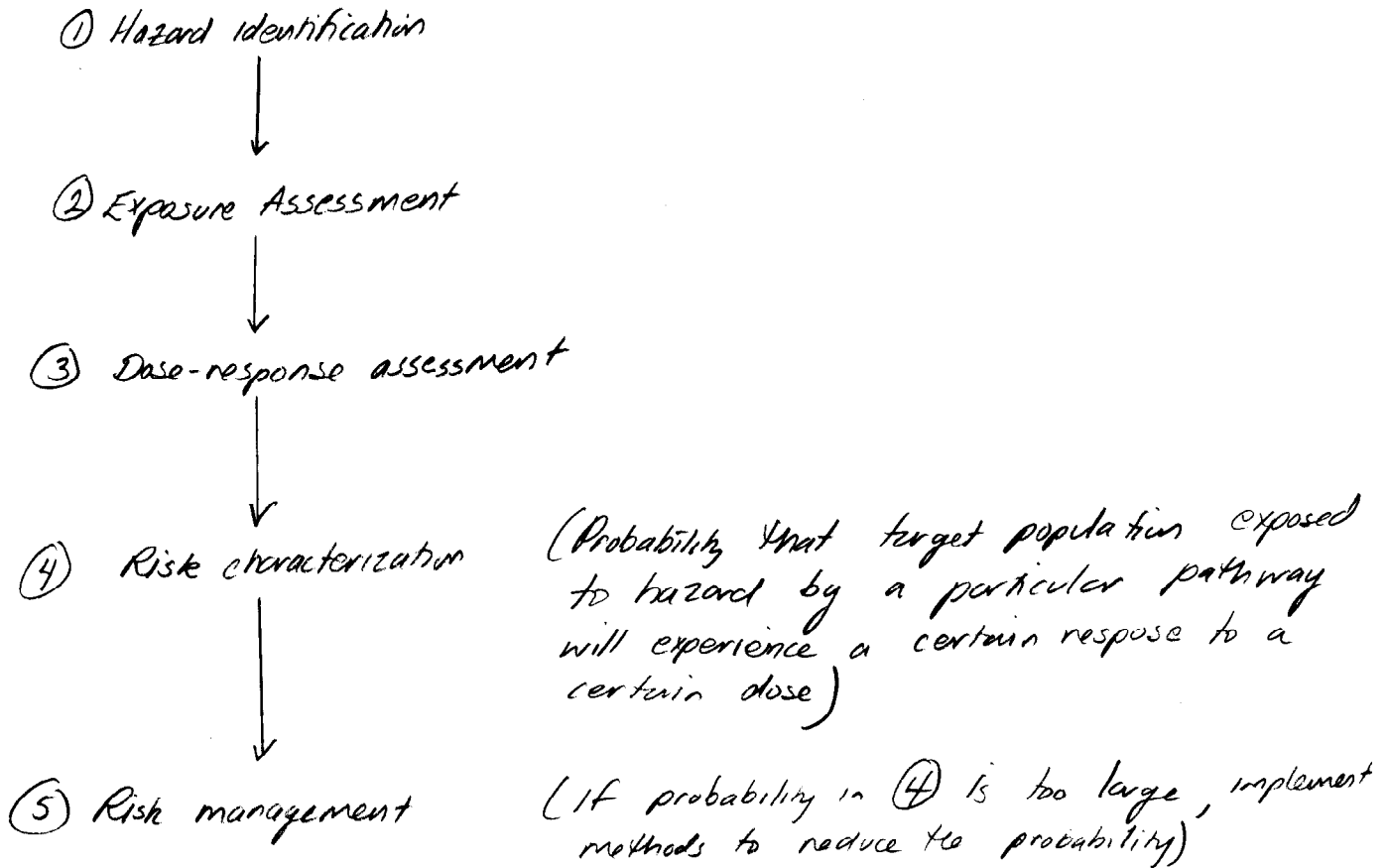
$$R = C \cup D$$

↑
↑
 concentration retention dose factor.

Threshold - Drug therapy threshold doses (mg/kg) where response changes. Usually 2 threshold. Lower threshold, beneath which no therapeutic effect is observed, upper threshold where damage occurs. Toxicants are also thought to have thresholds. Current practice is to use 1% of animal model threshold dose as acceptable human exposure.

Latency - Period between exposure and response increases as dose is decreased. $t = \left(\frac{K}{D}\right)^n$

Typical Risk Assessment Approach



Dose-response

depends on compound and route of entry into body.

Also depends on target organs. Many organs can withstand/repair if dose is small.

Acute Toxicity.

Lethal dose - amount of compound required to kill organism.

Usually LD_{50} ; Amount to kill $\frac{1}{2}$ of target population.

Shape of curve matters. LD_{50} by experiment is not pertained on humans.

Mutagenic compound

causes a mutation in cell DNA, may lead to cancer (carcinogen) or offspring birth defect (teratogen)

Testing

- Acute toxicity in animals
- Mutagenic testing in bacteria
- Chronic carcinogenic bioassay

Human Studies

- Usually by epidemiology
- Occasionally as result of drug testing / distribution.
 - warning read the labels of drugs & manufacturer circular.
(celebrex, viox) 12 week clinical trials, but intended for long-term OA therapy. intestinal bleeding effects
(provacid) heartburn; 120 days maximum therapy period.
liver metabolized effects on liver function

Simple epidemiologic analysis by matrix rate comparison

- ① divide population into exposed & not exposed groups.
- ② divide groups into consequence and no consequence

	C	\bar{C}
E	a	b
\bar{E}	c	d

$$\text{relative risk} = \frac{a}{a+b} \cdot \frac{c+d}{c}$$

Is probability of consequence higher in exposed group?

If > 1 then exposure may be a causal agent

attributable risk

$$\frac{a}{a+b} - \frac{c}{c+d} \quad \text{If } > 0 \text{ then exposure may be a causal agent}$$

odds ratio

$$\frac{ad}{bc}$$

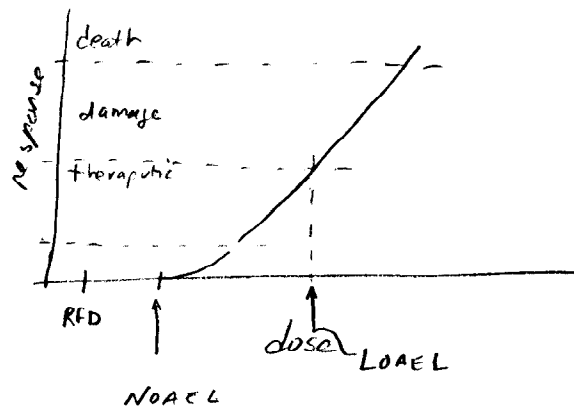
Once these types of data suggest a relationship much more rigorous statistical hypothesis testing is indicated

Currently EPA uses a weight-of-evidence approach.

It is intentionally overconservative.

Dose-Response extrapolation - controversial, various methods.

Lowest-observed-effect level



Various methods - INREC website, RBCA document

Comparative risk - Likelihood equivalent.

For Risk you need three things

- ① Exposure
- ② Dose
- ③ Consequence

Break any one of these apart and you can reduce actual risk



TNRCC Regulatory Guidance

Remediation

RG-366/TRRP-1

February 2000

SUBJECT: An Introduction to the Texas Risk Reduction Program

Objectives: This informational pamphlet introduces a new TNRCC environmental cleanup regulation and will cover the following:

- [Is the TRRP rule in effect yet?](#)
- [What types of sites does it apply to?](#)
- [Why is there a new rule?](#)
- [What is regulated under TRRP?](#)
- [Is the TRRP rule different from the 1993 rule?](#)
- [If I switch to the TRRP, do I have to start over?](#)
- [If I will be using the TRRP, what should I do?](#)
- [List of planned TRRP guidance.](#)

Audience: General Public, Regulated Community, and Environmental Professionals. In this document, “you” refers specifically to the person regulated by or implementing the TRRP rule.

References: The regulatory citation for the Texas Risk Reduction Program (TRRP) Rule is 30 TAC 350.

The TRRP Rule and Preamble are online at

<http://www.tnrcc.state.tx.us/oprd/rules/indxpdf5.html>.

The TRRP Rule, together with conforming changes to related rules, is contained in 30 Texas Administrative Code Chapter 350 (30 TAC 350), and was published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). Download Tier 1 PCL Tables, toxicity factors, and other TRRP information at <http://www.tnrcc.state.tx.us/permitting/trrp.htm>.

Contacts: Technical Support Section at 512/239-0310.

Corrective Action Section at 512/239-2343. Responsible Party Remediation Section at 512/239-2200. Site Assessment & Management Section at 512/239-2509. Superfund Cleanup Section at 512/239-2425. Voluntary Cleanup Program Section at 512/239-5891.

The Texas Natural Resource Conservation Commission (TNRCC) has adopted a new rule, the Texas Risk Reduction Program (TRRP). TRRP most commonly regulates the cleanup and management of hazardous wastes and substances, referred to as chemicals of concern (COCs), which are released into the environment from regulated commercial and industrial facilities, and on the closure of waste management facility components (e.g., tanks, container storage areas, surface impoundments). TRRP begins to apply on May 1, 2000. However, you may choose to have TRRP apply to your affected property before this date.

Releases of COCs can affect the quality of our air, groundwater, and other environmental media (Figure 1) and may pose unacceptable risks to human health and the environment.

However, when cleaned up to protective levels or properly managed, the releases do not pose unacceptable risk.

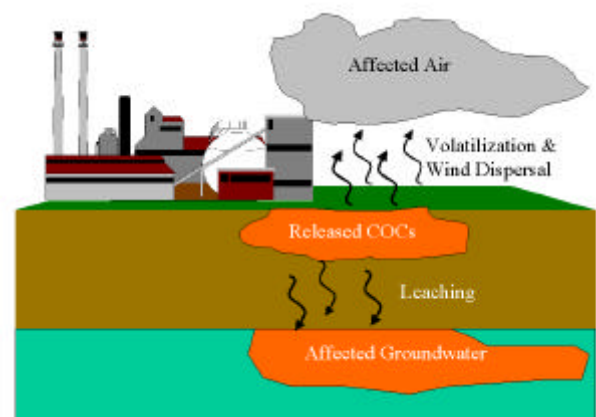


Figure 1. How COCs affect environmental media

The TRRP sets out new requirements for how to determine if releases or closures pose unacceptable risk. If they do, the rule defines requirements for what must be done to reduce the risk, prevent pollution, or protect natural resources.

The purpose of this document is to introduce the new TRRP and provide some basic background information, highlight some important features of the new rule, provide an overview of the applicability of the TRRP, and discuss how to transition to using the new rule.

Is the TRRP in effect yet?

Yes, TRRP went into effect on September 23, 1999. People can voluntarily use the rule now, but the rule does not have to be applied until May 1, 2000. However, even then the rule does not have to be applied if certain “grandfathering” conditions are met.

What types of sites does it apply to?

The TRRP applies to releases of COCs into the environment that are produced, stored, or disposed at commercial and industrial facilities or operations. The TRRP also applies to the closure of tanks, landfills, and other waste management facility components at locations that are regulated under any of these programs:

- State Superfund Program,
- Industrial Solid Waste and Municipal Hazardous Waste Program,
- Voluntary Cleanup Program,
- Underground Injection Control Program,
- Wastewater Treatment Program,

Some landfills regulated by the Municipal Solid Waste Program are also covered by the TRRP.

Beginning September 1, 2003, TRRP will also apply to the Petroleum Storage Tank Program.

For more information regarding the applicability of the TRRP, please see *TRRP Applicability and Grandfathering* (RG-366/TRRP-2).

Why is there a new rule?

This new rule was established for the following reasons:

- To keep pace with the advancement in the science of setting environmental cleanup levels.
- To implement new regulatory flexibility to encourage people to voluntarily address environmental problems.
- To clarify and further develop provisions that were contained within the former rules.
- To create one set of rules that can be universally applied to environmental releases covered under the different TNRCC remediation programs.

What is regulated under TRRP?

The rule defines the requirements for assessing the extent of the environmental problem, establishing human-health and environmentally protective concentration levels (PCLs), and cleaning up or controlling the environmental problem. The rule also addresses applicability, grandfathering matters, and report filing requirements. Complying with the TRRP rule involves the four key steps illustrated in Figure 2.

In each of these steps you may be required to file related notices, reports, or both. We are in the process of developing detailed guidance documents for each element of these steps. See the table at the end of this document for the tentative date by which each of these guidance documents will be available. This table will be updated on the web at www.tnrcc.state.tx.us/permitting/trrp.htm.

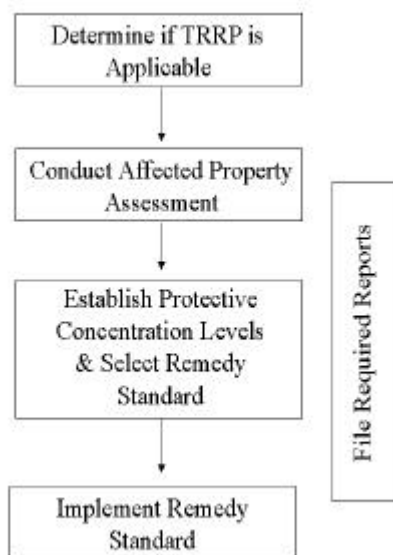


Figure 2. Complying with the TRRP Rule

Determine Applicability

The process begins with establishing the applicability of the TRRP to a given environmental problem. See the rule and *TRRP Applicability and Grandfathering* (RG-366/TRRP-2) for more information.

Assess Affected Property

The rule sets out guidelines to adequately assess the extent of any COCs in soil and groundwater, impacts to other environmental media, and the general surface and subsurface conditions at the affected property. As part of the assessment, the land and groundwater affected by the COCs must be classified in accordance with criteria defined in the rule so that proper cleanup levels and cleanup requirements can be established.

For example, the land use, which must be classified as either residential or commercial/industrial, is important because different cleanup levels are established for each of the land uses. More stringent cleanup levels are applied to residential properties than commercial/industrial properties.

Similarly, a groundwater classification system is set in the rule so that the sensitivity and use potential of the groundwater, which is different in different areas of the state, can be considered when setting cleanup levels and cleanup requirements. These new guidelines are different from those set forth in the previous rules. These new rule requirements appear in 30 TAC §§350.51-350.54.

Additionally, as part of the affected property assessment, the rule lists requirements notifying owners of properties that were sampled or affected by COCs and people who may be potentially exposed to levels of COCs that could pose a risk that critical information from the assessment is available. These new notification requirements appear in 30 TAC §350.55.

Establish PCLs

The rule sets out procedures for calculating cleanup levels that are protective of human health and the environment referred to as protective concentration levels (PCLs) in the rule. The procedures to calculate PCLs are set forth as Tier 1, 2, or 3.

Tier 1 is the simplest and cheapest method to set protective concentration levels, but generally results in the most stringent levels. Tier 3 uses the most sophisticated methods and is likely the most expensive, but it factors in the most site-specific considerations. Because of this, it makes sense to start with Tier 1 and progress to Tier 2 or 3 only when warranted.

On the other hand, under the tiered process for ecological issues, Tier 1 is actually a checklist that determines whether you must move into Tier 2 or 3 to set protective concentration levels.

COCs that are found in concentrations higher than the calculated PCLs must be cleaned up or controlled under one of the two remedy standards established in the rule. These rule requirements appear in 30 TAC §350.71-350.79.

Implement Remedy Standards

The rule provides two remediation options to address COCs that exceed protective concentration levels: Remedy Standard A and Remedy Standard B. These rule requirements appear in 30 TAC §§350.31-350.33 and §350.37.

- Remedy Standard A is a cleanup option. A person may initiate or “self-implement” Remedy Standard A without seeking prior approval from the TNRCC. However, you must submit a Self Implementation Notice to the TNRCC 10 calendar days before the actual cleanup begins.
- Remedy Standard B provides the option to control and manage the COCs instead of cleaning them up. Under Remedy Standard B, the COCs must be controlled and managed such that their extent does not spread in an unauthorized manner and so that no one will be exposed to COCs at a level above the PCL.

If Remedy Standard B is used, then long term monitoring will most likely be required, financial assurance may be required, and institutional controls (deed notices and restrictive covenants) must typically be filed in the county deed records. Remedy Standard B cannot be self-implemented. A Response Action Plan must be submitted to and approved by the TNRCC before a person can use Remedy Standard B.

File Reports

The rule defines notices and reports you may have to file at various points in the process. The number and type of notices and reports you must submit depends on whether you choose to self-implement cleanup, the remedy standard selected, and how long the remedy takes to complete.

Small, quickly addressed problems will require fewer reports than a large, complex problem that takes a long time to address. Further, you may combine several reports into a single report when that is most efficient. The report requirements appear in 30 TAC §§350.91-350.96.

Is the TRRP rule different from the 1993 rule?

Yes, some of the former requirements have been modified. Specifically, the new rule:

- sets up a new land use and groundwater classification system;
- modifies the method by which cleanup levels are set;
- modifies the assessment requirements; and
- provides more clarity for when controls may be allowed in lieu of cleanup, among other things.

For more details see *Comparison of 30 TAC 335 and 30 TAC 350: Points to Consider in Making the Shift* (RG-366/TRRP-4), which describes key differences between the TRRP and the 1993 rule.

If I switch to the TRRP, do I have to start over?

This is a logical question if you have already begun to address a release under the 1993 rule — and no, you will not have to start over. But you may have to do some things differently, perhaps do some additional work, or redo some work to conform with TRRP requirements. If you complied with the assessment requirements of the 1993 rule then you may have adequately addressed the TRRP assessment requirements (the 1993 rule required you to characterize the nature and extent of COCs in excess of background concentrations). However, you must meet the new notification requirements, establish cleanup levels based on the TRRP procedures, and perhaps make some adjustments to comply with the new remedial requirements.

The TNRCC intends that a transition into using the TRRP occur not by starting over, but by completing any additional or remaining work that may be necessary. The degree to which additional work may be needed, if any, depends on the situation.

To determine how changing to the TRRP may affect you, we recommend that you seek the services of an environmental professional. An environmental professional can determine what completed work satisfies the TRRP, determine what additional or remaining work may be necessary, help evaluate the costs and benefits of using Tier 1, 2, or 3 and Remedy Standard A or B, and provide an estimate of the associated cost and time involved in your transition to TRRP.

For more information on the matter, see *Use of Data Collected for 30 TAC 335 under the TRRP* (RG-366/TRRP-5).

If I will be using the TRRP, what should I do?

The TRRP rule does not address the actual reporting of releases of COCs. The reporting requirements you must follow depend on which regulatory program you fall under. When the TNRCC program area determines that the release must be addressed, you are ready to begin using TRRP.

If site work has not already begun under other rules, then you must initiate action to comply with the TRRP. You will have to assess the affected property and establish PCLs to determine the need for any remediation, all in accordance with the requirements of the TRRP.

We recommend that you plan sufficiently before you begin site activity so that you can identify and collect all of the needed information as efficiently as possible. The information needs will depend on whether you establish PCLs under Tier 1, 2, or 3 and whether you plan to use Remedy Standard A or B.

For example, if you collect data to support Tier 1 and Remedy Standard A only, you will likely not have the information needed to calculate protective concentration levels under Tier 2 or 3 or to exercise some of the more flexible options under Remedy Standard B. Be sure and submit a self-implementation notice or response action plan, as appropriate, before you begin a response action to meet Remedy Standard A or B requirements.

If you have already begun work under other rules, then you should determine what additional information you need to comply with the TRRP. Your assigned TNRCC project manager can help you with this determination and other aspects of your transition to the TRRP. Then you should begin to collect this information.

Table 1. Guidance Planned for the Texas Risk Reduction Program

GENERAL

RG-366	Topic*	Availability*
TRRP-1	Introduction to TRRP	2/00
TRRP-2	Applicability and Grandfathering	2/00
TRRP-3	Compatibility with RCRA	4/00
TRRP-4	Comparison to 30 TAC 335	2/00
TRRP-5	Use of Data Collected for 30 TAC 335	5/00

AFFECTED PROPERTY ASSESSMENTS

RG-366	Topic*	Availability*
TRRP-6	Planning and Receptor Surveys	4 th Qtr 2000
TRRP-7	Landuse Determinations	4 th Qtr 2000
TRRP-8	Groundwater Classification	4/00
TRRP-9	Exposure Pathway Evaluations	6/00
TRRP-10	Determining Target COCs	10/00
TRRP-11	Contrasts in Data Needs for Tiers 1, 2 and 3	1/01
TRRP-12	Assessment Requirements (Extent determinations)	4/00
TRRP-13	Validation Requirements for Analytical Data	4/00
TRRP-14	Screening of COCs	4/00
TRRP-15	Determining Representative Concentrations	7/00
TRRP-16	Analytical Testing	4 th Qtr 2000
TRRP-17	Notification of Affected Persons	4/00

DEVELOPMENT OF HUMAN HEALTH PCLs

RG-366	Topic*	Availability*
TRRP-18	Risk Levels and Cumulative Adjustments	1/01
TRRP-19	Toxicity Factors and COC Properties	10/00
TRRP-20	Exposure Factors	1/01
TRRP-21	Determining Points of Exposure	4/00
TRRP-22	Development of Human Health PCLs	8/00
TRRP-23	Correct Use of Tier 1 PCL Tables	3/00
TRRP-24	Determining PCLs for Surface Water and Sediment	8/00
TRRP-25	Determining Critical PCLs	8/00
TRRP-26	Use of Tier 1 and 2 Natural Attenuation Factor Models	9/00
TRRP-27	Development of PCLs for TPH	3/00

REMEDY STANDARDS

RG-366	Topic*	Availability*
TRRP-28	Application of Remedy Standards to Affected Properties	4/00
TRRP-29	Soil and Groundwater Response Objectives	4/00
TRRP-30	Compliance Sampling and Monitoring	4 th Qtr 2000
TRRP-31	Evaluating the Effectiveness of Remedies	4 th Qtr 2000
TRRP-32	Demonstrating Sufficient NAPL Recovery	4 th Qtr 2000
TRRP-33	Monitored Natural Attenuation Demonstrations	3 rd Qtr 2000
TRRP-34	Facility Operations Area	4/01

STANDARDIZED REPORT FORMS

Form No.	Title	Availability*	Form No.	Title	Availability*
10323/SIN	Self-Implementation Notice	2/00	10327/RAER	Response Action Effectiveness Report	1/01
10324/NOI	Notice of Intent (Grandfathering)	3/00	10328/RACR	Response Action Completion Report	7/00
10325/APAR	Affected Property Assessment Report	5/00	10329/PRACR	Post Response Action Care Report	1/01
10326/RAP	Response Action Plan	7/00	10337/NOIST	Notice of Intent to Switch to TRRP	3/00

* Topic refers to subject matter, not document title. Availability refers to a target date only. Documents will be issued as completed. Please keep track through the website <http://www.tnrcc.state.tx.us/permitting/trrp.htm>.



TNRCC Regulatory Guidance

Remediation

RG-366/TRRP-21 November 2000 Draft

SUBJECT: HUMAN HEALTH POINTS OF EXPOSURE

Objectives: To describe and depict the on-site and off-site locations of the prescribed and alternate human health points of exposure (POEs) to environmental media as presented in §350.37 of the Texas Risk Reduction Program (TRRP) rule.

Audience: Regulated Community and Environmental Professionals

References: The regulatory citation for the Texas Risk Reduction Program (TRRP) rule is 30 TAC 350.

The TRRP Rule and Preamble are found on-line at
<http://www.tnrcc.state.tx.us/oprd/rules/indxpdf5.html>.

The TRRP rule, together with conforming changes to related rules, is contained in 30 Texas Administrative Code Chapter 350, and was published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). From the TRRP web page (<http://www.tnrcc.state.tx.us/permitting/trrp.htm>) you can download Tier 1 PCL Tables, toxicity factors, and other TRRP information.

Contact: Technical Support Section at 512/239-0310

Corrective Action Section at 512/239-2343. Responsible Party Remediation Section at 512/239-2200. Site Assessment & Management Section at 512/239-2509. Superfund Cleanup Section at 512/239-2425. Voluntary Cleanup Program Section at 512/239-5891.

Introduction

This guidance document describes and depicts the on-site and off-site locations of the prescribed and alternate human health points of exposure (POEs) to environmental media as presented in §350.37 of TRRP. POE locations are prescribed in the TRRP rule rather than being determined on a site-specific basis by a baseline risk assessment as was the case for Standard 3 of the 1993 Risk Reduction Rule (30 TAC 335). A POE is defined at §350.4(a)(66) as “a location within an environmental medium where a receptor will have a reasonable potential to come into contact with COCs.” However, prescribed POEs are defined at §350.4(a)(67) as “prescribed on-site and off-site locations within an environmental medium where an individual human or population will be assumed to come into contact with COCs.” For the complete or reasonably anticipated to be completed human health exposure pathways, which are determined in accordance with §350.71(c), the person shall define the POEs to environmental media as described in §350.37. Further details regarding the determination of human health exposure pathways are provided in the TNRCC guidance document titled *Exposure Pathway Evaluations* (RG-366/TRRP-9).

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Prescribed POEs are presented in §350.37 for both on-site and off-site exposure of humans to chemicals of concern (COCs). This assures that any on-site response action is also protective of off-site human receptors. Also, this document pertains only to human health POEs to environmental media. POEs for ecological receptors are determined on a site-specific basis in response to §350.77(a). Refer to TNRCC guidance titled *Guidance For Conducting Ecological Risk Assessments at Remediation Sites in Texas* for further information on this topic. And finally, a POE may be a discrete point or may, depending upon the circumstances, be a plane, area, or volume. For ease of illustration, the human health POEs in this document are often depicted as points or planes.

The following sections of this document describe: the importance of prescribed POEs; the interrelationship between POEs and institutional controls; the prescribed human health POEs to particular environmental media; and the alternate POEs which may be applicable for class 2 or 3 groundwater.

Prescribed Human Health POEs

The TNRCC decided to use prescribed POEs to environmental media in order to specify the expectations of the agency and to reduce disagreements, thereby accelerating the response action process. By specifying the location where conformance with the protective concentration levels (PCLs) is relevant, a consistent level of performance for protection of human receptors is established. As a result, there will be less chance for the response actions at various affected properties to have unjustifiable differences in the level of protection provided to humans.

The prescribed POEs for the human health exposure pathways specifically listed in §350.71 are set by rule and may not be modified based upon a site-specific risk assessment or exposure scenario analysis. The locations of the POEs at an affected property must be identified. For example, since the POE to class 2 groundwater is defined as being throughout the groundwater protective concentration level exceedence (PCLE) zone, you will be required to identify the lateral and vertical extent of any COCs in class 2 groundwater in excess of the critical groundwater PCLs. Also, if an additional exposure pathway is specified on a site-specific basis, then a site-specific POE for that exposure pathway must be established.

The prescribed POEs are important because they define the locations within an environmental medium where the PCLs for various exposure pathways must be attained or human exposure prevented. The prescribed POEs are also important because they are a critical step in determining the size and location of the various PCLE zones. The PCLE zones are in turn used to define the performance objectives for Remedy Standard A (See §350.32) and Remedy Standard B (See §350.33).

POEs do not dictate where samples of environmental media must be collected. For example, the rule states that the residential human health POE to surface soil is within the upper 15 feet of soils. This does not mean that all soil borings must be at least 15 feet deep. What this statement means is that all residential surface soil exposure pathways are potentially relevant across this depth interval. The depth of borings and the collection of samples for analysis are established to attain the performance-based affected property assessment objectives stated in §§350.51-350.55. For example, given an affected property where a heavy metal is distributed in shallow clay-rich soils and has not penetrated into deeper soils, then you could focus your investigation on the shallower soils and an assessment of the deeper soils may not be necessary.

However, people should be cognizant of the POE criteria in relation to the distribution of COCs so that adequate samples may be collected from appropriate locations in order to determine concentrations for

POEs. Please refer to the TNRCC guidance document titled *Affected Property Assessment Requirements* (RG-366/TRRP-12) for further details regarding assessment requirements. Frequently, an existing physical control will be relied upon to prevent human exposure to affected environmental media at a prescribed POE. However, §350.37(a) states in part that “consideration of competent, existing physical controls during the pathway analysis described in §350.71(d) does not negate or otherwise supercede the POE locations specified in this section.” In other words, there must remain a POE to the contaminated soil resulting from a spill even though you cover them with a parking lot. You can use such a parking lot cover as a response action under Remedy Standard B, provided it is capable of meeting the response action performance requirements and you are willing to meet the associated remedy requirements. Thus, a competent, existing physical control can be used as a response action, but cannot be used to remove the POE to soil or groundwater.

Relationship Between POEs And Institutional Controls

In order to establish an on-site or off-site POE based on commercial/industrial land use, an institutional control must be established in accordance with §350.111. Also, to establish an alternate POE to on-site or off-site property, an institutional control must be filed in accordance with §350.111. In either of these circumstances, you must provide proof of written landowner consent for the filing of an institutional control before the TNRCC will approve the response action completion report. However, proof of written landowner consent is not necessary if you satisfy one of the provisions described in the following paragraph. The institutional control is filed within the real property records of the affected property in order to notify future owners of any limitations on the use of the property, such as its appropriate land use. In summary, both commercial/industrial land use and alternate POEs require the filing of an institutional control and the landowner’s consent with that control to be documented. Further details regarding institutional controls are provided in the TNRCC guidance document titled *Institutional Controls* (RG-366/TRRP-16).

Proof of written landowner consent for the filing of an institutional control is not necessary in the following circumstances.

- The property is subject to a zoning or governmental ordinance that is equivalent to the deed notice, VCP certificate of completion, or restrictive covenant that would otherwise be required.
- §350.111(b)(4) states that the agency will execute a superceding deed notice for an on-site or off-site property, provided there is a change in circumstances and you adequately describe why the original notice is no longer necessary to protect human health or the environment.
- §350.111(d) provides that you do not need to obtain landowner consent for the filing of a deed notice or voluntary cleanup program certificate of completion when it is technically impracticable to attain a residential-based, Remedy Standard A response action and you adequately document the other conditions required by this section.
- §350.111(f) explains that landowner consent for a deed notice or voluntary cleanup program certificate of completion will not be required if, after your extensive and diligent inquiry, the agency concludes that you cannot find the landowner.

Also, an executed restrictive covenant signed by the landowner satisfies the need for consent when a restrictive covenant is required.

Descriptions of Prescribed Human Health POEs

This section describes and depicts the prescribed on-site and off-site human health POEs to the following environmental media:

- air (§350.37(b))

- soil (§350.37(c))
- class 1, 2, and 3 groundwaters which do not contain COCs in excess of the critical groundwater PCLs (§350.37(d))
- class 1, 2, and 3 groundwaters which do contain COCs in excess of the critical groundwater PCLs (§350.37(e)-(h))
- surface water runoff and groundwater discharges to surface water (§350.37(i))
- releases of COCs directly to surface water (§350.37(j))
- sediment (§350.37(k))

The prescribed human health POEs are based on the following definitions:

Protective concentration level (PCL) (§350.4(a)(68)) – The concentration of a chemical of concern which can remain within the source medium and not result in levels which exceed the applicable human health risk-based exposure limit or ecological protective concentration level at the point of exposure for that exposure pathway.

Protective concentration level exceedence (PCLE) zone (§350.4(a)(69)) – The lateral and vertical extent of all wastes and environmental media which contain chemicals of concern at concentrations greater than the critical protective concentration level determined for that medium, . . .

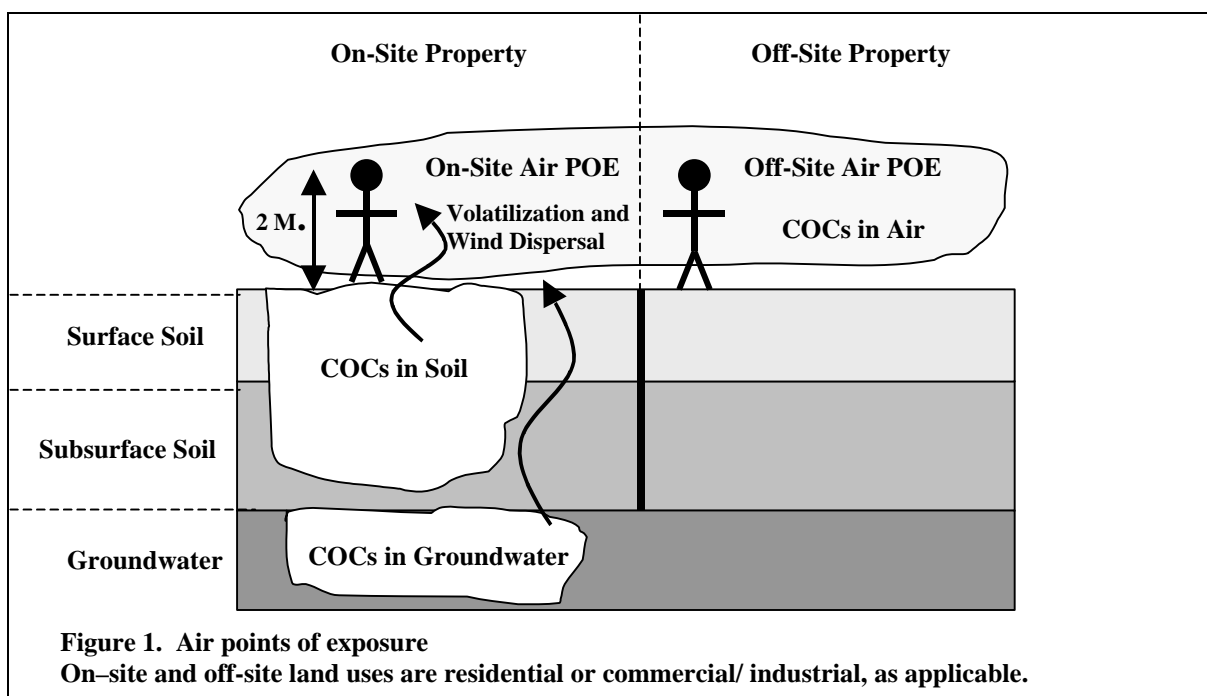
Critical protective concentration level (§350.4(a)(19)) – The lowest protective concentration level for a chemical of concern within a source medium determined from all of the applicable human health exposure pathways as described in §350.71 of this title (relating to General Requirements), and when necessary, protective concentration levels for applicable ecological exposure pathways as required in §350.77 of this title (relating to Ecological Risk Assessment and Development of Ecological Protective Concentration Levels).

General (§350.37(a))

You must use the prescribed on-site and off-site POEs for humans to determine the PCLs for use with Remedy Standard A (§350.32) or Remedy Standard B (§350.33). In all of the following figures which depict POEs, the on-site land use may be either residential or commercial/industrial depending upon the circumstances. Likewise, the off-site land use may be either residential or commercial/industrial. For a residential property, the human receptor is a resident. And for a commercial/industrial property, the human receptor is a commercial/industrial worker.

Air POEs (§350.37(b))

The prescribed on-site and off-site POEs to air are depicted in Figure 1. The on-site POE to air is located within the breathing zone (2 meter height) for a human receptor, either a resident or a commercial/industrial worker depending upon land use, located directly over COCs in soil and/or groundwater. COCs could be transported to a human receptor either as particulates (for soil) or by volatilization (for soil and groundwater). In Figure 1, the POE to air is shown as a “cloud” surrounding the head of the “stick figure” human receptor. An off-site POE is established since remedies under the TRRP rule must be protective for both on-site and off-site receptors. The off-site POE to air is within the breathing zone of a human receptor starting at the boundary with and continuing throughout the nearest off-site property. The off-site air POE is not limited to the downwind property boundary based upon the prevailing wind direction. This means that the COC concentrations in air must not exceed the critical PCLs for the applicable human receptor anywhere within off-site property. For example, suppose the on-site property

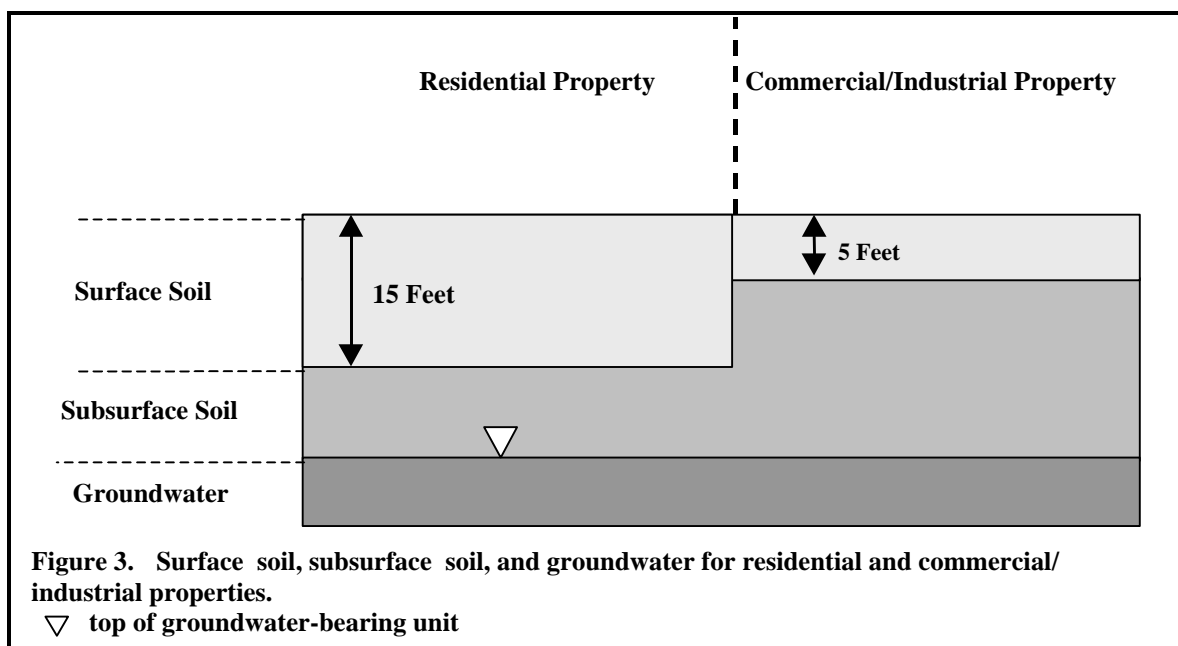
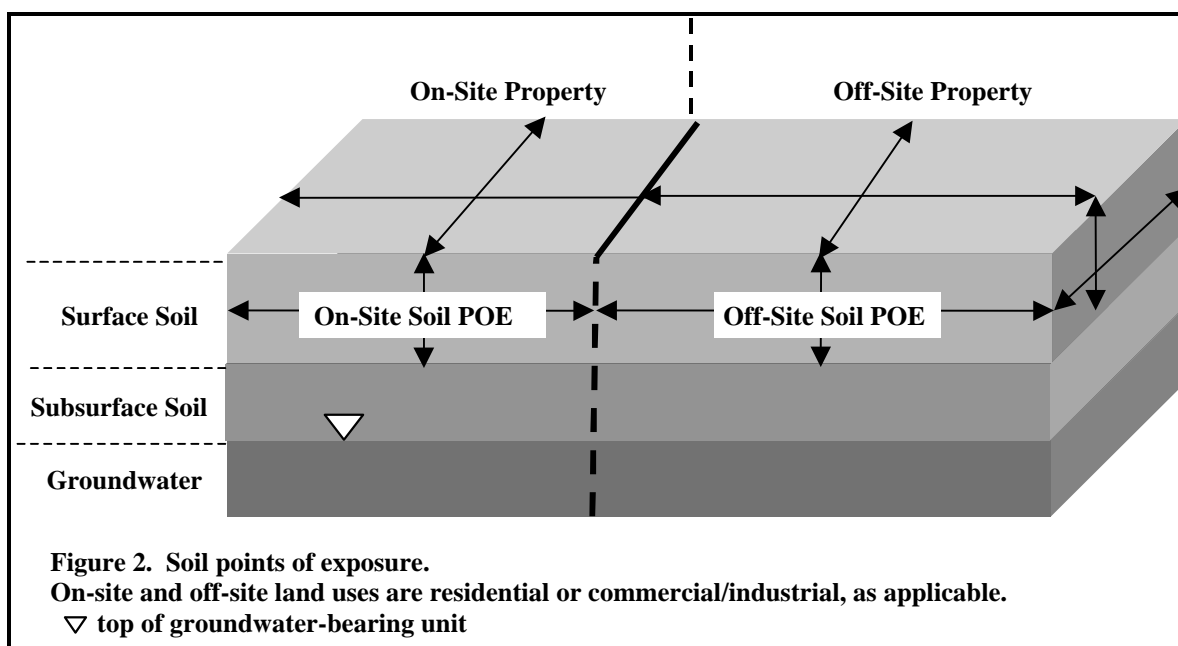


is commercial/industrial and the off-site property is residential. In this circumstance, it would be acceptable for the person to restore the on-site property to the critical commercial/industrial air PCLs, but the critical residential air PCLs would apply at the boundary of and throughout the off-site property. If you demonstrate conformance with on-site critical commercial/industrial air PCLs determined in accordance with TRRP's tiered risk-based process, then further demonstration of protective air concentrations at the off-site property boundary will generally not be required. A specific demonstration may be required in some cases such as when the COCs and an off-site residence are in immediate proximity of the property line. However, if you base the on-site commercial/industrial air PCLs on occupational levels, then further demonstration of acceptable off-site air concentrations is more likely to be required. In a circumstance not depicted in Figure 1, when the on-site property and an off-site property meet the conditions for commercial/industrial land use assumptions, a residential POE would be established at the nearest boundary with and continuing throughout the next nearest downwind off-site property. When relevant due to the on-site release of COCs, off-site POEs to air could extend as far as necessary throughout off-site properties in order to protect human health.

Soil POEs (§350.37(c))

The prescribed on-site and off-site POEs to soil are depicted in Figure 2. The on-site POE to soil for both residential and commercial/industrial land use is throughout the surface soil. As depicted in Figure 3, surface soil is generally the upper 15 feet of the soil zone for residential land use and the upper 5 feet of the soil zone for commercial/industrial land use. Further discussions explain exceptions to these generic depths. An off-site POE to soil is established in order to demonstrate protection for off-site human receptors. The off-site POE to soil is throughout the surface soil starting at the nearest boundary with and continuing throughout neighboring off-site properties. For example, assume that the on-site property is commercial/industrial and the nearest off-site property is residential. You could use the critical commercial/industrial and residential PCLs to determine the soil PCLE zones on the on-site and off-site properties, respectively. When relevant, due to the release and migration of COCs, off-site POEs to soil could extend as far as necessary throughout the surface soils on neighboring properties in order to protect human health.

An understanding of the definitions for “surface soil,” “subsurface soil,” and “bedrock” is essential in order to determine the POEs to soil at a variety of affected properties with different hydrogeologic characteristics. A representation of these three environmental media at typical residential and commercial/industrial properties is presented in Figure 3.



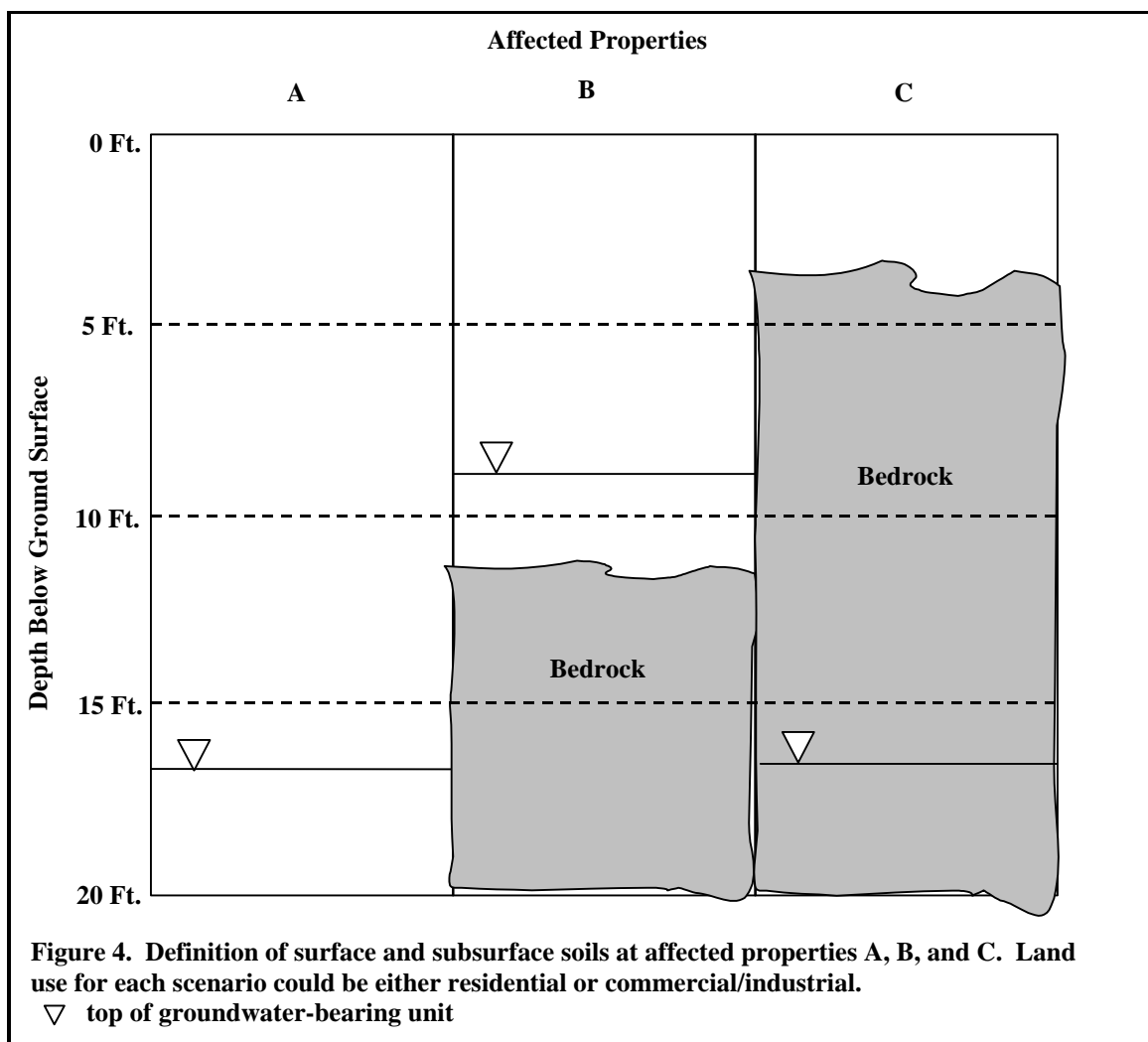
The definitions for these media are:

Surface soil (§350.4(a)(88)) – For human health exposure pathways, the soil zone extending from the ground surface to 15 feet in depth for residential land use and from ground surface to 5 feet in depth for commercial/industrial land use; or to the top of the groundwater-bearing unit or bedrock, whichever is lesser in depth.

Subsurface soil (§350.4(a)(86)) – For human health exposure pathways, the portion of the soil zone between the base of the surface soil and the top of the groundwater-bearing unit(s).

Bedrock (§350.4(a)(7)) – The solid rock (that is, consolidated, coherent, and relatively hard naturally formed material that cannot normally be excavated by manual methods alone) that underlies gravel, soil, or other surficial material.

As shown in Figure 3, for both residential and commercial/industrial affected properties, the soil zone from the land surface to the top of the groundwater-bearing unit consists of surface soils and subsurface soils. Unless shallow groundwater or bedrock is present, the depth of surface soils at residential and commercial/industrial affected properties is 15 feet and 5 feet, respectively. If the top of the groundwater-bearing unit and/or the top of bedrock occurs at a shallower depth, then the shallower of these depths defines the depth of surface soils.



To illustrate these considerations, Figure 4 depicts three examples described as affected properties A, B, and C with varying depths to the top of the groundwater-bearing unit and to bedrock.

Surface soils and subsurface soils in these examples are determined as follows:

For affected property A, surface soils constitute the upper 15 feet of soils for residential land use or the upper 5 feet for commercial/industrial land use. The generic values for surface soil thickness are used since the top of the groundwater-bearing unit occurs at a depth of 17 feet and due to the absence of bedrock at the property. In this example, subsurface soils for residential land use are the materials between 15 and 17 feet. Subsurface soils for commercial/industrial land use are between 5 and 17 feet.

- At affected property B, the top of the groundwater-bearing unit is at a depth of 8 feet while the top of bedrock is at a depth of 12 feet. Eight feet is the shallower of these two depths. For affected property B, surface soil consists of the upper 8 feet of soils for residential land use and the upper 5 feet for commercial/industrial land use. The surface soil thickness for residential land use is based upon the depth to the top of the groundwater-bearing unit rather than the generic value of 15 feet in this example. However, the surface soil thickness for commercial/industrial land use remains based on the generic value of 5 feet rather than the depth to the top of the groundwater-bearing unit. In this example, there are no subsurface soils for the residential property and subsurface soils on the commercial/industrial property are in the depth range from 5 to 8 feet.
- At affected property C, the top of bedrock occurs at a depth of 4 feet and the top of the groundwater-bearing zone occurs at 17 feet. Four feet is the shallower of these two depths. Thus, for affected property C, the upper 4 feet of soils constitute surface soils for both residential and commercial/industrial land uses. And for both land uses, the bedrock between 4 and 17 feet is classified as subsurface soil material.

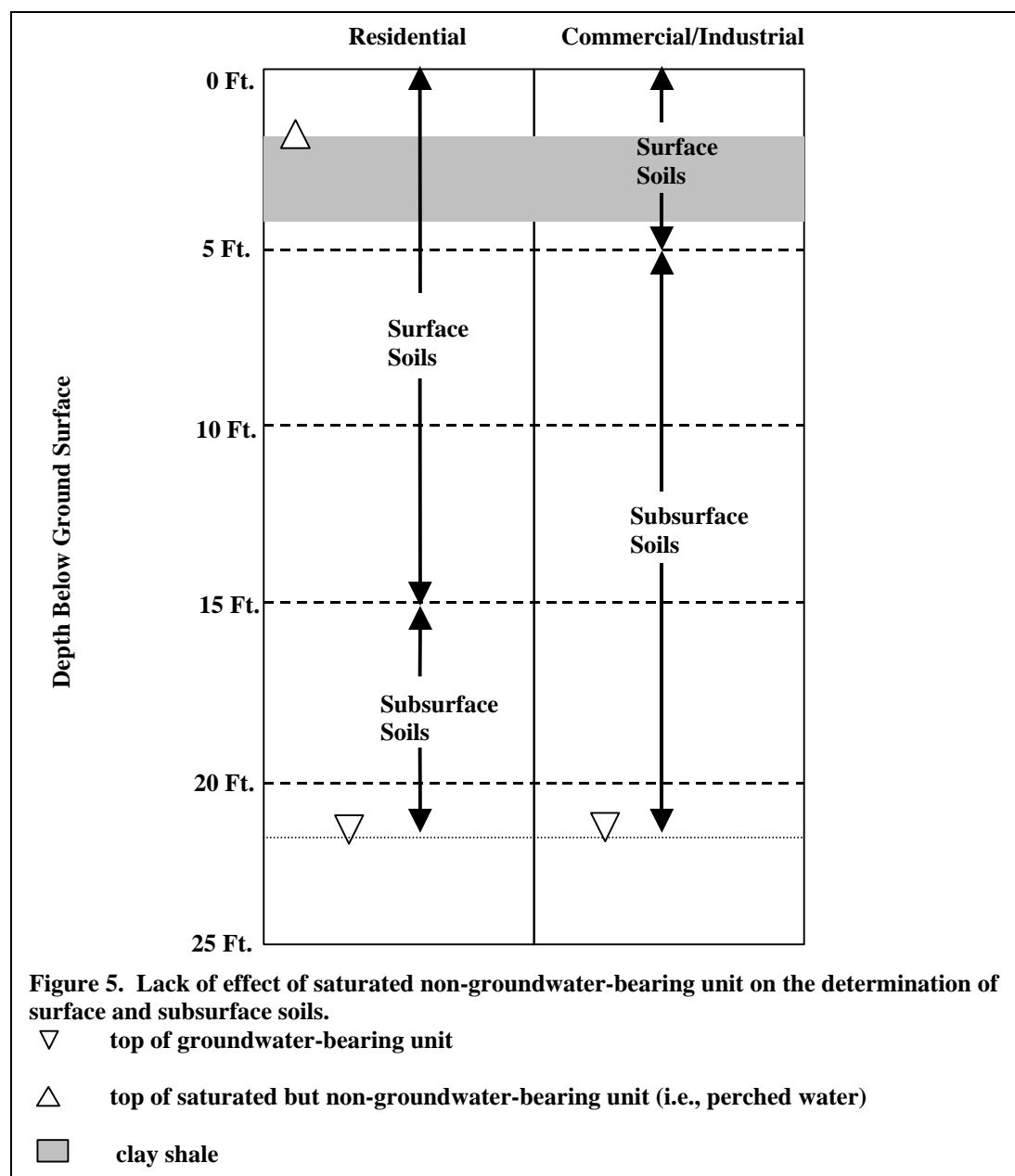
However, there are at least three site-specific considerations discussed in the following paragraphs which could yield a different thickness for surface soils at a particular affected property.

The first clarification involves those hydrogeologic settings where the elevation of the top of the groundwater-bearing unit varies substantially in different seasons throughout the year. In such a situation, you should use an annual average depth to the top of the groundwater-bearing unit as the thickness of the surface soil if such depth is less than 15 feet or 5 feet, as applicable, depending upon the land use of the particular affected property.

The second clarification pertains to those hydrogeologic settings where a zone is saturated but does not meet the definition of a groundwater-bearing unit (e.g., perched water). In order to be a groundwater-bearing unit a geologic zone must have a hydraulic conductivity of at least 1×10^{-5} centimeters/second. You may not use the presence of a saturated geologic zone which is not a groundwater-bearing unit as justification to modify the generic value for surface soil thickness. As an example, Figure 5 depicts an affected property which is underlain by a clay shale. This clay shale has a hydraulic conductivity less than 1×10^{-5} centimeters/second and is saturated at a shallow depth. The depth to the saturated zone in the clay shale is not a relevant factor in determining the thickness of surface soils. Figure 5 depicts residential land use on the left and commercial/industrial land use on the right. For both of the land uses, the top of the water-saturated clay shale occurs at a depth of only 2 feet. For both land uses the top of a groundwater-bearing unit occurs at a depth of 22 feet. Thus, for residential land use, the soils above 15 feet are surface soils and the soils between 15 feet and 22 feet are subsurface soils. For commercial/industrial land use, surface soils are located from the land surface to 5 feet and subsurface soils are located between 5 feet and 22 feet. The presence of the water-saturated zone in the clay shale does not change this determination. However, if such a water-saturated zone that does not meet the

definition of a groundwater-bearing unit is located within surface soil, then you may not need to evaluate the complete list of exposure pathways for that water-saturated zone. Please see the TNRCC guidance document titled *Exposure Pathway Evaluations* (RG-366/TRRP-9) for a description of the exposure pathways and PCLs applicable to various environmental media.

The third clarification pertains to “bedrock-like material” which does not meet the “solid rock” criteria. To be bedrock, an earthen material must be a “consolidated, coherent, and relatively hard naturally formed material that cannot normally be excavated by manual methods alone.” The bedrock limit on the depth of surface soils was inserted in the TRRP rule to prevent requiring this material to be removed,



decontaminated, and/or controlled based upon dermal contact, ingestion, or vegetable consumption concerns because there is a small potential for such exposure to ever occur. In order to use this language to vary the default thickness of surface soils, you must demonstrate that the geologic material in question satisfies the “solid rock criteria.” Bedrock is captured within the general meaning of soils as well.

Whether an affected soil unit is surface or subsurface soil is important because different exposure pathways and PCLs apply to surface and subsurface soils. Under circumstances at most affected properties, application of the surface and subsurface soil PCLs is all that is required to protect human health and the environment from soil materials. While materials below the top of the groundwater-bearing unit are by definition neither surface nor subsurface soils, they are still considered to be “soils” under TRRP. The term “soil” is used broadly and inclusively. You must assess and determine PCLs for these deeper soils in special circumstances. Please see the TNRCC guidance document titled *Affected Property Assessment Requirements* (RG-366/TRRP-12) for further details regarding the requirements for an affected property assessment. POEs for direct exposure to these deeper soils are not established. Instead, compliance with the PCLs for the deeper soils is typically determined by analyzing water samples from a threatened groundwater-bearing unit.

Groundwater POEs (§350.37(d)-(h))

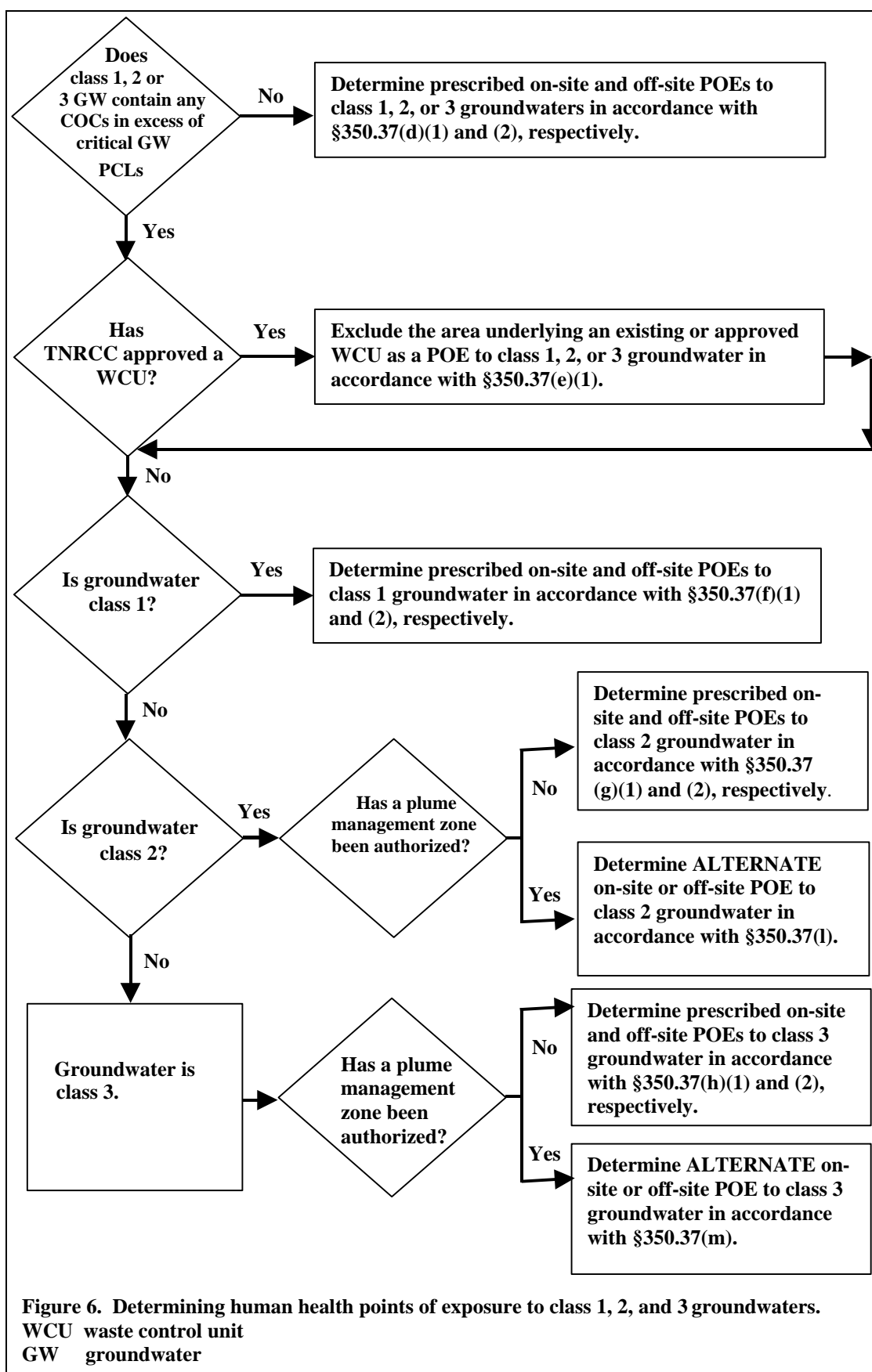
Figure 6 depicts the process for determining human health POEs under various circumstances for class 1, 2, or 3 groundwater. You should initially determine the on-site and off-site POEs to the uppermost groundwater-bearing unit by proceeding as far as necessary through this flowchart. You should also determine on-site and off-site POEs to successively deeper groundwater-bearing units in a similar fashion if there is a reasonable cause to believe that a unit may contain one or more COC in excess of its critical groundwater PCL.

POEs for class 1, 2, and 3 groundwaters which do not contain COCs in excess of the critical groundwater PCLs (§350.37(d))

The prescribed on-site and off-site POEs to class 1, 2, and 3 groundwaters with no COC in excess of a critical groundwater PCL are depicted in Figure 7. The prescribed on-site POE to such unaffected groundwater is throughout the lateral and vertical extent of the on-site portion of the uppermost groundwater-bearing unit. The prescribed off-site POE to unaffected groundwater is throughout the uppermost groundwater-bearing unit on the nearest boundary with the closest hydraulically downgradient off-site property. Note that the off-site POE is within the vertical extent of the uppermost groundwater-bearing unit at the boundary between on-site and off-site properties rather than being throughout the lateral extent of the uppermost groundwater-bearing unit throughout the off-site property. The soil and groundwater performance objective associated with these POEs is that on-site and off-site unaffected groundwater does not become affected over time.

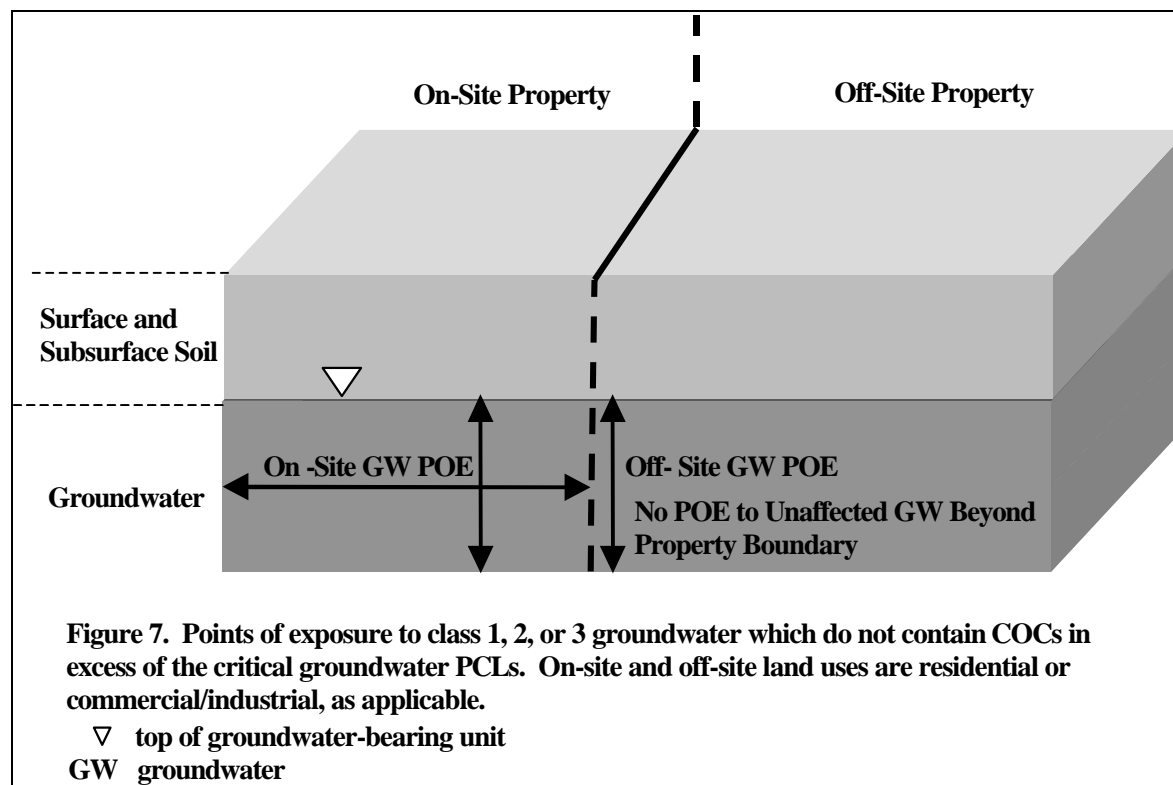
§350.37(d) does not apply on a COC-by-COC basis. This means that if any COC exceeds its critical PCL, then the groundwater does not meet the conditions for application of this section. However, §350.37(f), (g), or (h) would apply depending upon the classification of the affected groundwater.

Also, the presence of COCs in excess of critical groundwater PCLs within the uppermost groundwater-bearing unit beneath an affected property does not mean that §350.37(d) would not apply to lower groundwater-bearing units at that property. The commission stated in the preamble for the final rule that



persons should interpret “the uppermost groundwater-bearing zone” to mean not only the groundwater-bearing unit closest to the ground surface, but also the first unaffected groundwater-bearing unit. For example, if there are four groundwater-bearing units, and the first three are affected, but the deepest (that is, fourth) groundwater-bearing unit is not affected, then §350.37(d) would apply to that fourth groundwater-bearing unit, but not the upper three. As a result, you would have the responsibility to keep that fourth groundwater-bearing unit from receiving COCs in excess of the critical groundwater PCLs from source areas on your property.

And finally, the presence of COCs in excess of the critical groundwater PCLs in the uppermost groundwater-bearing unit beneath only a neighboring property cannot be used to conclude that §350.37(d) does not apply to the uppermost groundwater-bearing unit beneath the on-site property. The on-site POE is described in §350.37(d)(1) as being “throughout the uppermost groundwater-bearing unit.” The off-site groundwater POE is described in §350.37(d)(2) as “throughout the uppermost groundwater-bearing unit on the nearest boundary with the closest hydraulically downgradient off-site property.” The agency purposefully did not extend the off-site groundwater POE to beneath neighboring properties. When stating that the uppermost groundwater-bearing unit does not contain COCs in excess of the critical groundwater PCLs, the uppermost groundwater-bearing unit being referenced is beneath the affected property in question rather than throughout the regional extent of the groundwater-bearing unit. Thus, the presence or absence of COCs with concentration levels in excess of the critical PCLs in the uppermost groundwater-bearing unit below neighboring properties is not a relevant factor in determining whether §350.37(d) applies to the on-site uppermost groundwater-bearing unit. One effect of this is that you cannot use the presence of COCs in the uppermost groundwater-bearing unit beneath a neighboring off-site property to conclude that the uppermost groundwater-bearing unit beneath your property is affected. As a result, you cannot base the soil-to-groundwater response objectives for an on-site soil PCLE zone on the assumption that the uppermost groundwater-bearing unit is regionally

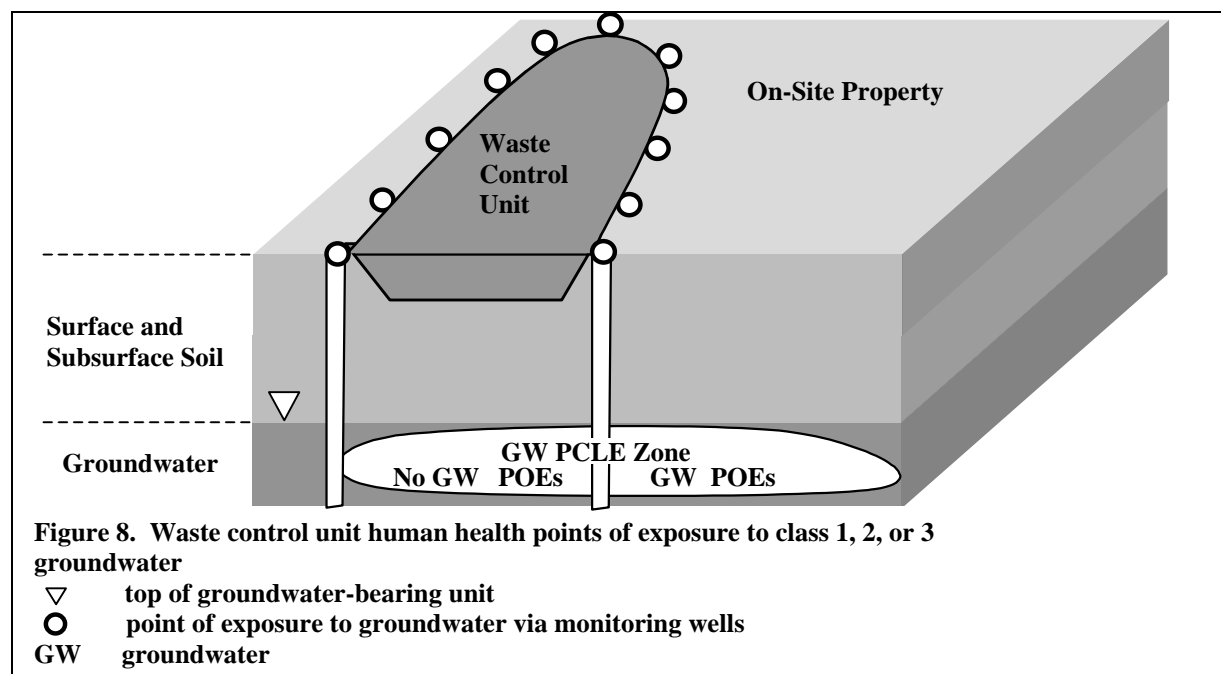


affected. If the uppermost on-site groundwater-bearing unit, regardless of its classification, does not contain COCs in excess of the critical groundwater PCLs, then units, facilities, and areas must be managed such that the uppermost on-site groundwater-bearing unit does not become affected over time.

General provisions for POEs for class 1, 2, and 3 groundwater (§350.37(e))

§350.37(e) describes two general provisions which may, depending upon the circumstances at an affected property, apply to define the location of human health POEs to class 1, 2, or 3 groundwater containing COCs in excess of critical groundwater PCLs.

First, Figure 8 depicts the specifications of §350.37(e)(1). This subsection specifies that in the event there is an existing PCLE zone in class 1, 2, or 3 groundwater beneath a waste control unit then, with the approval of the executive director, the area underlying the waste control unit may be excluded as a POE to groundwater. This means that a response action would not be required to restore the groundwater PCLE zone directly under a waste control unit to the critical groundwater PCLs. A *waste control unit* is defined at §350.4(a)(91) as “a municipal or industrial solid waste landfill, including those Resource Conservation and Recovery Act regulated units closed as landfills, with a liner system (i.e., synthetic or clay) and an engineered cap, that has been closed pursuant to an approved closure plan, previous regulations, or will be implemented pursuant to an approved response action plan.” Please note that a waste control unit has both a liner system and an engineered cap. You will have to demonstrate that the unit in question meets these requirements before the commission will approve its designation as a waste control unit. POEs do apply beyond the boundary of the waste control unit. Requirements for use of a waste control unit as part of a Remedy Standard B response action are described at §350.33(f)(2) of the rule. This provision was adopted so that you will not be forced to place potential migration pathways, such as borings and monitor wells, through the cap and liner systems of a waste control unit.



Second, §350.37(e)(2) specifies the manner in which groundwater travel time setback distances will be determined. Later sections of this document specify the circumstances when the POEs to class 1, 2, and 3 groundwater are based on a groundwater travel time setback distance. The setback distance is established at two years groundwater travel time upgradient of the closest downgradient property. In other words, a 2 year setback distance is measured from the property boundary and is equal to the estimated distance that groundwater will travel in two years. In Figure 9, the distance from the current boundary of the groundwater PCLE zone to the inner dashed line represents the distance groundwater travels in one year. Likewise, the distance from the current boundary of the groundwater PCLE zone to the outer dashed line represents the distance that groundwater travels in 2 years. The estimated distance that groundwater travels in two years is used as the setback distance.

§350.37(e)(2) states that groundwater travel time setback distances shall be based upon groundwater seepage velocity. Groundwater seepage velocity is dependent upon hydraulic gradient, hydraulic conductivity, and effective porosity. Groundwater seepage velocity typically is determined mathematically from the following equation derived from Darcy's Law:

$$V = (K \times dh/dl) / n_e$$

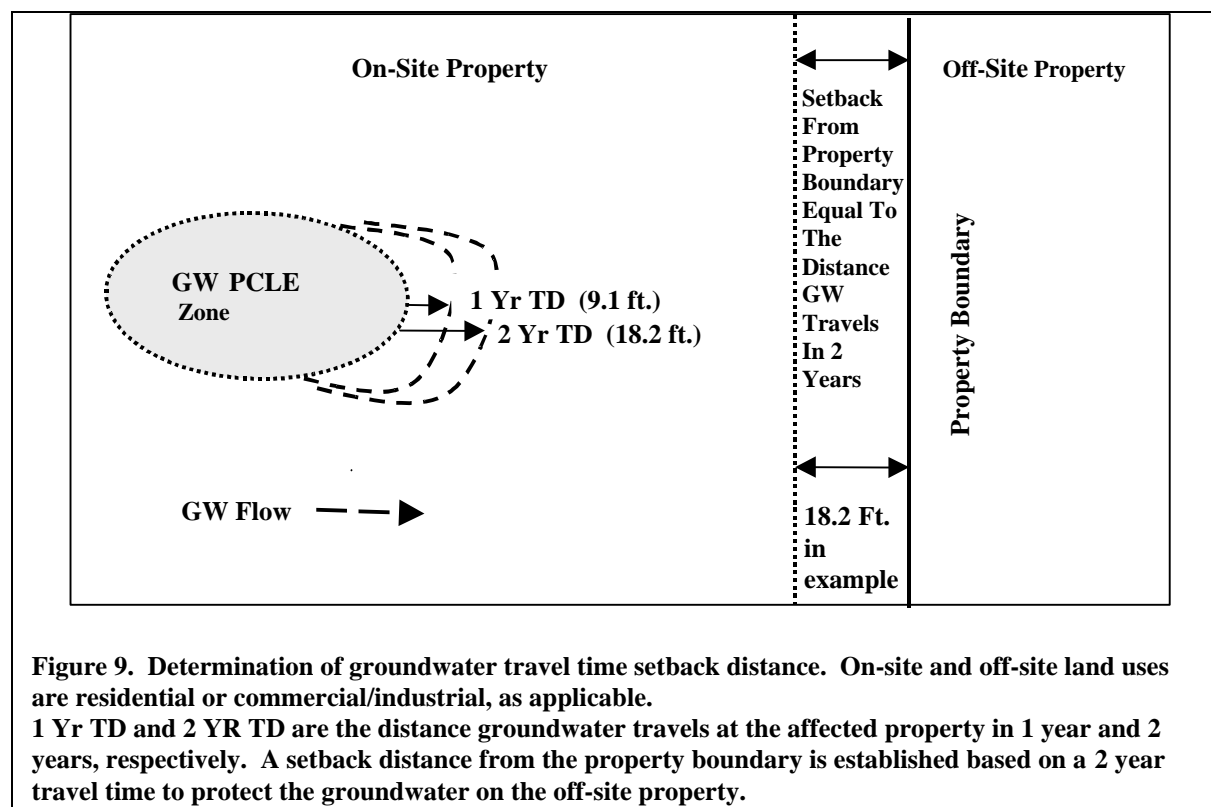
Where:

V = Groundwater seepage velocity (L/T)

K = Hydraulic conductivity (L/T)

dh/dl = Hydraulic gradient (L/L)

n_e = Effective porosity (unitless)



Seepage velocity is proportional to hydraulic conductivity and hydraulic gradient and inversely proportional to effective porosity. Please refer to *Contrasts in Data Needs for Tiers 1, 2, and 3* (RG-366/TRRP-11) for a description of how site-specific values for hydraulic conductivity and hydraulic gradient should be determined and when literature values for these parameters may be used.

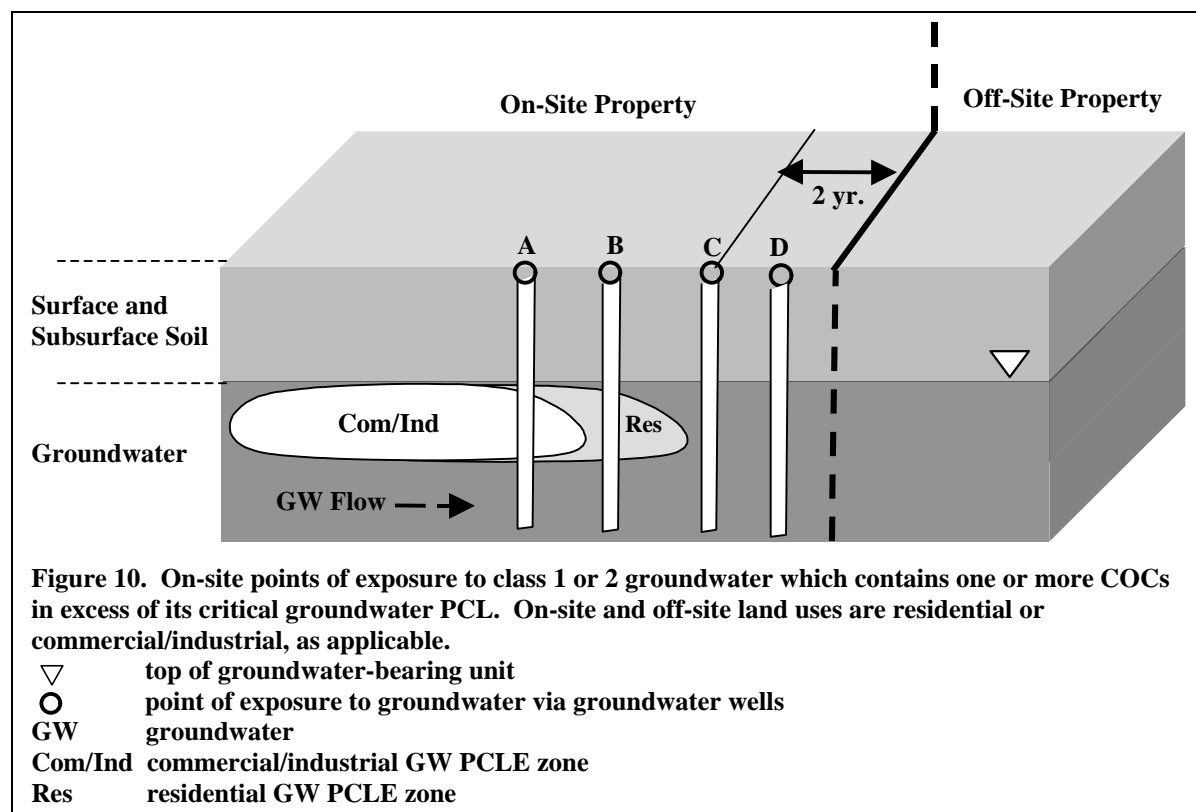
As an example travel time setback distance calculation, assume that the uppermost groundwater-bearing unit at an affected property is silty sand with a hydraulic conductivity of 0.1 ft/day. Also assume the hydraulic gradient of the water table is 0.1 ft/ft. And finally, the effective porosity of the silty sand is estimated as 0.400. Using these values, the groundwater seepage velocity is estimated as 9.1 ft/year in the following manner:

$$\begin{aligned} V &= (0.1 \text{ ft / day} \times 0.1 \text{ ft / ft}) / 0.400 = .025 \text{ ft / day} = .025 \text{ ft / day} \times 365 \text{ day / year} \\ &= 9.1 \text{ ft / year} \end{aligned}$$

A one-year travel time set back distance in this example is 9.1 feet. The two year travel time setback distance is 18.2 feet.

POEs for class 1 or class 2 groundwaters which contain COCs in excess of the critical groundwater PCLs (§350.37(f)-(g))

Figure 10 depicts the prescribed on-site human health POEs for affected class 1 or 2 groundwater. These on-site POEs are described in §350.37(f)(1) and (g)(1) of TRRP. Figure 11 shows the prescribed off-site human health POEs to class 1 or 2 groundwater. These off-site POEs are described in §350.37(f)(2) and (g)(2). The class 2 groundwater prescribed POEs may be modified by the specification of alternate POEs



in accordance with §350.37(1) when adopting a plume management zone under Remedy Standard B. Class 1 groundwater prescribed POEs may not be modified.

In Figure 10, the primary POE to affected class 1 or 2 groundwater is a well which may be completed at all locations throughout the on-site groundwater PCLE zone. This POE is throughout the on-site commercial/industrial PCLE zone if the on-site land use is commercial/industrial. This circumstance is depicted by the groundwater well labeled POE A. This groundwater well is presumed to be located at all locations within the commercial/industrial groundwater PCLE zone. If the on-site land use is residential, then this POE to groundwater is throughout the on-site residential groundwater PCLE zone. This is shown as a groundwater well located at POE B. This groundwater well is presumed to be located at all locations within the residential groundwater PCLE zone. In summary, this portion of the rule requires a POE to class 1 or 2 groundwater to be established whenever a critical groundwater PCL is exceeded on-site. When there is a class 1 or 2 groundwater PCLE zone either Remedy Standard A or B must be attained.

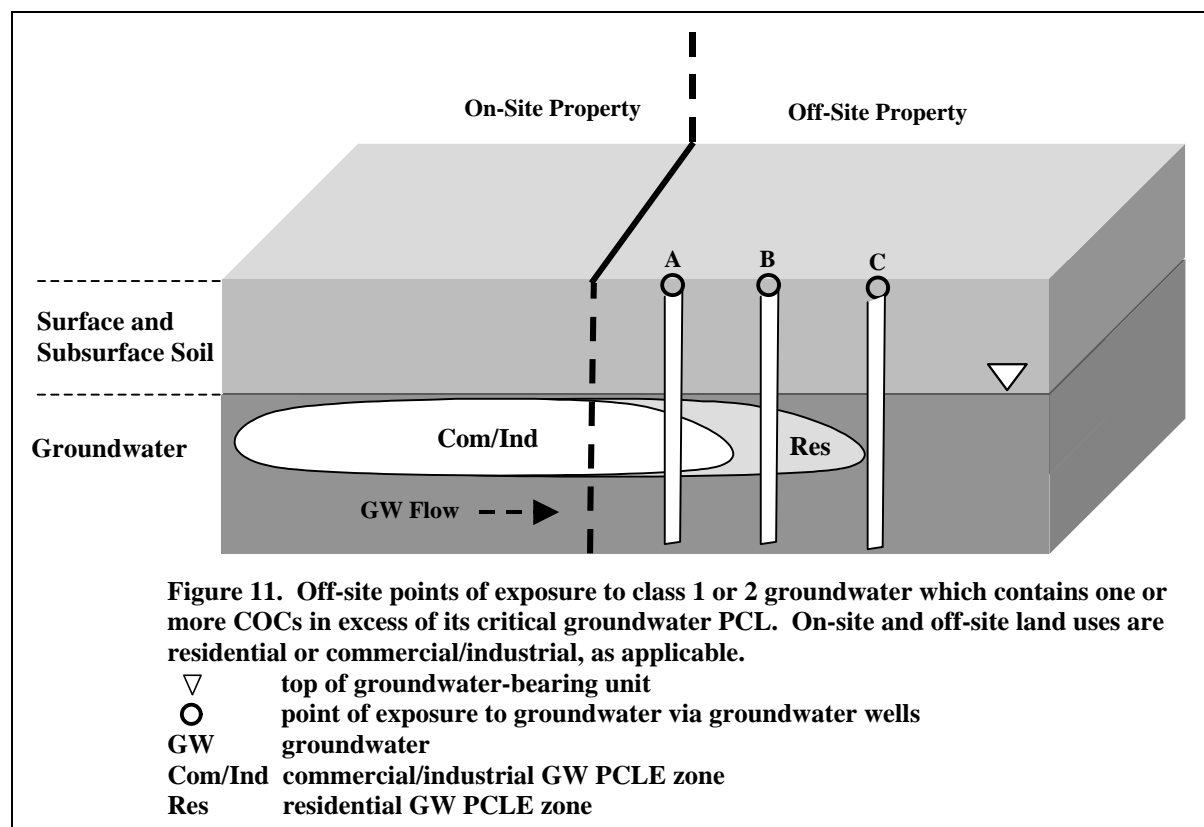
When the on-site land use is commercial/industrial, an additional on-site prescribed POE for class 1 or 2 groundwater must be established based upon residential land use, unless the residential groundwater PCLE zone already extends off-site. This additional POE is shown as POE C in Figure 10. POE C is located at a distance of two years groundwater travel time upgradient of the nearest boundary with the closest hydraulically downgradient off-site property.

In the circumstance where the residential-based groundwater PCLE zone already extends beyond the two-year setback distance but not off-site, the POE is set at the existing limit of the residential groundwater PCLE zone. This is shown as POE D in Figure 10.

Prescribed POEs C and D are required when commercial/industrial land use is assumed for on-site properties in order to protect the quality of class 1 or 2 groundwater under adjoining properties. If you are an owner of a commercial/industrial property, then you may choose to allow an on-site residential groundwater PCLE zone to migrate below your property. However, you may not allow this on-site residential groundwater PCLE zone to migrate closer than 2 years groundwater travel time upgradient of an off-site property. It makes no difference, pertaining to this requirement, whether the off-site property is presently being used for residential or commercial/industrial purposes. Also, if the residential PCLE zone is already within the two-year setback distance, then no further migration is allowed.

In Figure 11, the primary off-site POE to affected class 1 or 2 groundwater is a well which may be completed at all locations throughout an off-site groundwater PCLE zone. This POE is throughout the off-site commercial/industrial groundwater PCLE zone if the land use is commercial/industrial. This is depicted as POE A. To state this more simply, if a groundwater PCLE zone has migrated from source areas on your property to a neighboring property, then you must respond to that affected groundwater. Additionally where the off-site land use is commercial/industrial, you must establish an additional POE for residents. This residential POE is established at all locations beyond the existing limit of the off-site residential groundwater PCLE zone. This is shown as POE C on Figure 11. This means that even if the off-site property is commercial/industrial, you must not allow the residential groundwater PCLE zone to expand. This preserves that off-site commercial/industrial property owner's flexibility to use his property for residential purposes in the future.

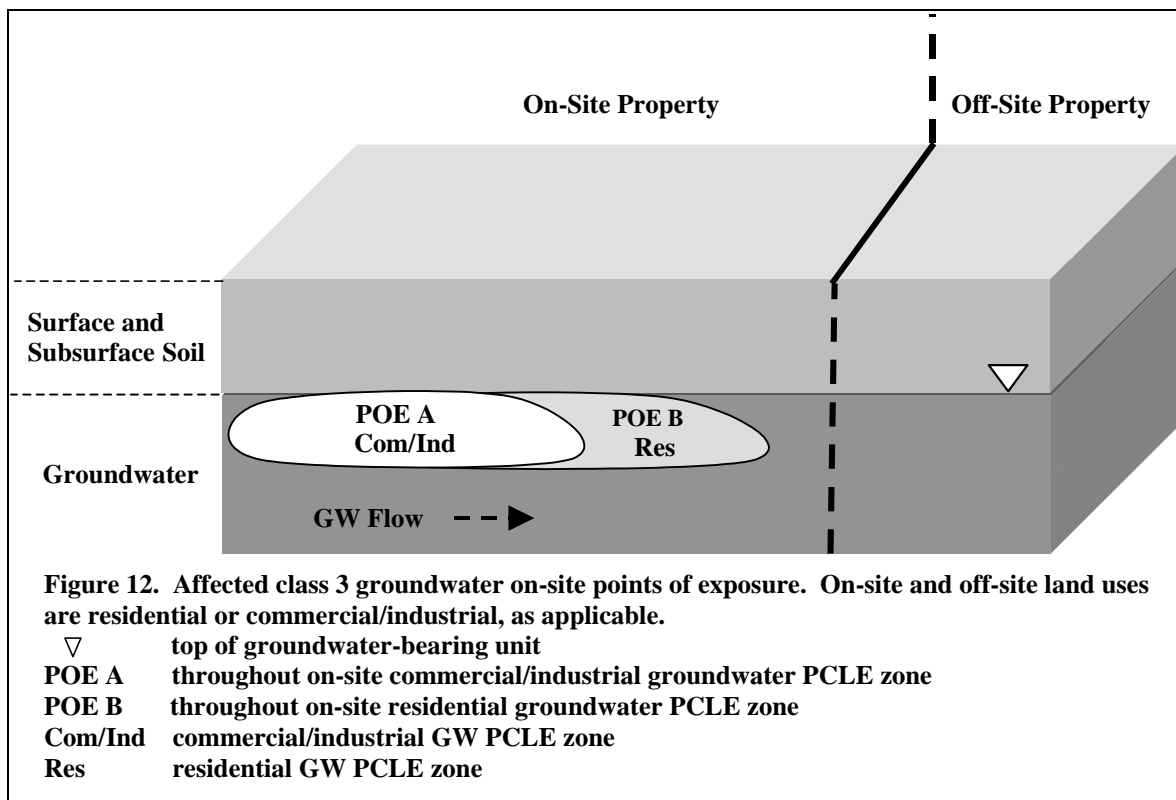
If the off-site land use is residential, then this POE is throughout the off-site residential groundwater PCLE zone. This is shown as POE B, in Figure 11.



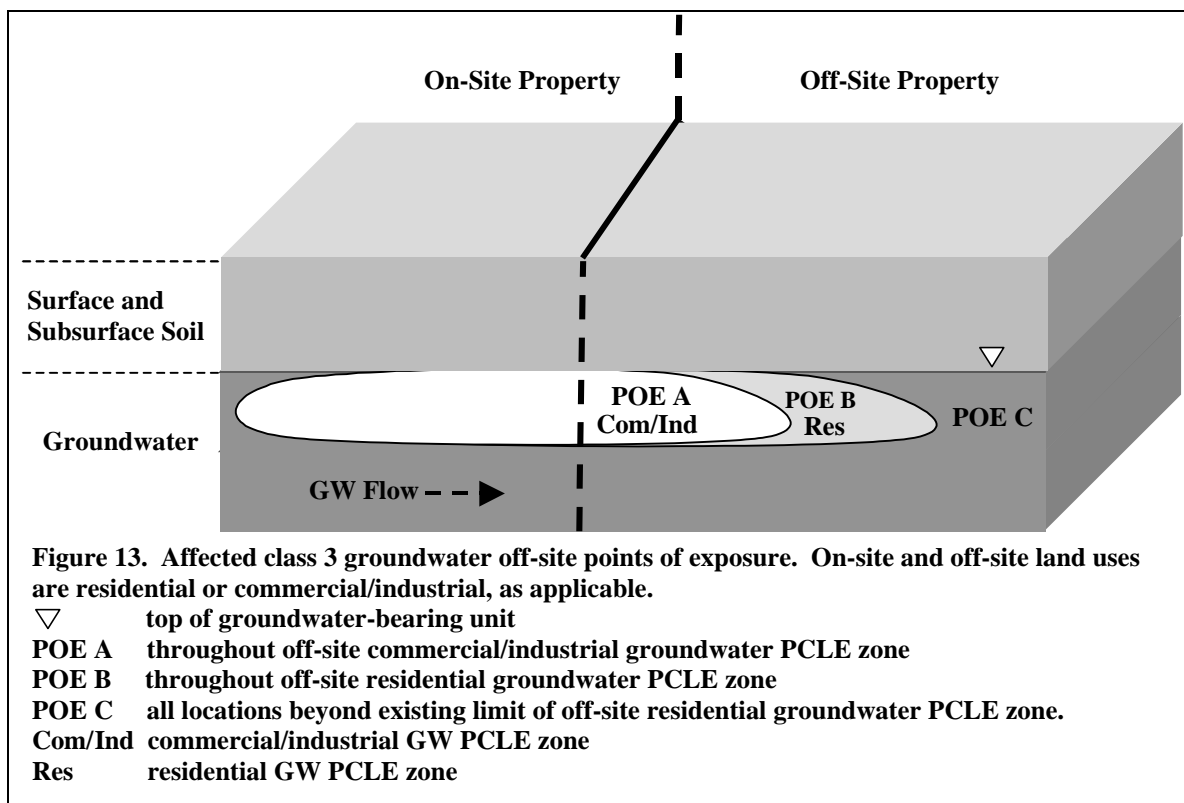
POEs for class 3 groundwaters which contain COCs in excess of the critical groundwater PCLs (§350.37(h))

Figure 12 presents the prescribed on-site POEs for affected class 3 groundwater. These POEs are described in §350.37(h)(1). The PCLs for class 3 groundwater are not based upon ingestion and are 100 times greater than the groundwater ingestion PCLs established for class 1 and 2 groundwater. The primary on-site POE to affected class 3 groundwater is at all locations throughout an on-site groundwater PCLE zone. The groundwater PCLE zone is defined by concentrations greater than $^{GW}GW_{Class\ 3}$ for the applicable on-site land use. If the on-site land use is commercial/industrial, then the on-site POE is throughout the commercial/industrial groundwater PCLE zone. This is depicted as POE A. However, if the on-site land use is residential, then the on-site POE is throughout the residential groundwater PCLE zone. POE B represents the residential POE (and also includes the commercial/industrial PCLE zone).

The prescribed off-site POEs for affected class 3 groundwater are depicted in Figure 13. These off-site POEs to class 3 groundwater are described in §350.37(h)(2). The primary off-site POE to class 3 groundwater is at all locations throughout an off-site groundwater PCLE zone. This groundwater PCLE zone is defined by all concentrations greater than $^{GW}GW_{Class\ 3}$ for the applicable off-site land use. The off-site groundwater PCLE zone includes only those COCs sourced from the on-site release. As depicted by POE A, if the off-site land use is commercial/industrial, then the off-site POE is throughout the commercial/industrial groundwater PCLE zone. Also, if the off-site land use is commercial/industrial, then an additional off-site POE represented as POE C must be established. This POE is established at, and at all locations beyond, the existing limit of the off-site residential-based groundwater PCLE zone.



This means that you may not permit a residential-based class 3 groundwater PCLE zone to continue to migrate underneath a neighboring property even if that property is classified as commercial/industrial.



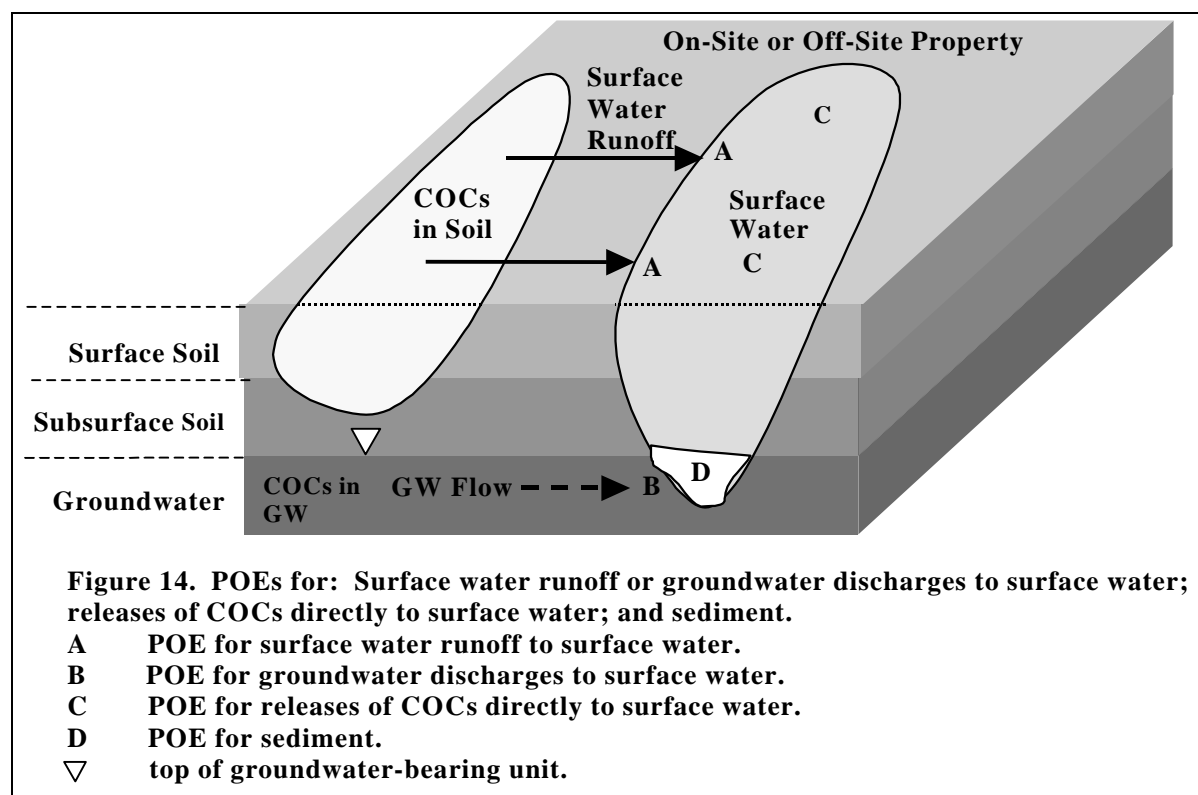
And finally, if the off-site land use is residential, then the off-site POE is throughout the residential groundwater PCLE zone as depicted by POE B (and also includes the commercial/industrial PCLE zone).

POEs for: surface water runoff or groundwater discharges to surface water (§350.37(i)); releases of COCs directly to surface water (§350.37(j)); and sediment (§350.37(k))

Figure 14 depicts the location of the POEs for:

- surface water runoff or groundwater discharges to surface water;
- releases of COCs directly to surface water; and
- sediment

POEs A and B in Figure 14 represent the POEs for surface water runoff and groundwater discharges to surface water, respectively. These POEs are defined at §350.37(i). The prescribed POE is at the point of surface water runoff or groundwater discharge into any on-site or off-site surface water body meeting the definition of surface water in the state as presented in §307.4 (relating to General Criteria). The POE for a groundwater release to surface water is within the groundwater-bearing unit at the point where it discharges into the surface water body. Because this location may be difficult to access, groundwater monitoring wells are often placed somewhat upgradient of the discharge zone. Groundwater monitoring results from this location and Tier 2 or 3 fate and transport equations are typically used to determine whether the applicable PCL, that is, ^{SW}GW, is presently exceeded or will be exceeded at the actual POE. Additional information regarding determining whether a surface feature constitutes “surface water in the state” and calculating ^{SW}GW and ^{Sed}GW values is presented in the TRRP guidance document for surface water (RG-366/TRRP-24).



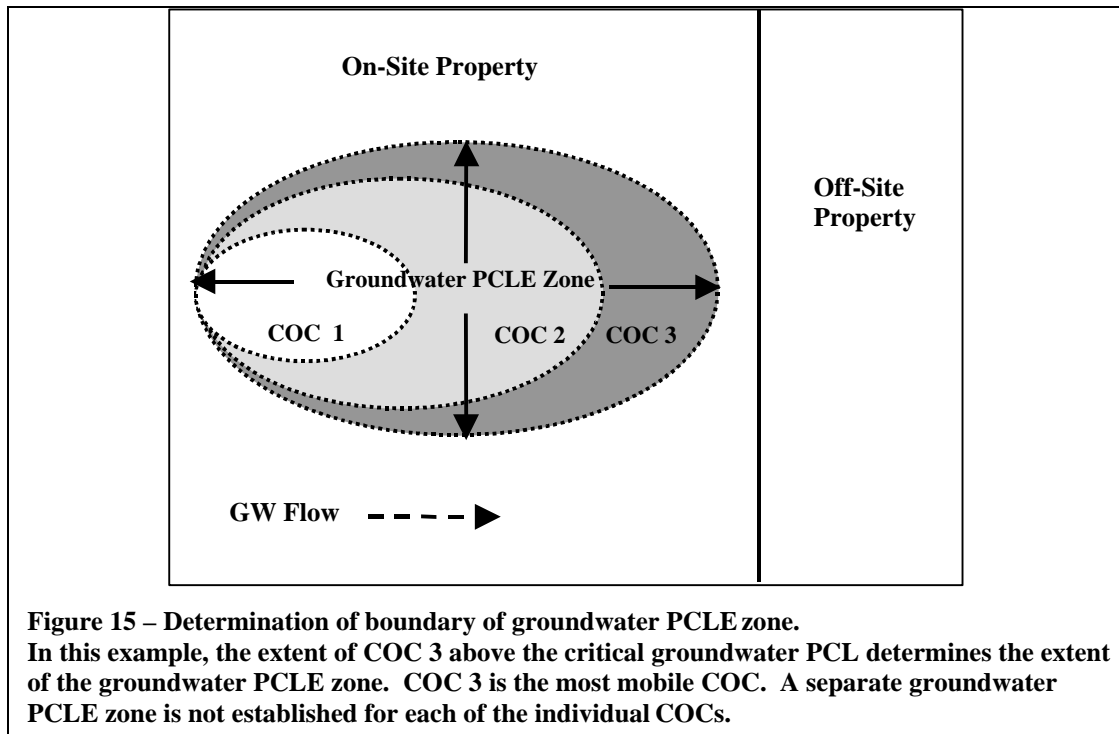
The POE for releases of COCs directly to surface water is discussed in §350.37(j) and is depicted as POE C in Figure 14. The prescribed POE for releases directly to surface water is at the point of entry of COCs into and throughout the extent of any surface water body meeting the definition for surface water in the state. For example, any COCs spilled directly into surface water are subject to this provision.

The POEs for sediment are described in §350.37(k) and are depicted as POE D in Figure 14. TRRP specifies that the prescribed POE to sediment is “within the upper one-foot of sediment beneath any surface water body meeting the definition of surface water in the state. . .” The human health POE for direct exposure to sediment is throughout the upper one-foot of sediment for that portion of a surface water body less than 2 meters deep. There is no human health POE for direct exposure to sediment where a surface water body is more than two meters deep. For surface water bodies with fluctuating levels, such as tidal bodies, the two meter depth is measured from the mean annual surface water elevation. Please refer to the TRRP guidance document for surface water (RG-366/TRRP-24) for further explanation.

Description of Alternate POEs for Class 2 and 3 Groundwater

With appropriate demonstration and agency authorization, a plume management zone (PMZ) may be used to respond to a PCLE zone in class 2 or 3 groundwater in accordance with §350.33(f)(4). A PMZ for class 2 or 3 groundwater specifies an alternate groundwater POE which will be used in place of the prescribed POE. A PMZ cannot be authorized for a PCLE zone in class 1 groundwater. The primary advantage of a PMZ is that the POE to groundwater is changed from a prescribed location throughout the groundwater PCLE zone to an alternate location established at the boundary of the PMZ. There is a boundary to the PMZ in all directions but for simplicity, the discussion is focused on the downgradient direction. Different rules apply for establishing the location of the downgradient boundary of a PMZ in class 2 and class 3 groundwater. The maximum distance “X” between the groundwater PCLE zone and the downgradient boundary of the PMZ is specified in §350.37(l) and (m) for class 2 and 3 groundwater, respectively.

The location of the boundary of the groundwater PCLE zone is an important factor in monitoring compliance with PMZ requirements. For both class 2 and class 3 groundwater, the location of the downgradient boundary of the PMZ is based upon the location of the residential groundwater PCLE zone, even for commercial/industrial properties. For class 2 groundwater, the allowable growth of a groundwater PCLE zone is based in part upon the current length of the residential groundwater PCLE zone at the time the response action plan is submitted. Figure 15 depicts how a groundwater PCLE zone is determined when several COCs with different migration capacities are present. The COC which migrates the farthest in a particular direction with a concentration greater than the critical groundwater PCL defines the limit of the groundwater PCLE zone in that direction. The length of the PCLE zone is determined at the time of response action plan submittal. When this evaluation is performed for all COCs in all directions, the extent of COCs exceeding critical PCLs is defined. This defines the limits of the groundwater PCLE zone. In the example in Figure 15, COC 3, which has the largest individual PCLE zone, defines the boundary of the groundwater PCLE zone. Thus, a PCLE zone is based upon all COCs present in an affected groundwater-bearing unit rather than on a COC-by-COC basis.



Flexibility to establish alternate POEs to class 2 or 3 groundwater is not automatic. Establishment of a PMZ requires the person to make appropriate demonstrations and to secure agency approval. The groundwater classification system is used to determine general eligibility; however, site-specific appropriateness must also be demonstrated. In this regard, §350.33(f)(4)(A) itemizes potentially adverse effects on groundwater and surface water quality which must be considered. Of course, the broad performance that must be demonstrated is that neither human health nor the environment is endangered by the PMZ. Also, to establish an alternate POE on on-site or off-site property which you do not own, an institutional control must be filed in accordance with §350.111. Except in the circumstances listed in the previous discussion, “Relationship Between POEs and Institutional Controls,” proof of landowner consent is necessary for the filing of an institutional control.

Alternate POEs to class 2 groundwater under Remedy Standard B (§350.37(1))

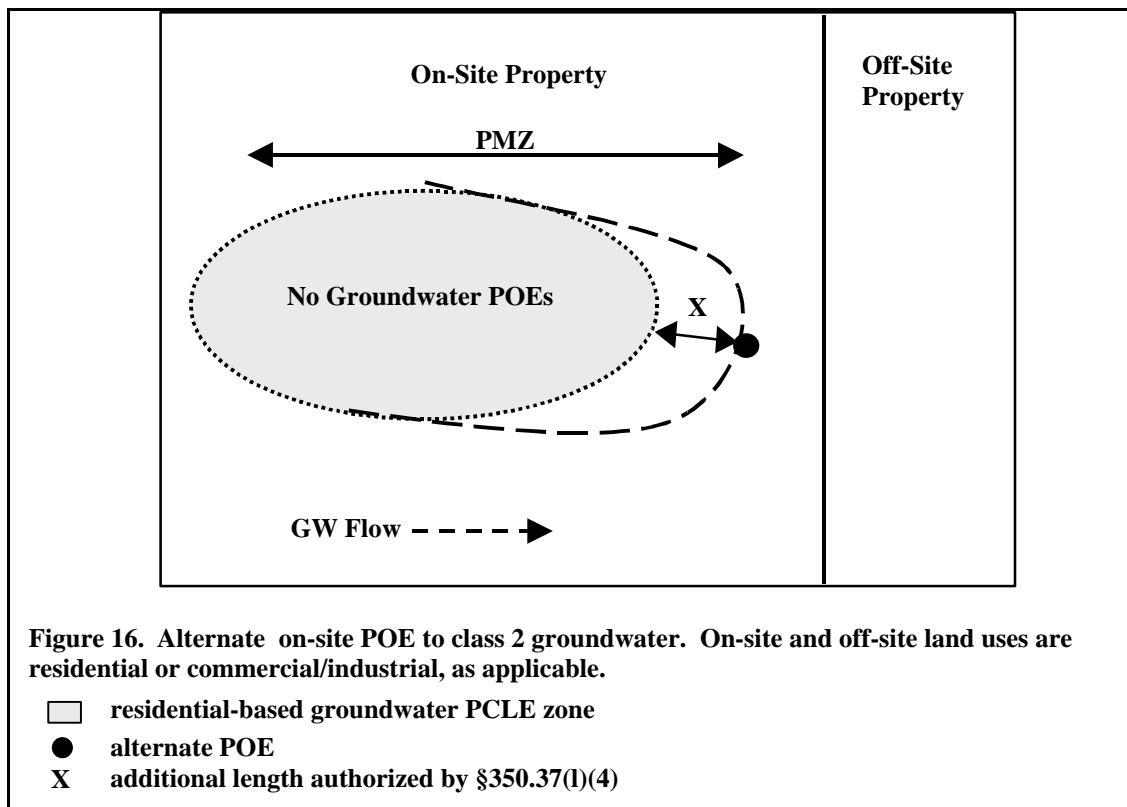
The rule specifies the requirements for a PMZ in class 2 groundwater in the following circumstances:

- when the residential groundwater PCLE zone is entirely on-site;
- when the residential groundwater PCLE zone has migrated onto neighboring property; and
- to determine whether a residential groundwater PCLE zone will be allowed to migrate onto off-site property.

These circumstances are described in §350.37(1)(1), (2), and (3), respectively and are depicted in Figures 16, 18, and 19, respectively. The establishment of a combined groundwater PCLE zone in class 2 groundwater is depicted in Figure 17. The allowable PCLE growth for a PMZ in class 2 groundwater is described in §350.37(1)(4) and is depicted in Figure 20. These subjects are discussed sequentially below.

Alternate On-Site POEs To Class 2 Groundwater (§350.37(l)(1))

TRRP in §350.37(l)(1)(A) specifies that the on-site POE to class 2 groundwater may be modified to be a well for residents completed at the on-site downgradient boundary of a PMZ. A PMZ is the current length of the residential groundwater PCLE zone determined at the time of response action plan submittal plus an additional length “X” determined in accordance with §350.37(l)(4). Figure 16 depicts an on-site PMZ in class 2 groundwater. Once the PMZ has been authorized there is no longer a POE to groundwater at any location throughout the on-site residential-based groundwater PCLE zone. Instead, the POE is a groundwater well located a distance “X” downgradient of the PCLE zone at the boundary of the PMZ.



Generally groundwater PCLE zones which have resulted from separate sources are managed as separate problems. However, §350.37(l)(1)(B) states that with site-specific approval for certain situations, a number of separate PMZs may be joined into a single combined PMZ. The alternate POE for the combined PMZ is determined in the same fashion as depicted in Figure 16. These circumstances are described as follows:

- multiple on-site PMZs exist, and have commingled, or
- multiple on-site PMZs are within 500 feet of one another such that management as a combined PMZ is more feasible and appropriate.

Note that this flexibility is granted upon approval for the management of on-site groundwater PCLE zones. This flexibility does not extend to allow on-site sourced groundwater PCLE zones to be combined with off-site sourced groundwater PCLE zones. Figure 17 depicts two on-site residential-based groundwater PCLE zones which are associated with different sources. These on-site PCLE zones may,

with approval, be combined into one groundwater PCLE zone provided such action is feasible and appropriate and the zones are less than 500 feet apart. However, the off-site groundwater PCLE zone may not be included in the combined zone even though it is within 500 feet. The off-site groundwater PCLE zone cannot be included because it has an off-site rather than on-site source area. Combining on-site sourced groundwater PCLE zones is not precluded in the event they extend off-site.

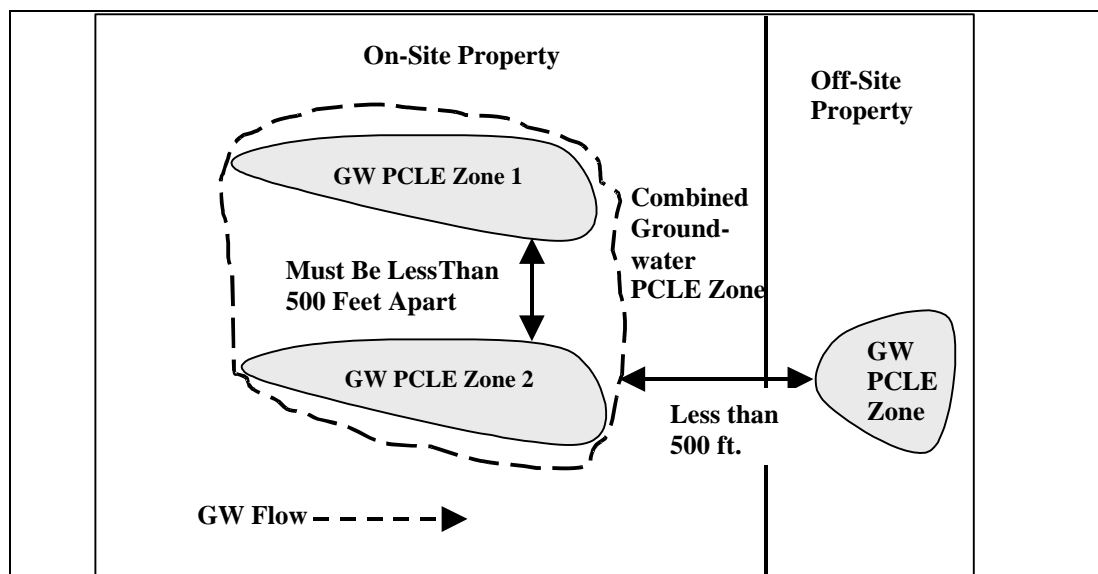


Figure 17. Multiple on-site class 2 groundwater PCLE zones. On-site and off-site land uses are residential or commercial/industrial, as applicable.

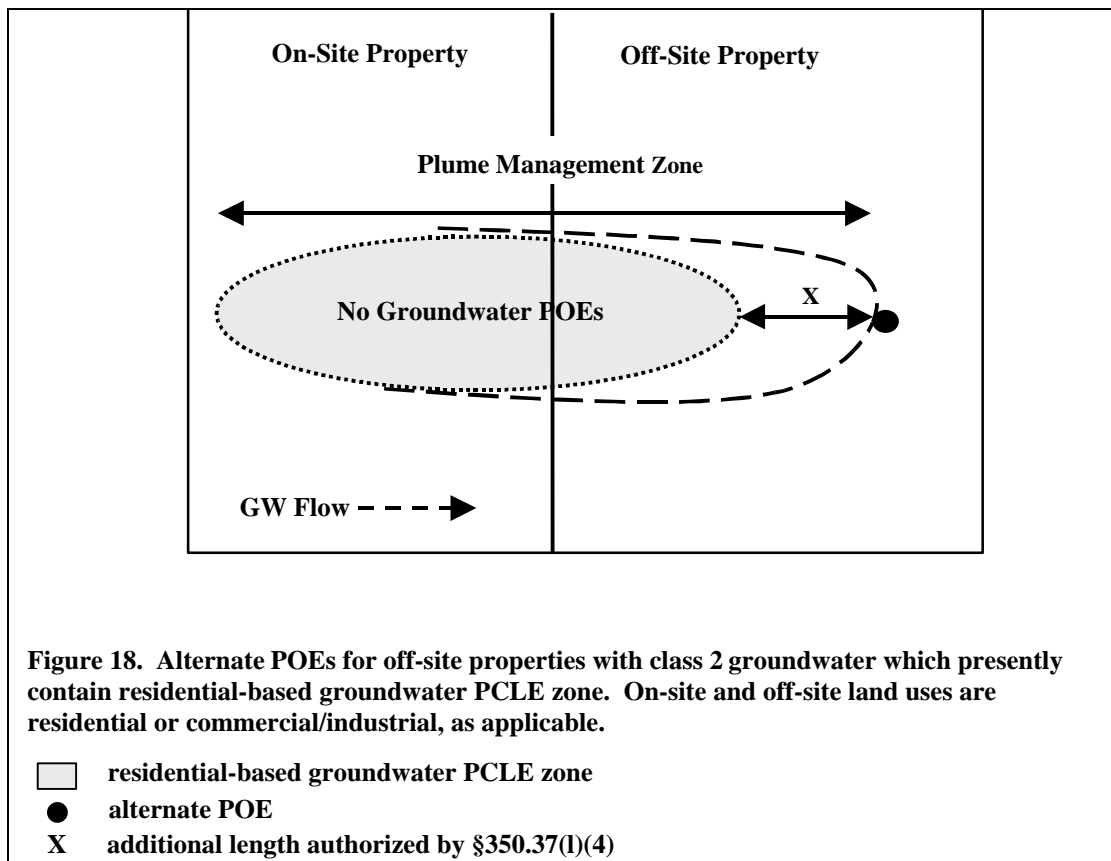
A combined on-site groundwater PCLE zone may be formed provided this is feasible and appropriate and the individual groundwater PCLE zones are within 500 feet of one another

Alternate POEs For Off-Site Properties With Class 2 Groundwater Which Contains Residential – Based Groundwater PCLE Zone (§350.37(1)(2))

When determining the location of an alternate POE associated with a PMZ on off-site property, the TRRP rule distinguishes between those off-site properties which presently contain a residential-based groundwater PCLE zone and those which do not. If the off-site property presently contains a residential groundwater PCLE zone and the PMZ has been authorized, then according to §350.37(1)(2) an alternate POE to class 2 groundwater may be established at the off-site downgradient boundary of the PMZ. This alternate POE replaces the prescribed POE and there is no longer a POE to groundwater within the PMZ. As shown in Figure 18, the PMZ includes the length of the residential groundwater PCLE zone plus an additional length “X.” The maximum allowed growth for a PCLE zone in class 2 groundwater is the smallest of the criteria described in §350.37(1)(4).

Alternate POEs For Off-Site Properties With Class 2 Groundwater Which Currently Do Not Contain A Residential-Based Groundwater PCLE Zone (§350.37(1)(3))

§350.37(1)(3) presents the conditions under which you can allow a residential-based groundwater PCLE zone to migrate onto an off-site property which does not currently contain a residential-based

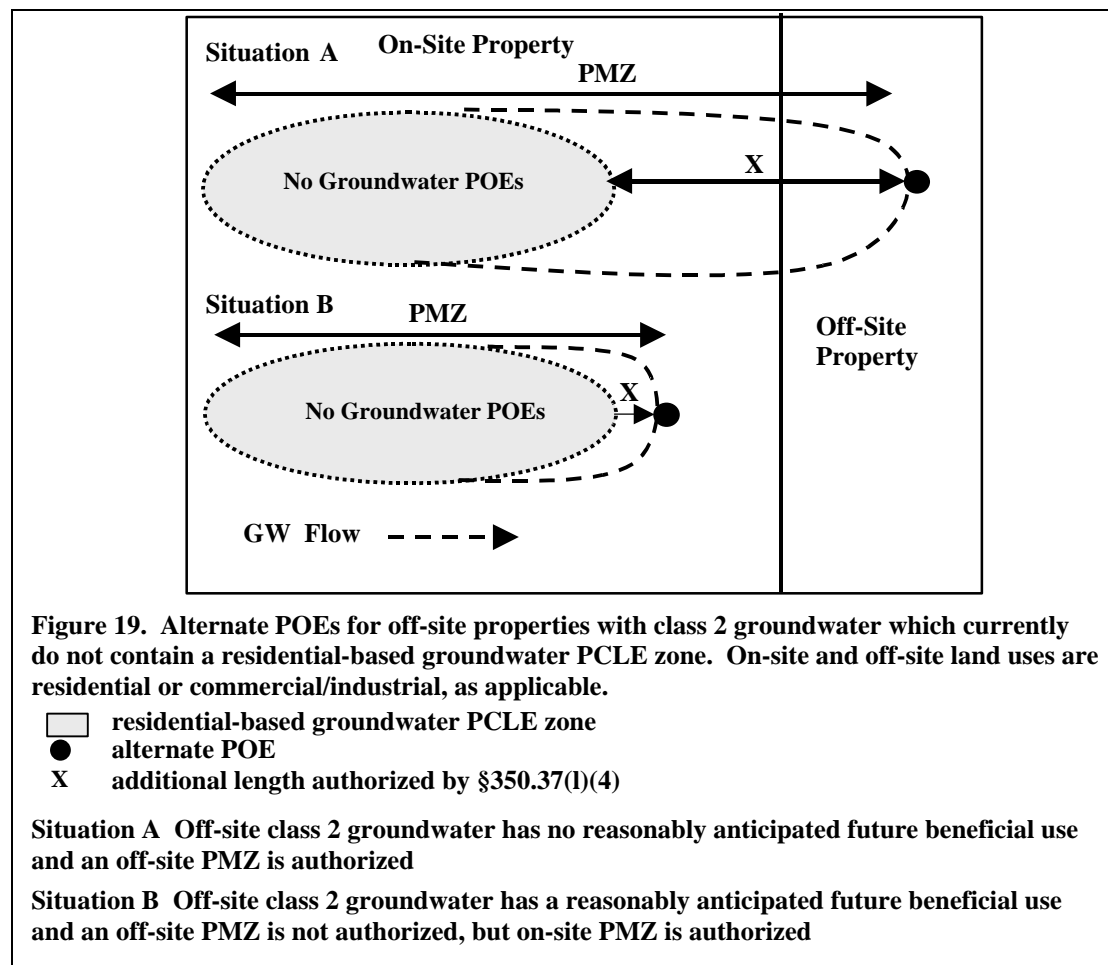


groundwater PCLE zone. You can allow a groundwater PCLE zone to migrate onto an off-site property that currently does not contain the PCLE zone provided you can demonstrate that the off-site class 2 groundwater in question has no reasonably anticipated future beneficial use. To allow such migration onto an off-site property you must also secure written concurrence from that off-site landowner unless the property is subject to zoning or a governmental ordinance which is equivalent to the institutional control that would otherwise be required. You cannot allow a groundwater PCLE zone to migrate onto off-site property in either of the following two circumstances: you cannot demonstrate that the groundwater has no reasonably anticipated future beneficial use; or you cannot secure off-site landowner written consent to an institutional control, unless an equivalent zoning or governmental ordinance is in place. These two circumstances are depicted in Figure 19 as Situation A and Situation B.

For Situation A, the demonstration that the off-site class 2 groundwater has no reasonably anticipated future beneficial use has been successfully made and the landowner has given written consent for the establishment of an institutional control. In this case you may establish a PMZ which extends onto an off-site property. The alternate off-site POE to class 2 groundwater is a well for residents completed at

the off-site boundary of the PMZ. The PMZ includes the current length of the residential-based PCLE zone plus an additional length “X” determined in accordance with §350.37(l)(4).

Situation B represents the circumstance where the demonstration cannot be made that the off-site class 2 groundwater does not have a reasonably anticipated future beneficial use. Thus, the PMZ will not be allowed to extend onto that off-site property. This determination does not necessarily mean that a PMZ could not be authorized. A PMZ could be established on-site with an additional length “X” determined in accordance with §350.37(l)(4).



There are three types of factors which will be used to determine whether a particular off-site class 2 groundwater-bearing unit has a reasonably anticipated future beneficial use. First, the rule in §350.37(l)(3)(C) presents the initial factors which will be considered when making this determination. These are:

- the existing quality of groundwater considering non-point sources of COCs and their cumulative impact on the groundwater quality;
- the lack of use of the groundwater based on the presence of superior water supplies;
- the proximity and withdrawal rates of groundwater users (see §350.52(2)(A)); or
- the property is subject to zoning or governmental ordinance which is equivalent to the deed notice, VCP certificate of completion, or restrictive covenant that otherwise would have been required.

Second, the information collected in response to §350.52 for the groundwater classification is relevant. Is the groundwater-bearing unit clearly, or just barely, a class 2 groundwater resource? The regulatory guidance document on this subject titled *Groundwater Classification* (RG-366/TRRP-8) is relevant to this determination. Since the determination pertains to reasonably anticipated future beneficial use, the intrinsic value of a groundwater-bearing unit will also play an important role in this determination. Intrinsic value is determined through an evaluation of groundwater yield and natural quality. Thus, it is not enough to demonstrate that a groundwater-bearing unit is not presently being used. You must make the added demonstration that there is no reasonable potential for the groundwater-bearing unit to be used for a beneficial purpose in the future. And third, there are site-specific circumstances which can influence this determination.

A demonstration that a groundwater-bearing unit has no reasonably anticipated future beneficial use does not remove the requirement for you to file an institutional control with the landowner's consent for any off-site POE based on commercial/industrial land use or an alternate POE, except in those circumstances where zoning or a governmental ordinance is demonstrated to be equivalent to a deed notice, VCP certificate of completion, or restrictive covenant that would otherwise be required.

§350.37(l)(3)(C) provides the opportunity for you to demonstrate that a groundwater-bearing unit has no reasonably anticipated future beneficial use as a result of zoning or a governmental ordinance. To take this path, you must demonstrate that a particular zoning or governmental ordinance is equivalent to a deed notice, VCP certificate of completion, or restrictive covenant that otherwise would have been required. The agency will accept zoning and governmental ordinances as acceptable equivalent institutional controls if:

- the zoning or governmental ordinance is by its terms sufficient to provide the control that is required to be protective of human health and the environment;
- the zoning or governmental ordinance provides notice of the COCs left in place and that the zoning or ordinance is necessary to prevent exposure to the COCs;
- the zoning or governmental ordinance applies to both current and future uses for the land covered; and
- the zoning or governmental ordinance cannot be modified or rescinded without the consent of the TNRCC.

Reliance on an equivalent zoning or governmental ordinance addresses only the institutional control issue. It does not circumvent or otherwise supercede the POE criteria. Therefore, plume management zones may only be established for class 2 or 3 groundwater, and this approach does not modify the groundwater classification established pursuant to §350.52. Additionally, ecological impacts or other hazards must be addressed in accordance with TRRP.

In the circumstance where zoning or a governmental ordinance cannot be demonstrated to be equivalent to a deed notice, VCP certificate of completion, or restrictive covenant, the zoning or ordinance can still influence the groundwater response decisions at an affected property. In particular, existing zoning or a governmental ordinance can be a very important factor in response to §350.33(f)(4)(A) regarding whether a PMZ should be authorized at all at an affected property, as well as for deciding if there is a reasonably anticipated future beneficial use. Please refer again to Situation B on Figure 19. This diagram could represent the circumstance where, based in part on the presence of zoning or a governmental ordinance, the affected property is determined to satisfy the criteria for authorization of an

on-site PMZ zone. However, this particular zoning or ordinance is determined to not be equivalent to a deed notice, VCP certificate of completion, or a restrictive covenant. Thus, while an on-site PMZ is authorized, in this example that PMZ is not approved to extend onto the off-site property that currently does not contain the PCLE zone. However, it is possible in a different example that an equivalent zoning or governmental ordinance could bolster the case of no anticipated future beneficial use and therefore support an off-site PMZ.

Maximum Additional Length Of PMZ In Class 2 Groundwater-Bearing Unit (§350.37(1)(4))

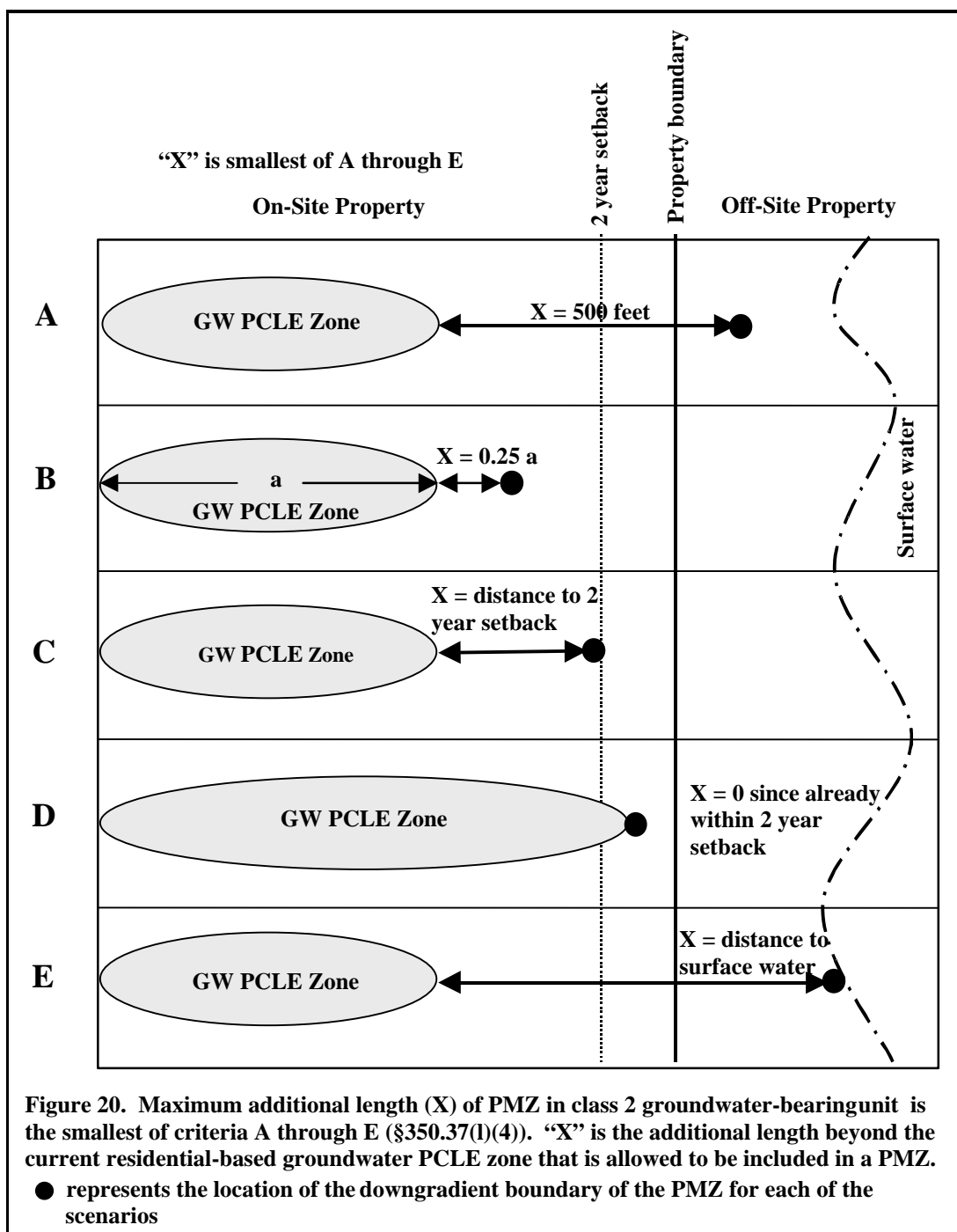
The total length of a PMZ within a class 2 groundwater-bearing unit consists of the current length of the residential-based groundwater PCLE zone plus an additional length “X” determined in accordance with §350.37(1)(4). The maximum additional length of the PMZ, that is “X,” is illustrated in Figure 20 and is the smallest of the following applicable distances:

- A. up to 500 feet beyond the current length of the residential-based groundwater PCLE zone;
- B. a length of up to 0.25 times the current length of the residential-based groundwater PCLE zone (that is, up to 25% additional plume length);
- C. to within two years groundwater travel time of the closest hydraulically downgradient off-site property when:
 - the off-site property owner has not provided written concurrence to allow the recording of an institutional control; or
 - the off-site property does not contain the residential-based PCLE zone and the groundwater has a reasonably anticipated future beneficial use;
- D. at the current downgradient extent of the residential-based PCLE zone when the residential groundwater PCLE zone is already within the two-year groundwater travel time setback distance from off-site property; or
- E. the distance to the surface water POE.

Thus, for a PMZ in a class 2 groundwater-bearing unit, the additional length for a PMZ varies between 0 and 500 feet, depending upon the circumstances at a particular affected property.

The smallest of the five criteria, A through E, is normally used to determine the maximum expansion of a groundwater PCLE zone within a class 2 groundwater resource at an affected property. However, when the closest hydraulically downgradient off-site property is subject to zoning or governmental ordinance which is equivalent to the institutional control that would otherwise be required, criteria C and D do not apply. The discussion regarding §350.37(1)(3) has previously described the requirements for demonstrating that zoning or a governmental ordinance is equivalent to a deed notice, VCP certificate of completion, or a restrictive covenant. In essence, this provision means that if an enforceable ordinance with an equivalent effect to one of the institutional controls accepted by TRRP prohibits use of the class 2 groundwater on an off-site property, then criteria C and D which are designed to protect that off-site groundwater resource will not be used as factors to limit groundwater PCLE zone growth. Instead criterion A, B, or E, depending upon which results in the shortest distance at a particular affected property, will be the limiting factor determining what growth, if any, will be allowed for a PMZ.

In the example illustrated in Figure 20, for the assumed PCLE zone size in scenarios A-C and E, “X” would be defined by scenario B since that scenario defines the shortest distance “X.”



Alternate POEs to class 3 groundwater under Remedy Standard B (§350.37(m))

The TRRP rule specifies in §350.37(m) that, provided a PMZ has been authorized in response to §350.33(f)(4), you may establish an alternate on-site or off-site POE to class 3 groundwater. Unlike class 2 groundwater, the PCL for class 3 groundwater is not based upon groundwater ingestion. Instead the

PCL to be applied at the alternate POE to class 3 groundwater is $^{GW}GW_{Class\ 3}$ which is 100 times greater than the residential-based $^{GW}GW_{Ing.}$. Upon approval of the PMZ, there is no POE to groundwater throughout the groundwater PCLE zone and the groundwater POE is located at the downgradient limit of the PMZ.

The additional length “X” incorporated into the PMZ is determined by establishing the downgradient boundary of the PMZ. Unlike the 500 foot maximum additional distance established for alternate POEs in class 2 groundwater, there is no maximum additional distance specified for alternate POEs to class 3 groundwater. The smallest of the following distances, measured from the current downgradient boundary of the residential-based class 3 groundwater PCLE zone, defines the maximum allowable expansion for the downgradient PMZ boundary:

- to within two years groundwater travel time upgradient of:
 - the closest hydraulically downgradient off-site property for which the landowner has not provided written concurrence to allow the recording of an institutional control for situations where zoning or a governmental ordinance does not serve as the institutional control; or
 - the downgradient limit of a zoning or governmental ordinance that serves as the institutional control; or
- the distance to a surface water POE.

A previous discussion in this document describes the determination of groundwater travel time setback distance and is relevant to establishing the alternate POE to class 3 groundwater. Also, to qualify as a “zoning or governmental ordinance that serves as the institutional control”, such zoning or governmental ordinance must be equivalent to the deed notice, VCP certificate of completion, or restrictive covenant that otherwise would be required. The previous discussion regarding §350.37(1)(3)(C) provides relevant criteria which should be used to determine whether a zoning or governmental ordinance is an equivalent replacement for the institutional control otherwise required by the TRRP rule.

Figures 21 and 22 depict the location of the alternate POE to class 3 groundwater in greater detail for two different circumstances.

Figure 21 depicts the situation where the zoning or governmental ordinance is determined to be equivalent to a deed notice, VCP certificate of completion, or restrictive covenant. In this instance, the additional distance “X” to the PMZ boundary is determined based on the smaller of: 1) the distance to two years groundwater travel time upgradient of the downgradient limit of the zoning or governmental ordinance that serves as the institutional control; and 2) the distance to a surface water POE. In this case the written concurrence of an off-site landowner for the recording of an institutional control is not needed prior to allowing a groundwater PCLE zone in class 3 groundwater to migrate onto an off-site property. No site-specific institutional control will be required in this case for the PMZ because an equivalent zoning or governmental ordinance will be relied upon instead to protect human health and the environment. In the example depicted in Figure 21, the shorter of these two distances is to two years groundwater travel time upgradient of the downgradient boundary of the zoning or governmental ordinance.

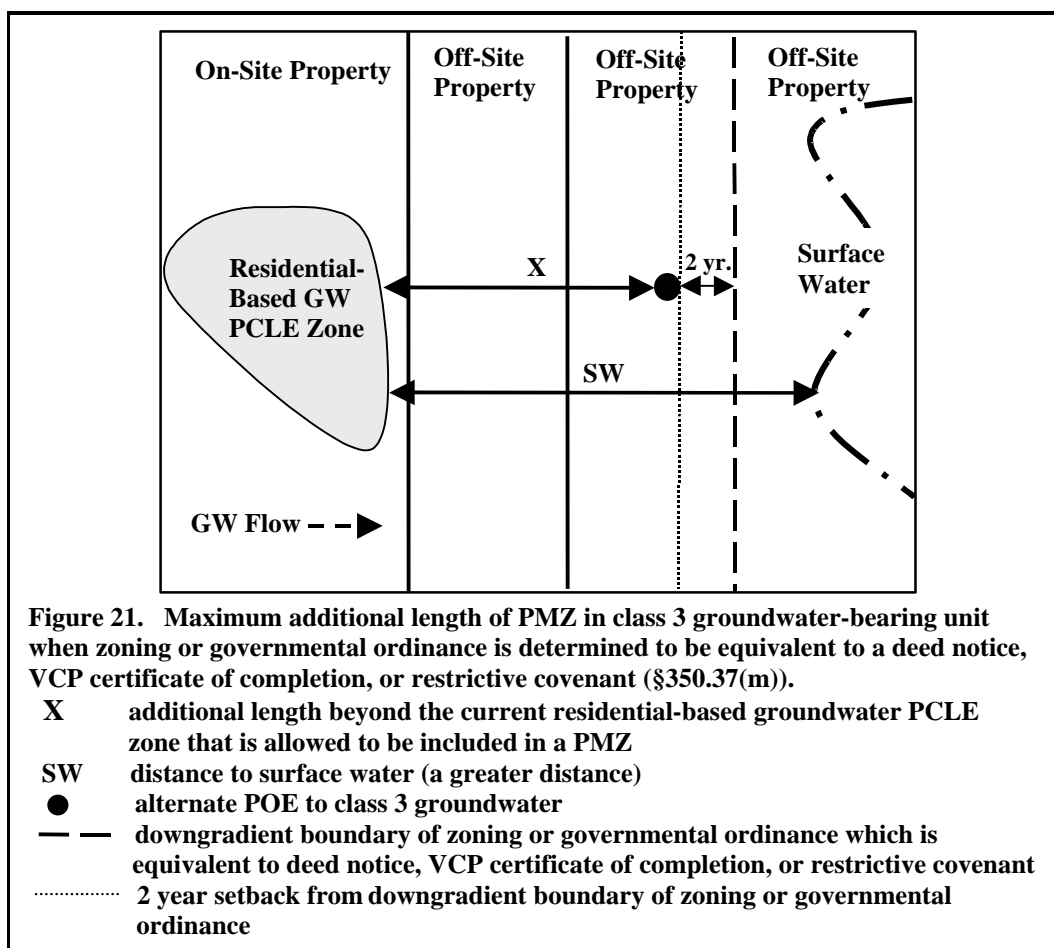


Figure 22 depicts the situation where the zoning or governmental ordinance is determined to not be equivalent to a deed notice, VCP certificate of completion, or restrictive covenant. In this instance, the additional distance “X” to the PMZ boundary is determined based upon the smaller of: 1) the distance to two years groundwater travel time upgradient of the closest hydraulically downgradient off-site property for which the landowner has not provided written concurrence to allow the recording of an institutional control for situations where zoning or a governmental ordinance does not serve as the institutional control; and 2) the distance to a surface water POE. In this case, a deed notice, VCP certificate of completion, or restrictive covenant will be required for all affected properties. You may not allow a groundwater PCLE zone in class 3 groundwater to migrate onto an off-site property unless you have received written concurrence from that off-site landowner for the recording of an institutional control. As implied, though, if you do secure written concurrence from an off-site landowner for the recording of an institutional control, then you may allow a groundwater PCLE zone in class 3 groundwater to expand onto that off-site property. Figure 22 depicts an example where the first downgradient off-site landowner is willing to file an institutional control but the second downgradient off-site landowner is not. The POE to surface water is located beyond either the on-site property or these two off-site properties. Therefore, in this example, the alternate POE to class 3 groundwater is located two years groundwater travel time upgradient of the property boundary between the first and second downgradient off-site properties.

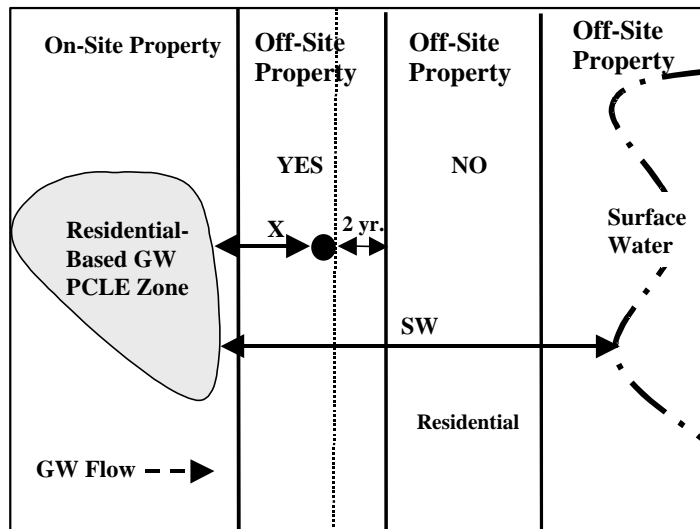


Figure 22. Maximum additional length of PMZ in class 3 groundwater-bearing unit when zoning or governmental ordinance is determined to not be equivalent to a deed notice, VCP certificate of completion, or restrictive covenant (§350.37(m)).

- X additional length beyond the current residential-based groundwater PCLE zone that is allowed to be included in a PMZ
- SW distance to surface water (a greater distance)
- alternate POE to class 3 groundwater
- YES off-site landowner concurs with recording of an institutional control
- NO off-site landowner does not concur with recording of an institutional control
- 2 year setback from downgradient boundary of zoning or governmental ordinance



TNRCC Regulatory Guidance

Remediation

RG-366/TRRP-27 June 2000

SUBJECT: **Development of Human Health
PCLs for Total Petroleum
Hydrocarbon Mixtures**

Objective: Describes the process to establish PCLs for total petroleum hydrocarbon mixtures
Audience: Environmental Professionals and the Regulated Community
References: The regulatory citation for the Texas Risk Reduction Program (TRRP) rule is 30 TAC 350.

The TRRP Rule and Preamble are on-line at
<http://www.tnrcc.state.tx.us/oprd/rules/indxpdf5.html>.

The TRRP rule, together with conforming changes to related rules, is contained in 30 Texas Administrative Code Chapter 350, and was published in the September 17, 1999 Texas Register (24 TexReg7413-7944). From the TRRP Web page (<http://www.tnrcc.state.tx.us/permitting/trrp.htm>) you can download Tier 1 PCLs, toxicity factors and other information.

Contact Point: Technical Support Section at 512/239-0310.
Corrective Action Section at 512/239-2343.
Site Assessment & Management Section at 512/239-2509.
Superfund Cleanup Section at 512/239-2425.
Voluntary Cleanup Program Section at 512/239-5891.

Please note that the Texas Risk Reduction Program (TRRP) does not require that total petroleum hydrocarbon (TPH) be evaluated as a chemical of concern (COC) at an affected property. The COCs to be evaluated under the TRRP, including TPH, are decided by the person undertaking the corrective action in coordination with the applicable TNRCC program area. See TNRCC guidance document *Determining Target COCs* (RG-366/TRRP-10) for further information. If you or the TNRCC program area determine that TPH is an applicable COC for an affected property, then this document should be followed to guide the development of appropriate PCLs for the TPH mixture(s) at the affected property.

Texas Natural Resource Conservation Commission • PO Box 13087 • Austin, Texas • 78711-3087

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RG-366/TRRP-27

Introduction

This guidance document describes a process to establish human health-based protective concentration levels (PCLs) for total petroleum hydrocarbons (TPH) in accordance with 30 TAC §350.76(g) of the Texas Risk Reduction Program (TRRP) rule. In many instances, the ability to establish PCLs for TPH will be a convenient tool to evaluate the protectiveness of a mass of petroleum hydrocarbons comprised of potentially hundreds of individual chemicals of concern (COCs), many of which lack the toxicity and chemical/physical property information needed for PCL development.

The development of TPH PCLs is dependent on the composition of the petroleum hydrocarbon product since different hydrocarbon products have different compositions. Therefore, the development of PCLs must be able to reflect the composition of the TPH in question. Contrasts in composition reflect differences in the relative percentages of toxic COCs and mobile COCs in the petroleum hydrocarbon product, both of which directly influence the derived PCL. The gross composition of a petroleum hydrocarbon product can be characterized by the chromatographic profiles or fingerprints generated using analytical gas chromatography techniques over a defined boiling point range. As shown in Figure 1, petroleum hydrocarbon products such as gasoline, diesel, motor oil, and jet fuel do not have the same compositions as reflected by the contrasts in the gas chromatographic fingerprints for the different products. Additionally, as illustrated by the gas chromatograms for the fresh and weathered gasoline in Figure 1, the products can change dramatically upon release into the environment due to environmental weathering and commingling with other petroleum hydrocarbon products (see the Product Composition and Weathering section at the end of this document for further discussion of this topic). Because the original petroleum hydrocarbon product may have weathered upon release to the environment or mixed with other petroleum hydrocarbon products such that the composition in the environmental medium may be dissimilar to the original product, the term “TPH mixture” will typically be used in following text in lieu of the term “petroleum hydrocarbon product.”

General Overview

To address issues of insufficient toxicity and chemical/physical property information for all potential COCs, the overwhelming number of COCs comprising petroleum hydrocarbon products, and the variability in the composition of the TPH, a process that closely follows the work of the national Total Petroleum Hydrocarbon Criteria Working Group¹ is described in this guidance to establish TPH PCLs. A general overview of the process is illustrated in Figure 2 and is briefly summarized here.

When TPH is established as an applicable COC, samples from environmental media affected with TPH are collected during the affected property assessment for laboratory analysis using a gas chromatography method (TNRCC Method 1005). The analytical results are used to determine the extent of TPH-affected property, compositional distribution of the hydrocarbons in the TPH, and the magnitude of TPH concentrations in each affected environmental medium. Gas chromatography fingerprints for the different samples collected from the TPH source areas (that is areas of highest TPH concentrations in an environmental medium) are then compared to determine if the gross hydrocarbon composition of the TPH changes across the sampled area. When the gas chromatographic fingerprints indicate that different petroleum hydrocarbon products (Figure 1) were released in different areas of the affected property, then

¹ The TPH Criteria Working Group is a consortium of industry, academia, and governmental representatives who have worked since 1993 to develop evaluation methods for TPH. Information on the working group and publications can be found at www.aehs.com.

PCLs need to be established for each of those different TPH compositions for application in the respective source area for that petroleum hydrocarbon product and associated affected areas.

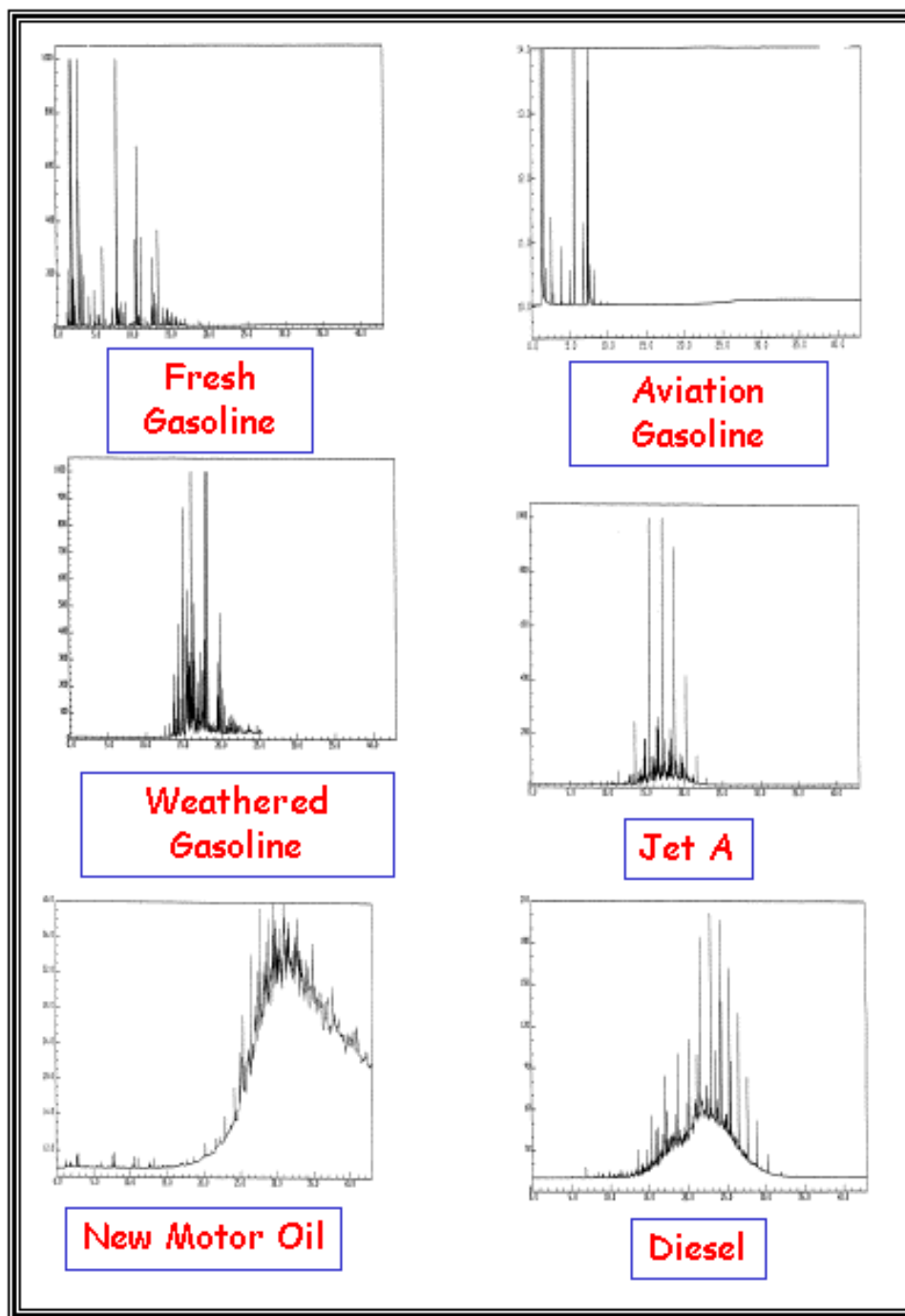


Figure 1. Chromatograms showing contrasts between the compositions of different petroleum hydrocarbon mixtures.

Based on chromatograms from TNRCC Method 1005 analysis, the sample with the highest concentration that is representative of the TPH in the source area(s) is selected and fractionated using a second laboratory analysis method (TNRCC Method 1006) into seven aliphatic boiling point ranges and six aromatic boiling point ranges of petroleum hydrocarbons (Figures 2 and 3). Subsequently, the concentration of each boiling point range is determined, and the mass fraction of each boiling point range relative to the total mass of the TPH mixture is determined by dividing the concentration of each boiling point range by the total concentration of the TPH mixture. Tier 1, 2, or 3 PCLs are then derived for each boiling point range for each complete or reasonably anticipated to be completed exposure pathway as defined in 30 TAC §350.71(c) by using surrogate toxicity factors and surrogate chemical/physical properties (Tables 1 and 2) that represent the toxicity and mobility of the hydrocarbon compounds comprising that boiling point range. By following this procedure, each boiling point range is essentially treated as a COC. Once a PCL is established for each of the boiling point ranges comprising the TPH mixture for each exposure pathway, a PCL is then established for the TPH mixture itself (Figures 2 and 3). The PCL for the TPH mixture for a given exposure pathway is established by taking the inverse weighted average of the sum of the individual PCLs determined for each boiling point range for that same exposure pathway. The PCL for each boiling point range is weighted according to the mass of each specific boiling point range in the TPH mixture. The PCLs established for the TPH mixture for each exposure pathway for an affected environmental medium are then compared to determine the critical, that is, the lowest TPH PCL for that environmental medium. The critical TPH PCL for each environmental medium is then compared to the TPH concentrations within that environmental medium using the TPH results originally measured with TNRCC Method 1005 to determine where the critical PCLs are exceeded. The volume of the environmental medium with TPH concentrations in excess of the critical TPH PCL is defined as the PCL exceedance (PCLE) zone(s) and is to be addressed by a response action (Figure 2).

A detailed step-by-step explanation of the process is provided in the Procedural Steps to Establish PCLs for TPH Mixtures section of this document. In that more detailed explanation, screening procedures are introduced that may prevent the need to establish site-specific PCLs for the TPH at an affected property.

The TPH PCLs developed using this document provide an estimate of acceptable aggregate risk based on noncarcinogenic effects only. In addition to establishing PCLs for TPH, you typically will need to address such individual COCs such as benzene, ethylbenzene, toluene, xylenes, polycyclic aromatic hydrocarbons, and other key petroleum hydrocarbon COCs, including metals in accordance with the requirements of the program area.

The process for setting PCLs for ecological receptors can be found in the TNRCC Ecological Risk Assessment Guidance Document available on the TRRP Web page. In general, the process to calculate TPH PCLs for ecological receptors would be the same, but different surrogate toxicity factors would likely be assigned to the boiling point ranges. Therefore, consult with the TNRCC ecological risk assessment experts in the Technical Support Section for more information on ecological risk assessments.

TPH PCLs and the Tiered PCL Development Process

The TRRP establishes a three-tiered framework for PCL development. The development of TPH PCLs fits within that framework. PCLs for the aliphatic and aromatic boiling point ranges can be established under Tiers 1, 2, or 3 as referenced in Figure 2. Non-site-specific PCLs for the aliphatic and aromatic boiling point ranges are established under Tier 1. The Tier 1 PCLs for the aliphatic and aromatic boiling point ranges can be downloaded from the TRRP Web page and used to calculate Tier 1 PCLs for the TPH mixture as described above and later in this document. For information on the use of the Tier 1 TPH PCL

Tables, see the TNRCC guidance document *Proper Use of the Tier 1 PCL Tables* (RG-366/TRRP-23). Alternatively, site-specific PCLs for the boiling point ranges, which consider characteristics of the affected property, lateral transport, and more appropriate natural attenuation factor models, may be established under Tiers 2 or 3 (see 30 TAC §350.75(a)-(d)). The Tier 2 or 3 PCLs for the different boiling point ranges can then be used to establish Tier 2 or 3 PCLs for the TPH mixture.

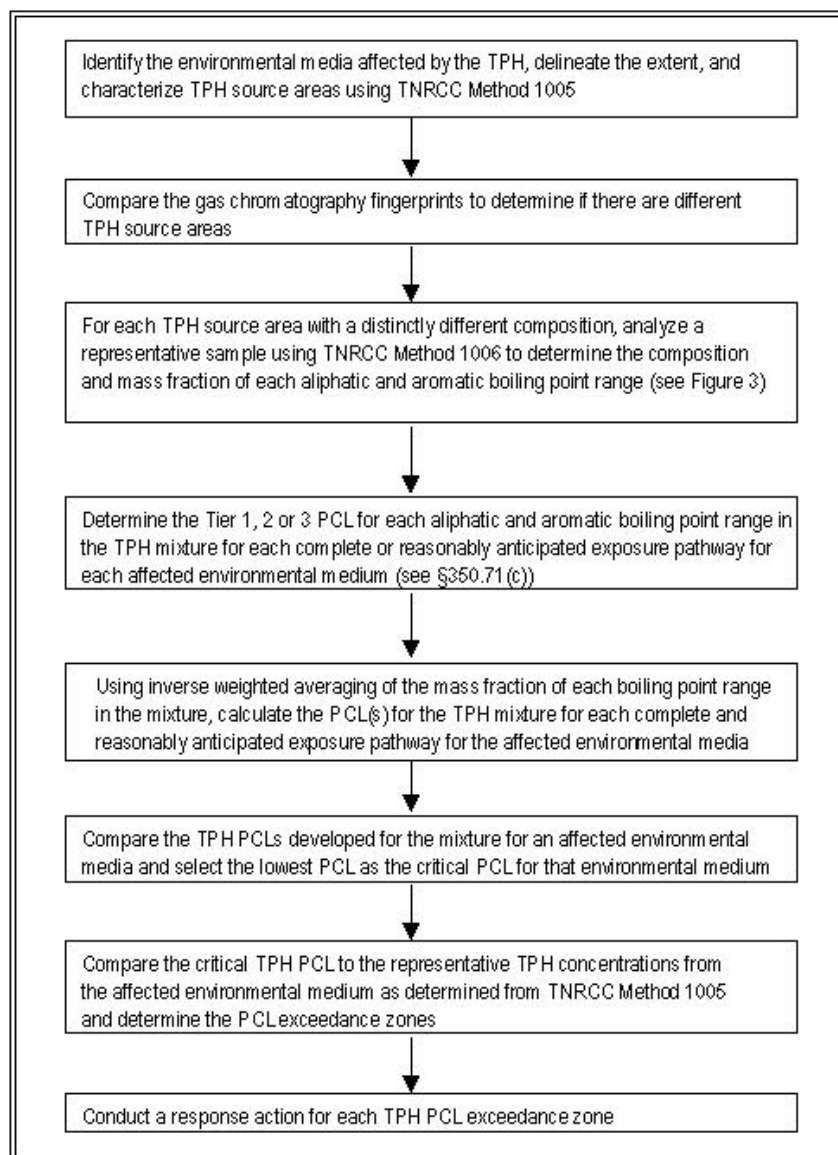


Figure 2. Overview of PCL Development Process.

Default versus Site-Specifically Determined TPH Mixture Compositions

As discussed previously, the composition of a petroleum hydrocarbon mixture is important to the development of PCLs. Therefore, the TNRCC may define, when appropriate and feasible, default

compositions for various petroleum hydrocarbon mixtures in order to establish Tier 1 PCLs for the TPH mixtures (not just for the aliphatic and aromatic boiling point ranges). Providing PCLs for TPH mixtures may lessen the need to fractionate samples, which expedites the process and reduces costs. A default composition for transformer mineral oil has been adopted for the TRRP and Tier 1 PCLs for transformer mineral oil have been established accordingly. Default compositions for other TPH mixtures such as gasoline and diesel may be adopted by the TNRCC over time as sufficient information becomes available. When default compositions for TPH mixtures are adopted, you may use that default composition as long as it is used only for the same TPH mixture it is intended to represent. Laboratories can typically evaluate a gas chromatography fingerprint and determine the probable original petroleum hydrocarbon product unless it is mixed or so weathered so as to be unrecognizable. When a default composition for a TPH mixture has not been adopted for the particular TPH mixture under consideration, and the screening criteria discussed in Step 4 below are failed, then you will need to determine the site-specific TPH mixture composition using TNRCC Method 1006.

Analytical Methods for TPH

The measurement of TPH is a method-defined parameter, meaning that the composition and concentration of TPH is determined by the procedures followed in the analytical method. As introduced earlier, the TNRCC has developed two analytical methods for TPH. TNRCC Methods 1005 and 1006 should be used for determining concentrations of TPH, for establishing PCLs, and/or determining the composition of TPH for PCL development. If you wish to use an alternate method, then you must first submit a proposal to use an alternate method to the TNRCC and include in that proposal the data needed to validate the alternate method against TNRCC Method 1005 and 1006 as the reference methods. Once an alternate method has been approved for use under TRRP, the method, or reference to the method, will be placed on the TRRP Web page for others to use.

TNRCC Method 1005

Analytical results from TNRCC Method 1005 are primarily intended to be used to:

- determine the composition and concentration of the TPH at the affected property,
- identify source areas, and
- determine compliance with the established critical TPH PCLs.

Additionally, the results from the method may also be used as a screening tool to determine whether or not the development of PCLs for the TPH mixture is warranted as discussed under Steps 3 and 4 of the next section of this document.

TNRCC Method 1005 is an n-pentane extraction followed by a gas chromatography/flame ionization detection (GC/FID) analysis method that measures the concentration of hydrocarbons between n-C₆ and n-C₃₅. The laboratory includes a normal (n-) C₁₂ alkane marker and an n-C₂₈ alkane marker to aid the data user in evaluating the distribution of the hydrocarbons in the TPH based on the chromatographic profile. Results from TNRCC Method 1005 are reported as concentrations for the C₆ -C₁₂ boiling point range, the C₁₂ -C₂₈ boiling point range, the C₂₈ -C₃₅ boiling point range when applicable, and the sum of the concentration of the two or three boiling point range concentrations. TNRCC Method 1005 can be downloaded from www.tnrcc.state.tx.us/permitting/analysis.htm.

TNRCC Method 1006

As discussed earlier, the analytical results from TNRCC Method 1006 are to be used to determine the concentrations of seven aliphatic boiling point ranges and six aromatic boiling point ranges of the TPH mixture in order to support development of TPH PCLs (Figure 3). The PCL for a TPH mixture is dependent upon the mass fraction represented by each boiling point range. Only the sample(s) to be used to represent the composition for the source area(s) need to be subjected to analysis using TNRCC Method 1006. Relative to TNRCC Method 1005, TNRCC Method 1006 is more expensive and therefore the agency is trying to minimize the use of the method to the extent possible.

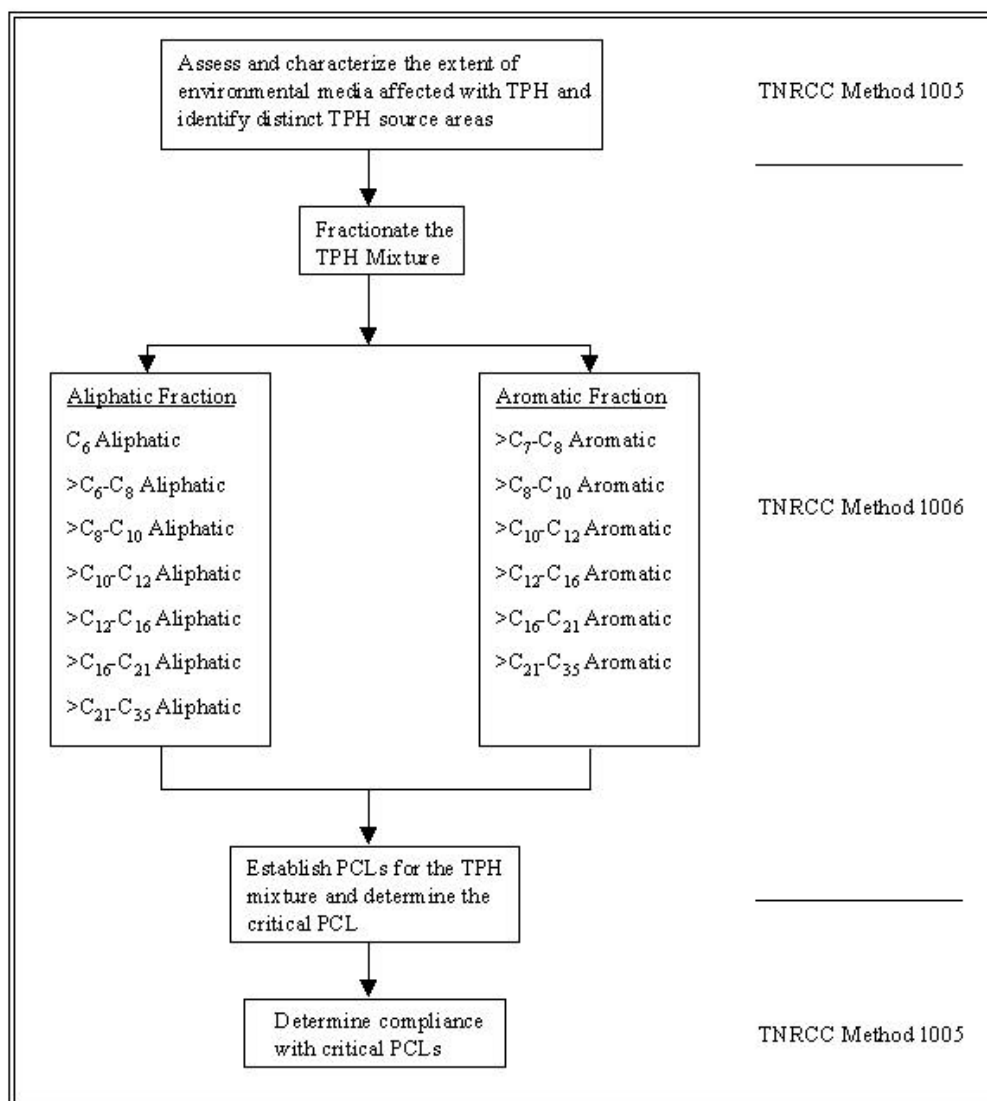


Figure 3. The applicability of TNRCC Methods 1005 and 1006 and boiling point ranges.

TNRCC Method 1006 uses a silica gel fractionation of the n-pentane extract to separate the TPH into the aliphatic hydrocarbon fraction and the aromatic hydrocarbon fraction and includes the analysis of each of

these fractions by GC/FID. The GC/FID analysis of the fractions separates each fraction into discrete boiling point ranges based on normal alkane markers. TNRCC Method 1006 can be downloaded from www.tnrcc.state.tx.us/permitting/analysis.htm.

Procedural Steps to Establish PCLs for TPH Mixtures

This section details the steps to establish PCLs for TPH mixtures. The section also discusses a screening step using the TNRCC Method 1005 data to avoid unwarranted development of PCLs for the TPH mixture. Figure 4 provides a decision framework that illustrates the process described in this section and identifies critical decision points. However, process Steps 8 and 9 are only cursorily addressed in Figure 4. A spreadsheet may be downloaded from the TRRP Web page that calculates the TPH mixture PCLs.

Step 1 Field Sampling

If TPH is an applicable COC, begin by collecting a sufficient number of samples for analysis using TNRCC Method 1005 to determine the concentrations and extent(s) of TPH in the environmental medium and to evaluate the number of source areas at the affected property to satisfy §350.51 requirements. Ensure that an adequate sample volume is collected from each sample point to allow for any subsequent analysis using TNRCC Method 1006 (see the documentation for TNRCC Method 1006 for specifics regarding required sample volume). As noted in Table 1 under footnote 4, the TNRCC Method 1005 and 1006 analyses can be truncated at C₂₈ when there does not appear to be significant mass of hydrocarbons in the >C₂₈ boiling point range based on the TNRCC Method 1005 chromatogram, and it is anticipated that the TPH is composed of lighter hydrocarbons (for example, gasoline, diesel, and not transformer mineral oil or used motor oil).

Step 2 Source Area Identification

Use TNRCC Method 1005 data to identify TPH source areas. To determine the number of source areas of TPH and the volume of environmental media impacted by those sources, collect samples from the suspected source areas for TNRCC Method 1005 analysis. Compare TNRCC Method 1005 chromatograms to one another to determine if the chromatographic profile of the TPH is consistent across the affected property. A change in the distribution of the TPH in the TNRCC Method 1005 chromatographic profile, independent of concentration, may indicate the presence of a different source. For example, in Figure 5 three samples were collected and analyzed using TNRCC Method 1005. As can be seen the chromatographic profiles for samples 1 and 2 are the same, indicating the same source TPH mixture. However, the chromatographic profile for sample 3 is different, indicating a different TPH mixture. Therefore, in the example the affected property includes at least two suspected sources of TPH and therefore PCLs will need to be set for the two different TPH mixtures for application at the respective source area and associated affected area.

Step 3 Compare TNRCC Method 1005 Results to Tier 1 TPH PCLs for the TPH Mixture

If Tier 1 TPH PCLs are available in the TRRP Tier 1 PCL Tables for the specific default composition TPH mixture (for example, Tier 1 PCLs for the default composition for transformer mineral oil), then compare the TPH concentration measurements obtained from TNRCC Method 1005 to the applicable Tier 1 TPH PCLs for the TPH mixture.

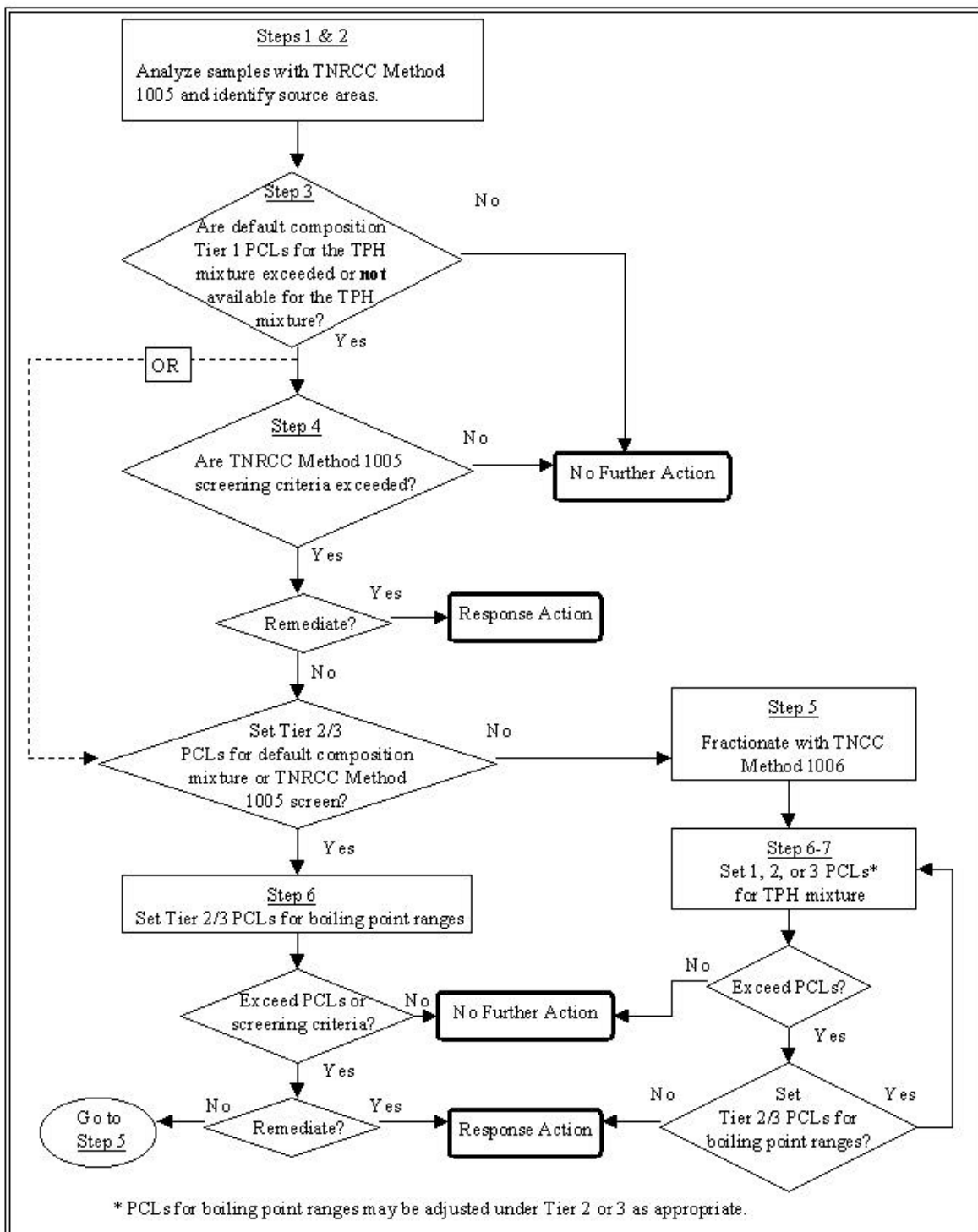


Figure 4. Decision framework for TPH PCL development process.

If the Tier 1 PCLs are not exceeded, then no further action is necessary to address the TPH (Figure 4). If the Tier 1 PCLs are exceeded, then you have several alternatives:

- conduct a response action in accordance with Remedy Standard A or B;
- develop Tier 2 or 3 PCLs for the boiling point ranges and recalculate the PCLs for the TPH mixture using the same default composition (see the “or” pathway following Step 3 in Figure 4); or
- proceed to Step 5; fractionate samples and then proceed to Steps 6 and 7 and establish Tier 1, 2, or 3 PCLs considering the site-specific composition of the TPH mixture(s) at the affected property.

If the relevant Tier 1 PCLs for the specific mixture are unavailable, then proceed to Step 4.

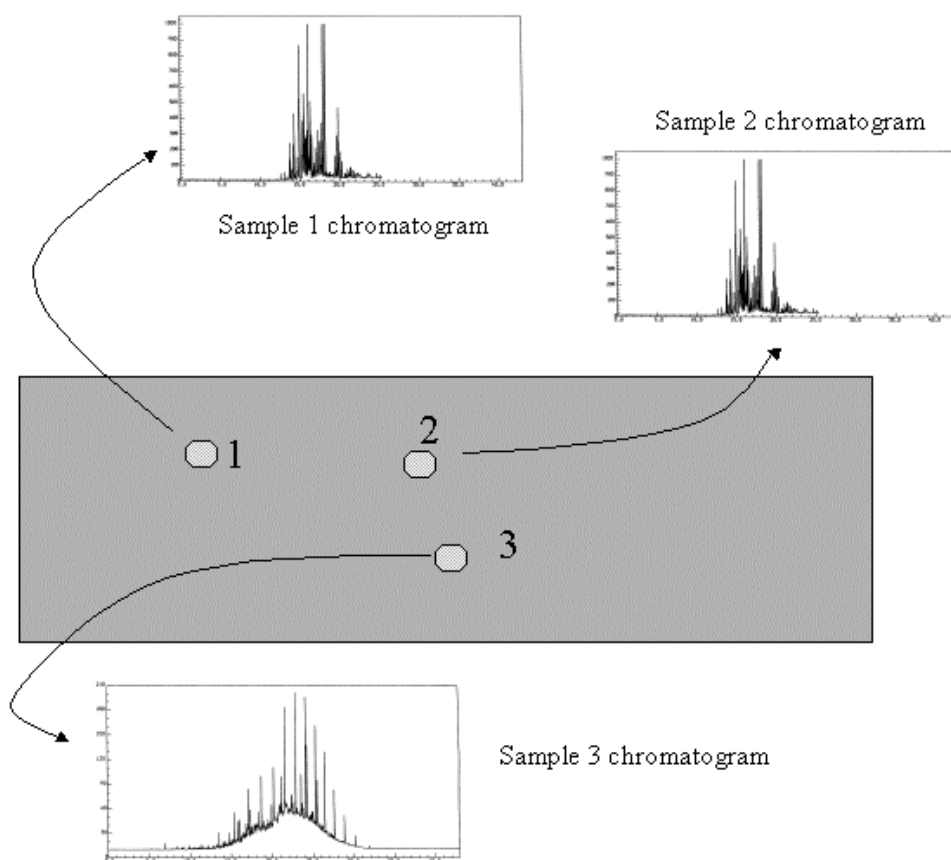


Figure 5. Map view of affected property with sampling locations for TPH samples and corresponding TNRCC Method 1005 chromatographic profiles.

Step 4 TNRCC Method 1005 Results Screening

Compare the concentration measurement for the C_6 - C_{12} range obtained from the TNRCC Method 1005 results for each sample to the Tier 1 PCLs for the aromatic $>C_8$ - C_{10} boiling point range appropriate for the exposure pathways applicable to the affected environmental medium as defined in §350.71(c). Then compare the concentration measurement for the C_{12} - C_{28} range, or C_{12} - C_{35} range if applicable, obtained from the TNRCC Method 1005 results for each sample to the Tier 1 PCLs for the aromatic $>C_{12}$ - C_{16}

boiling point range appropriate for the exposure pathways applicable to the affected environmental medium as defined in §350.71 (c). The development of a PCL for the TPH mixture is only warranted for those samples where the TNRCC Method 1005 levels exceed the aromatic >C₈-C₁₀ boiling point range and the aromatic >C₁₂-C₁₆ boiling point range Tier 1 PCLs.

If either of these Tier 1 boiling point range PCLs are exceeded when compared to TNRCC Method 1005 results, you have several alternatives (Figure 4):

- conduct a response action in accordance with Remedy Standard A or B;
- proceed to Step 6; develop Tier 2 or 3 PCLs for the aromatic >C₈-C₁₀ and aromatic >C₁₂-C₁₆ boiling point ranges and re-compare the TNRCC Method 1005 results to those PCLs; or
- proceed to Step 5; fractionate samples and then proceed to Steps 6 and 7 and establish Tier 1, 2, or 3 PCLs considering the site-specific composition of the TPH mixture(s) at the affected property.

Step 5 Fractionate Selected TPH Samples

Select and analyze the sample with the highest TPH concentration from the source area(s) using TNRCC Method 1006 to determine the appropriate PCLs to apply to the source area and its associated affected area. Typically, only a single sample needs to be analyzed from each source area by TNRCC Method 1006. However, for an affected property where different TPH products have been released, multiple TPH samples may need to be analyzed using TNRCC Method 1006 to ensure representative analysis and to establish PCLs for each of the identified TPH source areas. The sample with the highest TPH concentration is needed to allow adequate quality assurance recovery results. The concentration and mass fraction of each boiling point range in each fraction as shown in Figure 3 should be reported. The mass fraction for each boiling point range of the TPH mixture is determined by dividing the concentration of each boiling point range by the total concentration of the TPH mixture.

Step 6 Establish the PCLs for Each Aliphatic and Aromatic Boiling Point Range

Tier 1 PCLs for the aliphatic and aromatic boiling point ranges are available in the Tier 1 PCL Tables for the standard exposure pathways listed in §350.71(c). The PCLs were calculated using the Tier 1 PCL equations provided in Figure: 30 TAC §350.75(b)(1) of the TRRP rule. The surrogate COCs that are to be used to define the toxicity factors for each fraction are presented in Table 1. The COC chemical/physical properties for the boiling point ranges have been extracted from Figure: 30 TAC §350.73(e) of the TRRP rule and are provided in this guidance document as Table 2. For Tiers 2 and 3, site-specific PCLs can be established for each boiling point range provided the requirements of §350.75 are followed.

Please note that for the >C₁₆-C₂₁ and >C₂₁-C₃₅ aliphatic boiling point ranges, two different toxicity surrogates are provided. Be certain to use the correct toxicity surrogate. If the TPH is a transformer mineral oil, then use the surrogates for transformer mineral oil releases (for transformer mineral oil releases, >C₁₆-C₂₁ and >C₂₁-C₃₅ boiling point ranges only) noted in Table 1. Otherwise, use the white mineral oils toxicity surrogate.

Step 7 Establish the PCLs for the TPH Mixture.

To establish the PCL for the complete TPH mixture (i.e., the whole product), for each exposure pathway calculate the inverse weighted average using the formulas in Table 3. For the soil-to-groundwater PCL

(^{GW}Soil), adjustments are needed to account for solubility limitations. Therefore, use the equations provided in Table 4 for this exposure pathway.

Step 8 Select the Critical PCL

For each environmental medium affected by TPH, select the lowest of the PCLs established for the different applicable exposure pathways as the critical PCL.

Step 9 Compare Critical PCL to Representative TPH Concentrations

Compare the established critical PCL for the relevant source area as determined by TNRCC Method 1005 to representative TPH concentrations to identify any exceedances. For all exceedances, you should either pursue a response action under Remedy Standard A or B, or further evaluate TPH PCLs under Tier 2 or 3 if you have not already done so.

Table 1: Hydrocarbon Fractions and Toxicity Factors

Boiling Point Range	Surrogate for Oral RfD	Surrogate for Inhalation RfC
C ₆ Aliphatic	n-hexane	n-hexane ¹ commercial hexane ²
>C ₆ -C ₈ Aliphatic	n-hexane	n-hexane ¹ commercial hexane ²
>C ₈ -C ₁₀ Aliphatic	JP-8 and other petroleum streams	JP-8 and other petroleum streams
>C ₁₀ -C ₁₂ Aliphatic	JP-8 and other petroleum streams	JP-8 and other petroleum streams
>C ₁₂ -C ₁₆ Aliphatic	JP-8 and other petroleum streams	JP-8 and other petroleum streams
>C ₁₆ -C ₂₁ Aliphatic	white mineral oils	----
>C ₁₆ -C ₂₁ Aliphatic ³	transformer mineral oil	----
>C ₂₁ -C ₃₅ Aliphatic ⁴	white mineral oil	----
>C ₂₁ -C ₃₅ Aliphatic ³	transformer mineral oil	----
>C ₇₋₈ Aromatic	ethylbenzene	ethylbenzene
>C ₈ -C ₁₀ Aromatic	multiple aromatic compounds	high flash aromatic naphtha
>C ₁₀ -C ₁₂ Aromatic	multiple aromatic compounds	high flash aromatic naphtha
>C ₁₂ -C ₁₆ Aromatic	multiple aromatic compounds	multiple aromatic compounds
>C ₁₆ -C ₂₁ Aromatic	pyrene	----
>C ₂₁ -C ₃₅ ³ Aromatic	pyrene	----
1. For mixtures with greater than 53% n-hexane content. 2. For mixtures with less than 53% n-hexane content. 3. For Transformer Mineral Oil only 4. The person may truncate the analysis at C ₂₈ when there does not appear to be significant mass of >C ₂₈ based on the gas chromatogram and the product is anticipated to be a lighter hydrocarbon (for example, gasoline, diesel, not transformer mineral oil or used motor oil).		

Table 2. COC Properties for TPH Boiling Point Fractions

Boiling Point Range	Physical State	M.W. (g/mole)	H' (cm ³ -H ₂ O/cm ³ -air)	LogK _{oc}	D _{air} (cm ² /s)	D _{wat} (cm ² /s)	Solubility (mg/l)	Vapor Pressure (mm Hg)
C ₆ Aliphatic	liquid	81	3.3E+01	2.9	1.0E-01	1.0E-05	3.6E+01	2.7E+02
>C ₆ -C ₈ Aliphatic	liquid	100	5.0E+01	3.6	1.0E-01	1.0E-05	5.4E+00	4.8E+01
>C ₈ -C ₁₀ Aliphatic	liquid	130	8.0E+01	4.5	1.0E-01	1.0E-05	4.3E-01	4.8E+00
>C ₁₀ -C ₁₂ Aliphatic	liquid	160	1.2E+02	5.4	1.0E-01	1.0E-05	3.4E-02	4.8E-01
>C ₁₂ -C ₁₆ Aliphatic	liquid	200	5.2E+02	6.7	1.0E-01	1.0E-05	7.6E-04	3.6E-02
>C ₁₆ -C ₃₅ Aliphatic	liquid	270	4.9E+03	8.8	1.0E-01	1.0E-05	2.5E-06	8.4E-04
>C ₇ -C ₈ Aromatic	liquid	92	2.76E-01	2.15	8.7E-02	8.6E-06	5.30E+02	2.82E+01
>C ₈ -C ₁₀ Aromatic	liquid	120	4.8E-01	3.2	1.0E-01	1.0E-05	6.5E+01	4.8E+00
>C ₁₀ -C ₁₂ Aromatic	liquid	130	1.4E-01	3.4	1.0E-01	1.0E-05	2.5E+01	4.8E-01
>C ₁₂ -C ₁₆ Aromatic	liquid	150	5.3E-02	3.7	1.0E-01	1.0E-05	5.8E+00	3.6E-02
>C ₁₆ -C ₂₁ Aromatic	liquid	190	1.3E-02	4.2	1.0E-01	1.0E-05	6.5E-01	8.4E-04
>C ₂₁ -C ₃₅ Aromatic	solid	240	6.7E-04	5.1	1.0E-01	1.0E-05	6.6E-03	3.3E-07

M.W. = molecular weight H' = Henry's Law Constant LogK_{oc} = logarithmic organic carbon partition coefficient
D_{air} = diffusivity in air D_{wat} = diffusivity in water

Table 3. TPH PCL equations for all exposure pathways other than ^{GW}Soil

$PCL_{TPH\ Mixture} = HI / \sum(MF_i / PCL_i) \quad (3-1)$ <p style="text-align: center;">or</p> $PCL_{TPH\ Mixture} = \min(PCL_i / MF_i), \quad (3-2)$
<p>Use (3-1) and (3-2) then set PCL_{TPH Mixture} as the lesser of the two.</p> <p>PCL_{TPH Mixture} = the generic reference for the PCL for the TPH mixture for the exposure pathway of interest</p> <p>HI = hazard index; HI must be ≤ 10 (see §350.76(g)(8)).</p> <p>SUM = summation</p> <p>MF_i = mass fraction of the TPH boiling point range i (Note: varies with TPH mixture, must be calculated for each boiling point range each time assumed TPH mixture composition is changed)</p> <p>PCL_i = the PCL for TPH boiling point range i from the Tier 1 PCL Tables (or calculated for Tier 2 or 3)</p> <p>MIN = minimum (PCL_i/MF_i) for all TPH boiling point ranges</p>

Table 4. TPH PCL Equations for ^{GW}Soil

Theoretical Maximum $HQ_i = (x_i S_i) / (K_{sw,i} PCL_i)$	(4-1)
$x_i = (MF_i / MW_i) / \text{SUM}(MF_i / MW_i)$	(4-2)
Theoretical Maximum $HI = \text{SUM}(HQ_i + HQ_h + \dots)$	(4-3)
<p>If each Theoretical Maximum $HQ_i \leq 1$ and Theoretical Maximum HI is ≤ 10, then the TPH is protective of the underlying groundwater and a ^{GW}Soil PCL does not need to be calculated for the TPH mixture. However, if the Soil_{Res} concentration is exceeded in the soils, then the potential for the presence of mobile NAPLs should be evaluated (§350.75(i)(10)).</p> <p>Otherwise, use (4-4) and (4-5) then set $\text{PCL}_{\text{TPH Mixture}}$ as the lesser of the two.</p>	
$\text{PCL}_{\text{TPH Mixture}} = HI / \text{SUM}(MF_i / PCL_i)$	(4-4)
or	
$\text{PCL}_{\text{TPH Mixture}} = \text{MIN}(PCL_i / MF_i)$	(4-5)
$\text{Soil}_{\text{Res}} = \{(\text{Res.sat}) (\rho) (\theta_T) / (\rho_b)\} \times 1,000,000 \text{ mg/kg}$	
<p>$\text{PCL}_{\text{TPH Mixture}}$ = the generic reference for the PCL for the TPH mixture for the exposure pathway of interest HI = hazard index; HI must be ≤ 10 (see §350.76(g)(8)). HQ_i = hazard quotient of boiling point range i; HQ must be ≤ 1 (see §350.76(g)(8)) SUM = summation MF_i = mass fraction of boiling point range i (Note: varies with TPH mixture, must be calculated for each boiling point range each time assumed TPH mixture composition is changed) MW_i = molecular weight of boiling point range i PCL_i = the PCL for boiling point range i from the Tier 1 PCL Tables (or calculated for Tier 2 or 3) MIN = minimum (PCL_i / MF_i) for all boiling point ranges x_i = mole fraction for boiling point range i; (Note: varies with TPH mixture, must be calculated for each carbon range each time assumed TPH mixture composition is changed) S_i = solubility of TPH boiling point range i (mg/l) (see Table 2) $\text{Res.sat} = (10,000 \text{ mg/kg} \times \rho_b) / (1,000,000 \text{ mg/kg} \times \rho \times \theta_T)$, Tier 1 default: 0.045 ρ = density of the non-aqueous phase liquid (g/cm^3) Tier 1 default: 1 θ_T = total soil porosity ($\text{cm}^3\text{-pore space/cm}^3\text{-soil}$) = $1 - (\tilde{n}_b / \tilde{n}_s)$ Tier 1 default: 0.37 ρ_b = soil bulk density (g/cm^3), Tier 1 default: 1.67 ρ_s = particle density (g/cm^3), Tier 1 default: 2.65</p>	
$K_{sw} \left[\frac{(mg / L - H_2O)}{(mg / kg - soil)} \right] = \frac{r_b}{q_{ws} + K_d r_b + H' q_{as}}$	
K_{sw} = Soil-leachate partition factor for COC (Note: varies with affected property parameter assumptions and not TPH mixture, therefore, may vary only under Tier 2 or 3); K_d = soil-water partition coefficient ($\text{cm}^3\text{-water/g-soil}$) (see Table 2); $K_d = K_{oc} * \text{foc}$	
θ_{ws} = Volumetric water content of vadose zone soils ($\text{cm}^3\text{-water/cm}^3\text{-soil}$), Tier 1 default: 0.16	
K_{oc} = soil organic carbon-water partition coefficient ($\text{cm}^3\text{-water/g-carbon}$) (see Table 2)	
foc = fraction of organic carbon in soil (g-carbon/g-soil), Tier 1 default: 0.002	
H = dimensionless Henry's Law Constant (see Table 2)	
θ_{as} = volumetric air content of vadose zone soils ($\text{cm}^3\text{-air/cm}^3\text{-soil}$), Tier 1 default: 0.21	

Case Study For Setting TPH PCLs for Transformer Mineral Oil

For this case study, it is assumed that field sampling has been conducted (Step 1), the source area has been identified (Step 2), the TNRCC Method 1005 analytical results have been compared to the default composition Tier 1 TPH PCLs where available (Step 3), the TNRCC Method 1005 screening level PCLs have been exceeded (Step 4), and the TPH mixture has been fractionated by TNRCC Method 1006 (Step 5). The provided Tier 1 PCLs for each boiling point range are being used to determine the site-specific TPH mixture PCL (Step 6). The case study begins with examples on how to establish the PCLs for the site-specific mixture (Step 7).

The analytical results (presented in Table 5) were obtained from the fractionation of weathered transformer mineral oil using TNRCC Method 1006.

Table 5. Mass Fraction for Each Aliphatic and Aromatic Boiling Point Range (determined from Step 5)

Boiling Point Range	Mass Fraction (MF_i)	Concentration (C_i) (mg/kg)
C ₆ Aliphatic	0.00e+00	0.0
>C ₆ -C ₈ Aliphatic	6.40e-04	0.32
>C ₈ -C ₁₀ Aliphatic	3.03e-03	1.52
>C ₁₀ -C ₁₂ Aliphatic	7.72e-03	3.86
>C ₁₂ -C ₁₆ Aliphatic	1.81e-01	90.62
>C ₁₆ -C ₂₁ Aliphatic	5.96e-01	297.79
>C ₂₁ -C ₃₅ Aliphatic	2.10e-01	104.74
>C ₇ -C ₈ Aromatic	0.00e+00	0.0
>C ₈ -C ₁₀ Aromatic	0.00e+00	0.0
>C ₁₀ -C ₁₂ Aromatic	0.00e+00	0.0
>C ₁₂ -C ₁₆ Aromatic	7.90e-04	0.40
>C ₁₆ -C ₂₁ Aromatic	1.30e-03	0.65
>C ₂₁ -C ₃₅ Aromatic	2.10e-04	0.11
Sum Aliphatic Fraction	98.71	498.85
Sum Aromatic Fraction	0.23	1.15
Total TPH	1*	500
* Less than 1 due to rounding		

Step 5. Determine the mass fraction (MF_i) of each TPH aliphatic and aromatic boiling point range.

The mass fraction (MF_i) of each TPH aliphatic and aromatic boiling point range is determined by dividing the particular boiling point range concentration (C_i) by the total TPH concentration (C_i / Total TPH) = MF_i. For example, for the >C₂₁-C₃₅ aliphatic boiling point range, the mass fraction is: 104.74 mg/kg / 500 mg/kg = 0.21. The results are presented in Table 5 above.

Step 6. Determine the Tier 1 PCLs (PCL_i) for each exposure pathway for each aliphatic and aromatic boiling point range

In this example, the human health PCL ($^{Tot}Soil_{Comb}$) and soil-to-groundwater PCL ($^{GW}Soil$) are calculated for surface soil, based on residential land uses and 0.5 acre source area assumptions. The Tier 1 PCLs for each boiling point range for these exposure pathways are presented in Tables 6 and 7, respectively.

PCLs have already been calculated for the two exposure pathways being considered for each aliphatic and aromatic boiling point range for Tier 1. Those PCLs were used here. The Tier 1 PCLs were calculated using the PCL equations as presented in Figure: 30 TAC §350.75(b)(1), the toxicity information presented in Table 1, and the COC chemical/physical properties presented in Table 2 of this document. To establish Tier 2 or 3 PCLs for the individual boiling point fractions, site-specific information would be used in accordance with §350.75(c) and (d) in lieu of Tier 1 default assumptions.

Step 7 Determine the PCL for the TPH mixture ($PCL_{TPH\ Mixture}$).

Use the equations in Tables 3 and 4 as appropriate for the particular exposure pathway to determine the PCL TPH mixture.

The Surface Soil Human Health Exposure Pathway ($^{Tot}Soil_{Comb}$)

1. Calculate MF_i , MF_i/PCL_i , PCL_i/MF_i

The mass fraction (MF_i), and the ratios of MF_i/PCL_i and PCL_i/MF_i , must first be calculated. The results for this example are presented in Table 6.

2. Calculate $^{Tot}Soil_{Comb}$ using Equation (3-1) and (3-2), Table 3 and set the PCL as the lesser of the two.

A. From Equation (3-1) in Table 3, and Table 6:

$$^{Tot}Soil_{Comb} = 10/4.58e-05 \text{ (mg/kg)}^{-1} = 2.18e+05 \text{ mg/kg}$$

B. From Equation (3-2) in Table 3, and Table 6:

$$^{Tot}Soil_{Comb} = 2.87e+04 \text{ mg/kg}$$

The minimum of the two PCLs is $2.87e+04 \text{ mg/kg}$ ($^{Tot}Soil_{Comb}$ for the TPH mixture)

The soil-to-groundwater ($^{GW}Soil$) pathway

To determine the soil-to-groundwater PCL ($^{GW}Soil$) for the TPH mixture, the same criteria as above must be met. That is, HQ_i must be ≤ 1 and HI must be ≤ 10 . However, the effective solubility of the TPH mixture components should be considered when determining $^{GW}Soil$. Therefore, equations from Table 4 are used.

The potential for the TPH mixture to generate unprotective leachate is limited by the solubility of the mixture. If $HQ_i \leq 1$ for each boiling point range and $HI \leq 10$, then the leachate is protective for the underlying groundwater because of solubility limits and the PCL $^{GW}Soil$ does not need to be calculated for the TPH mixture. The reason the $^{GW}Soil$ PCL does not need to be calculated is that the TPH mixture cannot dissolve enough TPH into the groundwater to exceed the groundwater PCLs, regardless of the concentrations of that TPH mixture in the soils. However, irregardless of whether or not the development

of the ^{GW}Soil PCL is warranted in consideration of solubility limits, if the TPH mixture concentration in soils at the affected property exceeds the Tier 1 Soil_{Res} value of 10,000 mg/kg, then the potential for mobile non-aqueous phase liquids (NAPLs) to be present must be determined (§350.75(i)(10)). This determination can be accomplished by calculating a Tier 2 or 3 Soil_{Res} value and determining whether or not that concentration is exceeded, or by using field evidence to determine if mobile TPH NAPL is present. All calculation results for this ^{GW}Soil example are presented in Table 7.

Table 6: Calculation results for Transformer Mineral Oil Case Example for ^{Tot}Soil_{Comb}
Residential Land Use (0.5 acre)

Boiling Point Range	MF _i	^{Tot} Soil _{Comb} PCL _i (mg/kg)	MF _i /PCL _i (mg/kg) ⁻¹	PCL _i /MF _i (mg/kg)	HQ _i
C ₆ Aliphatic	0.00e+00	1.90e+03	0.00e+00	0.00e+00	0.00e+00
> C ₆ -C ₈ Aliphatic	6.40e-04	1.90e+03	3.38e-07	2.96e+06	9.68e-03
> C ₈ -C ₁₀ Aliphatic	3.03e-03	5.30e+03	5.71e-07	1.75e+06	1.64e-02
> C ₁₀ -C ₁₂ Aliphatic	7.72e-03	4.60e+03	1.68e-06	5.96e+05	4.82e-02
> C ₁₂ -C ₁₆ Aliphatic	1.81e-01	5.20e+03	3.48e-05	2.87e+04	1.00e+00
> C ₁₆ -C ₂₁ Aliphatic	0.00e+00	1.30e+03	0.00e+00	0.00e+00	0.00e+00
> C ₂₁ -C ₃₅ Aliphatic*	8.05e-01	1.10e+05	7.30e-06	1.37e+05	2.10e-01
> C ₇ -C ₈ Aromatic	0.00e+00	5.30e+03	0.00e+00	0.00e+00	0.00e+00
> C ₈ -C ₁₀ Aromatic	0.00e+00	1.60e+03	0.00e+00	0.00e+00	0.00e+00
> C ₁₀ -C ₁₂ Aromatic	0.00e+00	1.90e+03	0.00e+00	0.00e+00	0.00e+00
> C ₁₂ -C ₁₆ Aromatic	7.90e-04	2.30e+03	3.44e-07	2.91e+06	9.87e-03
> C ₁₆ -C ₂₁ Aromatic	1.30e-03	1.90e+03	6.85e-07	1.46e+06	1.97e-02
> C ₂₁ -C ₃₅ Aromatic	2.10e-04	1.90e+03	1.10e-07	9.05e+06	3.18e-03
Sum =			4.58e-05	2.87e+04	
				HI =	1.32e+00
* > C ₁₆ -C ₂₁ Aliphatic and C ₂₁ -C ₃₅ Aliphatic are lumped for convenience because the toxicity surrogate is the same for both boiling point ranges for transformer mineral oil					

1. Determine the theoretical maximum HQ_i and HI for the TPH mixture:

A. Calculate the mole fraction (x_i) for each boiling point range using Equation (4-2), Table 4.

$$x_i >C_{16}-C_{35} \text{ aliphatic} = (8.05e-01/270 \text{ g/mol}) / 3.98e-03 \text{ (g/mol)} = 7.50e-01$$

B. Calculate the hazard quotient (HQ) for each boiling point range using Equation (4-1), Table 4.

$$HQ >C_{16}-C_{35} \text{ aliphatic} = (7.50e-01 * 2.5e-06 \text{ mg/L} / (7.92e-07 \text{ mg/L-water/mg/kg-soil} * 1.00e+06 \text{ mg/kg})) = 2.37e-06$$

C. Calculate the hazard index (HI) using Equation (4-3), Table 4.

As shown in Table 7, $HQ_i \leq 1$ for each boiling point fraction and $HI \leq 10$, therefore the TPH mixture does not pose a threat to the underlying groundwater, and therefore $^{GW}Soil$ does not need to be calculated. However, in order to provide a complete set of example calculations, $^{GW}Soil$ PCLs are calculated using Equations (4-4) and (4-5) from Table 4 even though it is not warranted in this particular case study.

2. Determine $^{GW}Soil$ as the lesser of PCLs calculated from Equations (4-3) and (4-5), Table 4.

Solving for Equation (4-4), Table 4:

$$PCL_{TPH \text{ Mixture}} \text{ for } ^{GW}Soil = 10/1.06e-05 = 9.43e+05$$

Solving for Equation (4-5), Table 4:

$$PCL_{TPH \text{ Mixture}} \text{ for } ^{GW}Soil = 2.53e+05$$

Table 7: Calculation results for $^{GW}Soil$ Transformer Mineral Oil Case Example.

Boiling Point Range	MF _i	MF _i /MW _i	$^{GW}Soil$ PCL _i (mg/kg)	x _i	MF _i /PCL _i (mg/kg) ⁻¹	PCL _i /MF _i (mg/kg)	HQ _i
C ₆ Aliphatic	0.00e+00	0.00e+00	1.70e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00
> C ₆ -C ₈ Aliphatic	6.40e-04	6.4e-06	4.20e+02	1.61e-03	1.52e-06	6.56e+05	2.97e-04
> C ₈ -C ₁₀ Aliphatic	3.03e-03	2.33e-05	3.60e+03	5.86e-03	8.42e-07	1.19e+06	5.15e-05
> C ₁₀ -C ₁₂ Aliphatic	7.72e-03	4.83e-05	2.50e+04	1.21e-02	3.09e-07	3.24e+06	8.55e-07
> C ₁₂ -C ₁₆ Aliphatic	1.81e-01	9.05e-04	4.90e+05	2.28e-01	3.69e-07	2.71e+06	3.69e-07
> C ₁₆ -C ₂₁ Aliphatic	0.00e+00	0.00e+00	1.00e+06	5.55e-01	0.00e+00	0.00e+00	0.00e+00
> C ₂₁ -C ₃₅ Aliphatic	8.05e-01	2.98e+03	1.00e+06	1.95e-01	8.05e-07	1.24e+06	2.37e-06
> C ₇ -C ₈ Aromatic	0.00e+00	0.00e+00	2.00e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00
> C ₈ -C ₁₀ Aromatic	0.00e+00	0.00e+00	6.50e+01	0.00e+00	0.00e+00	0.00e+00	0.00e+00
> C ₁₀ -C ₁₂ Aromatic	0.00e+00	0.00e+00	1.00e+02	0.00e+00	0.00e+00	0.00e+00	0.00e+00
> C ₁₂ -C ₁₆ Aromatic	7.90e-04	5.27e-06	2.00e+02	1.32e-03	3.95e-06	2.53e+05	3.89e-04
> C ₁₆ -C ₂₁ Aromatic	1.30e-03	6.84e-06	4.70e+02	1.72e-03	2.77e-06	3.53e+05	7.58e-05
> C ₂₁ -C ₃₅ Aromatic	2.10e-04	8.75e-07	3.70e+03	2.20e-04	5.68e-08	1.76e+07	9.88e-08
SUM=		3.98e-03			MIN=	2.53e+05	
			SUM =		1.06e-05	HI =	8.27e-04

Step 8. Choose the Critical Surface Soil PCL for this transformer mineral oil example.

To determine the critical PCL the PCLs for each of the exposure pathways applicable to the affected environmental medium must be compared. Table 8 below presents all the residential PCLs prescribed in the Tier 1 PCL table that would apply for surface and subsurface soils.

The critical PCL is the lowest of the pathway specific PCLs. For this transformer mineral oil TPH mixture, the critical surface soil PCL is 2.87e+04 mg/kg (the lower of $^{Tot}Soil_{Comb}$ and $^{GW}Soil$), assuming mobile NAPL is not present in soils and therefore $Soil_{Res}$ is not limiting.

Table 8. Critical Transformer Mineral Oil PCLs for Residential Soil Exposures

Exposure Pathway:	TotSoil_{Comb} (mg/kg)	AirSoil_{Inh-v} (mg/kg)	GWSoil* (mg/kg)
PCL:	2.87e+04 ¹	1.33e+05 ²	2.53e+05 ³
Critical PCL for Surface Soils:			2.87e+04
Critical PCL for Subsurface Soils:			1.33e+05
1 applies to surface soil only			
2 applies to subsurface soil only			
3 applies to surface and subsurface soils			
* the ^{GW} Soil PCL was not actually required for this particular example.			

Frequently Asked Questions

Question 1: *When do I consider TPH in my assessment?*

Answer 1: You make the decision to include TPH in an assessment in conjunction with the applicable program area. Information on the contact point for each program area is provided in the front page of this guidance document. In addition, the TNRCC guidance document, *Determining Target COCs* (RG-366/TRRP-10) provides further information on selecting chemicals of concern for analysis.

Question 2: *Are TNRCC Methods 1005 and 1006 the only methods that can be used to determine concentrations of TPH in environmental media?*

Answer 2: Other methods can be used. However, to use an alternate method, a proposal to use an alternate method that includes the data needed to validate the alternate method against TNRCC Method 1005 and 1006 as the reference methods must be submitted to the agency. Once the use of an alternate method has been approved, additional proposals to use that method will not be needed. The TNRCC will update a list of additional methods and will have the list available on the TRRP Web page. See question 5 below for a related matter.

Question 3: *When do I compare site data directly to boiling point range PCLs listed in the Tier 1 PCL tables versus calculating a PCL for the entire TPH mixture?*

Answer 3: The only time the PCLs included in the Tier 1 PCL tables for the boiling point ranges should be directly compared to TNRCC Method 1005 results is when conducting the TNRCC Method 1005 screen as explained earlier in Step 4.

Question 4: *Is there double counting of compounds when there is COC-specific analytical data (for example, benzene concentrations in soil) and assessment of TPH is required?*

Answer 4: The TPH approach described in this document only addresses the noncarcinogenic effects of each fraction. The toxicity endpoint of concern for benzene and the carcinogenic polycyclic aromatic hydrocarbons is different than that of TPH as a mixture. For benzene, TNRCC Method 1006 does not characterize the C₆ aromatic fraction, which is the fraction of interest for benzene. Double counting

might be a concern when using historical data. For example, some petroleum hydrocarbons are detected in both the Method 8015 gasoline range organics and diesel range organics analyses. Concentrations of individual VOCs or SVOCs should be characterized by methods such as EPA Methods 8260 or 8270, respectively.

Question 5: *Is it possible to use historical data yielded from other (non-TNRCC Method 1005 or 1006) analytical methods?*

Answer 5: The use of historical data collected prior to the implementation of the TRRP rule will be evaluated on a case-by-case basis, which will consider the assumptions being made in interpreting the data to ensure that those data meet project objectives. The historical data should allow for the qualitative evaluation of the distribution of hydrocarbons within the mixture and quantitation of the mixture between the C₆-C₂₈, or when applicable, C₆-C₃₅. The data should provide quantitation of the petroleum hydrocarbons within each of the boiling point ranges for each fraction listed in Table 1. Further guidance on the use of historical data is included in the TNRCC guidance document *Use of Data Collected for 30 TAC 335 under the TRRP* (RG-366/TRRP-5).

Question 6: *How do I develop Tier 2 PCLs?*

Answer 6: To calculate Tier 2 PCLs for the TPH mixture, calculate Tier 2 PCLs for each boiling point range present in the TPH mixture using site-specific information in the Tier 2 PCL equations in accordance with 350.75(c). Then use the equations in Tables 3 and 4 to develop Tier 2 TPH PCLs for the TPH mixture using the Tier 2 PCLs developed for each boiling point range.

Product Composition and Weathering

Once a petroleum hydrocarbon product (e.g., gasoline, diesel, etc.) has been released into the environment, the chemical composition (i.e., the petroleum hydrocarbon makeup) changes. This change could be attributed to the commingling of different petroleum hydrocarbon mixtures released into the same area resulting in a new mixed composition of TPH, or environmental weathering of the petroleum hydrocarbons. For example, a release of gasoline onto the soil in the month of July will undergo significant changes within the first five hours after the release due to the volatility of the petroleum hydrocarbons in the gasoline. The extent and rate of change in the released mixture depends on the type of petroleum hydrocarbons that make up the TPH, the number of mixtures that contributed to the TPH source area (source area as defined by 30 TAC §350.4 (a)(84), prevailing weather conditions, fate and transport aspects such as the rate of biodegradation and the potential of the TPH to undergo partitioning as it interacts with environmental media into which it is released.

You can use chemical analysis of a product by gas chromatography to determine the specific mixture of hydrocarbons in that product so that a PCL can be developed. The chemical analysis is based on a comparison of the boiling point ranges for the petroleum hydrocarbons in the product relative to the boiling points for the normal alkane hydrocarbon series. This series extends from normal methane (n-C₁) and to beyond normal hexatriacontane (n-C₃₆). For example, the TPH in crude oil is composed of petroleum hydrocarbons between the boiling point ranges from n-C₁ to beyond n-C₃₄. Refined products from crude oil include: (1) gasolines which characteristically have TPH composed of hydrocarbons between the boiling point ranges of normal hexane (n-C₆) and normal dodecane (n-C₁₂); (2) diesel fuels with TPH characteristically composed of hydrocarbons found between the boiling point ranges of normal octane (n-C₈) and normal heneicosane (n-C₂₁); and (3) motor oils having a characteristic TPH composition from normal octadecane (n-C₁₈) to beyond n-C₃₆.