TNRCC Regulatory Guidance

Remediation Division

RG-366/TRRP-29 August 2001

SUBJECT: # Soil and Groundwater Response Objectives

Objectives: To describe the soil and groundwater response objectives that a response action at an affected property must achieve in order to attain Remedy Standard A or B under the Texas Risk Reduction Program (TRRP).

Audience: Regulated Community and Environmental Professionals

References: The regulatory citations for the TRRP soil and groundwater response objectives are 30 TAC 350.31-.33 and .37.

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). Download Tier 1 PCL Tables, toxicity factors, and other TRRP information at **http://www.tnrcc.state.tx.us/permitting/trrp.htm**.

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

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Introduction

This document describes the soil and groundwater response objectives that must be achieved in order to attain Remedy Standard A or B. Response objectives are described in §350.31-.33 and .37 and define the performance that soil and groundwater protective concentration level exceedence (PCLE) zones must attain in order for a response action to achieve Remedy Standard A or B. Implementing a response action to achieve Remedy Standard A or B is a necessary part of the TRRP process when critical protective concentration levels (PCLs) have been exceeded.

This document provides a detailed explanation of the Remedy Standard A and B soil and groundwater response objectives. This document is important since persons must demonstrate in reports submitted to the TNRCC that the appropriate soil and groundwater response objectives have been satisfied. Moreover, the soil and groundwater response objectives affect the manner in which PCLs are calculated. Also, in the end, the assessment of the affected property must be adequate to document attainment of the soil and groundwater response objectives.

This document describes what must be demonstrated, but does not describe how a person should demonstrate in TNRCC reports that a proposed or completed response action attains the pertinent soil and groundwater response objectives. Possible approaches to demonstrate that a response action will conform to the soil and groundwater PCLE zone requirements are presented in the TNRCC guidance document entitled *Evaluation of Remedy Effectiveness* (RG-366/TRRP-31). The TNRCC guidance document entitled *Application of Remedy Standards A and B* (RG-366/TRRP-28) addresses the overall requirements of Remedy Standards A and B and provides guidance for selecting the appropriate remedy standard for an affected property.

Key Definitions Regarding Response Objectives

A firm understanding of the definitions for "remove," "decontaminate," and "control" is necessary to fully comprehend the surface soil, subsurface soil, and groundwater response objectives under Remedy Standards A and B. These three terms figure prominently in defining the level of performance that a person must attain to meet Remedy Standard A or B. These terms are defined as follows:

- *Remove* (§350.4(a)(73)) - To take waste or environmental media away from the affected property to another location for storage, processing, or disposal in accordance with all applicable requirements. Removal is an irreversible process that results in permanent risk reduction at an affected property.

- *Decontaminate* (§350.4(a)(21)) – Application or occurrence of a permanent and irreversible treatment process to a waste or environmental medium so that the threat of release of chemicals of concern at concentrations above the critical protective concentration levels is eliminated.

- *Control* (§350.4(a)(18)) – To apply physical or institutional controls to prevent exposure to chemicals of concern. Control measures must be combined with appropriate maintenance, monitoring, and any necessary further response action to be protective of human health and the environment.

Summary of Remedy Standards A and B

Remedy Standard A is a pollution cleanup remedy in that all PCLE zones in surface and subsurface soil, groundwater, and other environmental media must be removed and/or decontaminated to yield chemical of concern (COC) concentrations less than applicable critical PCLs. Physical controls are not allowed as a response action under Remedy Standard A. For example, a person cannot use a physical control to prevent exposure to environmental media with COC concentrations above critical PCLs. Instead the person must remove and/or decontaminate the environmental media such that COC concentrations are less than the critical PCLs. Table 1 provides a partial list of removal and decontamination response actions which a person could use under Remedy Standard A to reduce COC concentrations in surface soils, subsurface soils, and groundwater to below critical PCL levels. Table 1 does not necessarily provide a final answer regarding whether a particular response action will be considered a removal, decontamination, or control measure. By comparison to the requirements expressed in the definitions for remove, decontaminate, and control, a person does have the opportunity to demonstrate that a particular response action at a specific affected property should be categorized as a different type of response action than is listed in Table 1. For example, a stabilization process could be considered as a decontamination action rather than a physical control if the person documents that the planned stabilization at the affected property in question will satisfy the performance objectives for decontamination. For the most part, Remedy Standard A is self-implementing, that is, the person may choose to conduct the response action without the TNRCC's prior approval. The exception occurs when a person seeks to modify exposure factors under Tier 2 or Tier 3 of the PCL development process. For information regarding the tiered development of human health PCLs, see the TNRCC guidance document titled *Development of Human Health PCLs* (RG-366/TRRP-22).

Remedy Standard B allows exposure prevention response actions. In addition to removal and/or decontamination, physical control measures are allowed to prevent exposure of receptors to COCs at concentrations above the critical PCLs. Table 1 identifies some of the removal, decontamination, and control response actions that a person may use under Remedy Standard B in order to attain the response objective for surface soil, subsurface soil, and groundwater. Long term monitoring and financial assurance may be necessary to demonstrate that a physical control continues to perform as designed. Also, Remedy Standard B is not self-implementing. The person must secure the TNRCC's approval of the affected property assessment report (APAR) and the response action plan (RAP) prior to implementing a Remedy Standard B response action. However, the person is not precluded from taking interim actions which are necessary to mitigate emergency situations, to abate on-going releases, or to stabilize the spread of released COCs.

Table 1. Categorization of some typical TRRP response actions [1]

Response Action Type	Surface and/or Subsurface Soils	Groundwater
Removal [2,3]	• Excavation and transport	• Groundwater pumping and disposal
Decontamination [2,3]	• Soil vapor extraction • Thermal desorption and disposal • Steam injection • Air stripping • Soil washing • Biological degradation • Incineration • Chemical fixation, stabilization, or solidification constituting decontamination[4]	• Chemical oxidation • Groundwater pumping and treatment • Monitored natural attenuation (MNA) constituting decontamination[5] • Carbon adsorption and disposal • Surfactant flushing • Air sparging • UV treatment
Physical Control [3]	• Engineered cap • Slurry wall/lateral containment • Impermeable barrier • Liners • Chemical fixation, stabilization, or solidification constituting a physical control[4] • Landfill	• Hydraulic barrier • Slurry wall/lateral containment • Impermeable barrier • Interceptor trench • Groundwater pumping for containment • MNA constituting a physical control[5] • Permeable reactive barrier

[1] This is only a partial list of potential response actions which may be used under TRRP. Other response actions may be used but must be categorized as to whether they are removal, decontamination, or control measures.
[2] Remedy Standard A response actions must use removal and/or decontamination measures.
[3] Remedy Standard B response actions may use removal, decontamination, and/or control measures.
[4] The initial presumption is that fixation, stabilization, and solidification are physical controls; however, this categorization can be changed to decontamination if the requirements of §350.31(b) are satisfied.
[5] Under Remedy Standard B, MNA may, depending upon the circumstances at an affected property, be either a decontamination or a physical control response action. For example, MNA based on biodegradation is a decontamination response. MNA as a physical control is allowable only in the context of a PMZ. MNA is a physical control for a PMZ when the COCs are not being biodegraded.

Environmental media affected by the same source area must be addressed under the same remedy standard. Thus, for a given affected property, a soil PCLE zone **could not** be addressed under Remedy Standard A while an associated groundwater PCLE zone is responded to under Remedy Standard B. However, given the broad removal, decontamination, and/or control performance objectives provided for Remedy Standard B, a removal and/or decontamination soil response action could be performed under this standard which is essentially identical to a Remedy Standard A response action. The response action would still be Remedy Standard B, but the institutional control would only be pertinent to groundwater.

When PCLE zones extend onto off-site property, a different level of response may be used for on-site versus off-site environmental media. For example, assume that soil and groundwater PCLE zones extend onto an off-site property and that the owner of this property demands that all media be restored to levels such that institutional controls are not required. Remedy Standard B can be used for both on-site and off-site PCLE zones. If the off-site portion is restored by removal/decontamination to the residential PCLs, then an institutional control would not be required for the off-site land.

If separate source areas have resulted in contamination in different environmental media, then different remedy standards may be used to address these environmental media. Assume, for example, that a shallow soil PCLE zone is underlain by a large groundwater PCLE zone that is associated with a different source area. In this example, the soil response could be performed under Remedy Standard A and the groundwater response could be performed under Remedy Standard B. Moreover, releases from different source areas to the same environmental medium could be managed under different remedy standards, unless commingling of such releases makes such an approach infeasible.

An acceptable response action under Remedy Standard A or B must be capable of achieving the response objectives within a reasonable time frame. TRRP does not specify a particular reasonable time frame for application to response actions at all affected properties. Instead, an individual determination is made for each affected property. Paragraph 350.32(b)(3) for Remedy Standard A and §350.33(b)((2) for Remedy Standard B specify that a reasonable time frame will be based on the particular circumstances at an affected property. Criteria for this determination include: hydrogeologic characteristics of the affected property, COC characteristics, and the potential for unprotective exposure conditions to continue or result during the remedial period. A more extensive discussion of this topic is presented in the TNRCC guidance document titled *Application of Remedy Standards A and B* (RG-366/TRRP-28).

Also, long remediation periods can present a problem in the event that the landowner will not agree to the placement of an institutional control on the property deed records. This should be taken into account on MNA response actions but also applies to all other types of response strategies. In accordance with §350.31(h), the TNRCC may require the person to file a notice in the property deed records stating that there is long-term remediation on-going whenever the response action is predicted to take in excess of 15 years to complete or whenever the response action has not been completed within 15 years. The person must provide written proof of landowner concurrence in order to demonstrate compliance with the institutional control requirements.

Response Objectives which Apply to both Remedy Standards A and B

The general requirements for response objectives which apply to both Remedy Standards A and B are presented in §350.31. Table 2 summarizes the two performance requirements from §350.31 which apply to both Remedy Standards A and B. Other administrative and procedural requirements which are not response objectives are also presented in §350.31 but are not discussed here.

Table 2. Response objectives which apply to both Remedy Standards A and B

Response Objective	Rule Citation
Persons shall sufficiently address affected properties such that surface and subsurface structures do not contain explosive atmospheres originating from the released COCs, and areas of routine construction are adequately protected. This subsection requires the person under Remedy Standard A or B to assess released COCs at an affected property and to respond when necessary to assure that surface and subsurface structures do not contain explosive atmospheres. When making this determination, the person should consider the proximity of volatile non-aqueous phase liquids (NAPLs) and high concentrations of volatile COCs to utility conduits, basements, storm or sanitary sewers, and other surface and subsurface structures which may be subject to vapor accumulation. This also includes situations where volatile COCs are below the critical PCLs but the potential exists for vapors to accumulate to explosive levels.	§350.31(c)
Persons shall perform any more stringent or additional response actions which are required by statute or regulations governing the program areas specified in §350.2.	§350.31(j)

Remedy Standard A Response Objectives

The response objectives for Remedy Standard A are described in §350.32 and are summarized in Table 3.

Table 3. Summary of Remedy Standard A response objectives

Response Objective	Rule Citation
Persons must remove and/or decontaminate the surface soil, subsurface soil, and groundwater PCLE zones, other environmental media such as surface water or sediment to achieve COC concentration levels below the residential or commercial/industrial critical PCLs, as applicable. Ecological receptors are protected since they are considered in the establishment of the critical PCLs.	§350.32(a)(3) and (4) §350.74(i)
Persons must within a reasonable time frame considering the particular circumstances at an affected property achieve these response objectives.	§350.32(a)
Response actions must result in permanent risk reduction.	§350.32(b)
Persons must remove any listed hazardous waste from a waste management facility component, for example, a tank or surface impoundment. The person must also remove any listed hazardous waste which is separable from environmental media using simple mechanical removal processes.	§350.32(a)(1)
Persons must remove and/or decontaminate waste or environmental media which is characteristically hazardous due to ignitability, corrosivity, reactivity, or toxicity characteristic.	§350.32(a)(2)
Persons may not use either a physical control or a demonstration of technical impracticability under Remedy Standard A.	§350.32(b)(1) and §350.32(e)
Persons must prevent the groundwater PCLE zone from expanding.	§350.32(f)

Remove and/or Decontaminate Response Objective for Remedy Standard A

The primary requirement for Remedy Standard A is to remove and/or decontaminate all COCs to levels below the critical PCLs (human health and ecological receptors). This is shown in Figure 1. This means that PCLE zones will no longer exist at an affected property once Remedy Standard A is attained. Attaining Remedy Standard A means that, subsequent to the approval of the response action completion report (RACR), the property may be reused without either monitoring or the maintenance of physical controls. An institutional control is required for a Remedy Standard A response action for land with a commercial/industrial land use classification but not for land with a residential land use classification. Information regarding sampling and analyses to demonstrate whether these response objectives are being or have been attained for groundwater is presented in the TNRCC guidance document entitled *Compliance Sampling and Monitoring* (RG-366/TRRP-30).

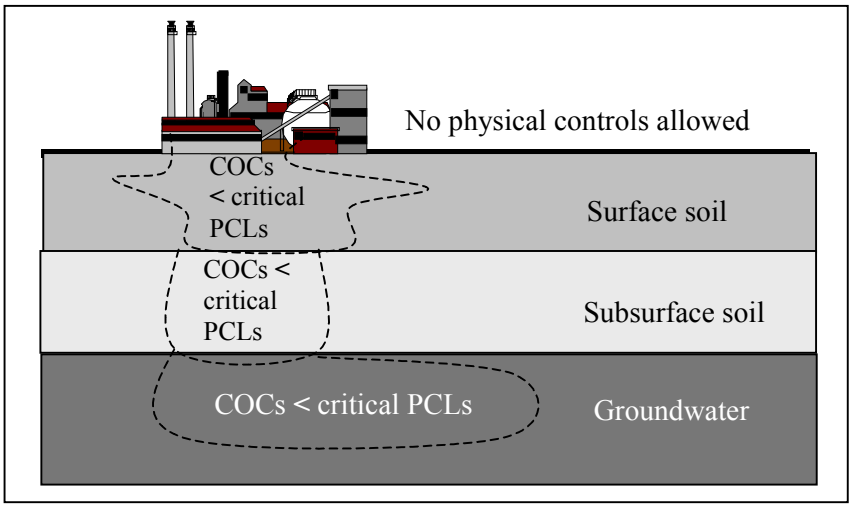

Figure 1. Depiction of the response objectives which must be met in order to attain Remedy Standard A.

The following discussion provides an example of a Remedy Standard A response action. This example pertains to an affected property for which a person is considering various Remedy Standard A response actions. The groundwater beneath the affected property has been affected primarily by dissolved trichloroethylene (TCE). The primary groundwater PCLE zone is for TCE. There is, however, a minor groundwater PCLE zone based upon the presence of trivalent chromium. These PCLE zones are located in the uppermost groundwater-bearing unit which is comprised of interbedded sands and clays. TCE breakdown products at low concentrations are present within the uppermost groundwater-bearing unit. The TCE PCLE zone continues to expand.

The person desires to remediate the affected property under residential, Remedy Standard A so as to avoid physical and institutional controls, post-response action care, and financial assurance. The response actions the person is considering include: a slurry wall to contain the groundwater PCLE zone, MNA, groundwater pumping and treating, and the injection of chemical oxidants.

A slurry wall cannot serve as part of the final response action under Remedy Standard A. A slurry wall is a physical control and does not qualify as a removal or decontamination measure which are required to be used under Remedy Standard A. A slurry wall could, however, be used as an interim component of the

overall response action. For this affected property, the PCLE zone for TCE is known to be migrating downgradient. The groundwater response objective in §350.32(f) requires the person to prevent the groundwater PCLE zone from expanding. An additional response objective in §350.32(a)(3) requires that the COC concentration levels throughout the groundwater PCLE zone be reduced to the critical PCLs. Considering these two response objectives, a slurry wall could be used to prevent groundwater PCLE zone expansion during the life of the response action but some other remedial measure would need to be taken to reduce the COC concentrations in groundwater to the acceptable levels.

MNA may, depending upon the situation, be none of, part of, or all of a groundwater response action under Remedy Standard A. Additional details regarding the evaluation and use of MNA under TRRP are provided in the TNRCC guidance document entitled *Monitored Natural Attenuation Demonstrations* (RG-366/TRRP-33). Section 350.32(b)(3) states that a remedial alternative, including MNA, must be capable of achieving the Remedy Standard A response objectives within a reasonable time frame. The meaning of "reasonable time frame" is to be determined on a site-specific basis and is to be based upon the particular circumstances at an affected property. These circumstances include the hydrogeologic characteristics, the COC characteristics, and the potential for unprotective exposure conditions to continue or to result during the remedial period. So if the rate of natural attenuation is slow and if it will not achieve the response objectives within a reasonable period of time, then MNA will not be an acceptable response action to address the groundwater PCLE zone. At other affected properties, the rate of natural attenuation will be higher but not sufficiently high to prevent the groundwater PCLE zone from expanding. In this circumstance, MNA could be combined with either groundwater pump and treat or a slurry wall, for example, to form an acceptable combined response action. For this circumstance, natural attenuation will reduce the concentration of COCs in groundwater at an acceptable rate and a containment measure, such as pump and treat or a slurry wall, will act to prevent the expansion of the groundwater PCLE zone. It is also possible that natural attenuation may be occurring at such a rate that MNA may be adequate by itself to serve as a Remedy Standard A groundwater response action. This type of circumstance is characterized by a stable or shrinking groundwater PCLE zone. Also, methods such as the injection of nutrients can be used, if appropriate for a particular affected property, to actively enhance the attenuation rate of COCs in groundwater. If the rate of attenuation is enhanced such that the groundwater PCLE zone will not expand and such that COC concentrations in groundwater will be reduced to the critical PCLs within a reasonable time period, then such enhanced MNA could serve as the entire groundwater response action.

Groundwater pump and treat can be used in at least two fashions to achieve the Remedy Standard A groundwater response objectives. Pump and treat could be used to reduce the COC concentrations throughout the entire groundwater PCLE zone to below the critical PCLs. Also, as discussed above, pump and treat can be used to prevent the expansion of a groundwater PCLE zone while some other remedial method is relied upon to reduce the COC concentrations in groundwater.

Chemical oxidation may also be an acceptable response action and could achieve rapid decontamination of the TCE PCLE zone. However, a secondary effect of chemical oxidation may be to oxidize the trivalent chromium into more toxic and mobile hexavalent chromium creating an additional PCLE zone that would require removal or decontamination.

Soil-to-Groundwater Response Objective for Remedy Standard A

For Remedy Standard A, the surface soil and subsurface soil must be removed and/or decontaminated to the extent necessary to achieve COC concentrations in the uppermost groundwater-bearing unit which are less than the critical groundwater PCLs applicable for the land use classification. This means that the soil-to-goundwater PCL, that is ^{GW}Soil, is the concentration of a COC in soil which will not result in the

critical groundwater PCL for that COC being exceeded in the uppermost groundwater-bearing unit. For the Remedy Standard A soil-to-groundwater PCL evaluation, the uppermost groundwater-bearing unit is always presumed to be directly below the soil being evaluated and lateral transport considerations are not allowed.

Hazardous Waste Response Objectives for Remedy Standard A

Several response objectives for hazardous waste under Remedy Standard A are specified at §350.32(a). Hazardous waste means waste classified as hazardous under the Resource Conservation and Recovery Act (RCRA). As defined under Part 261 Subparts C and D of RCRA, hazardous waste can be either listed hazardous waste or characteristically hazardous waste. The listed hazardous wastes are specifically identified in Parts 261.30 through 261.33 of RCRA. Characteristic hazardous waste is that waste which meets the definition for ignitable, corrosive, reactive, or toxic provided in Parts 264.20 through 264.24 of RCRA.

To attain Remedy Standard A, §350.32(a)(1) requires the person to remove any listed hazardous waste which is contained within a waste management facility component, for example, a tank or surface impoundment. The person does not have the option of decontaminating or controlling listed hazardous waste in such waste management units. This paragraph also requires the person to remove any listed hazardous waste which is separable from environmental media using simple mechanical removal processes. For the release of a listed hazardous waste to soils, simple mechanical removal processes could include, depending upon conditions, vacuum trucks, absorbent pads, shovels, and/or backhoes. The intent here is that all environmental media which contains listed hazardous waste is removed to the extent practicable using mechanical means. Releases of listed hazardous waste to environmental media must also conform to the performance specified in §350.32(a)(3). This paragraph requires the person to remove and/or decontaminate such environmental media so that COC concentration levels do not exceed the critical PCLs for the applicable land use.

Under RCRA regulations, such an environmental medium will continue to be regulated as a listed hazardous waste until it is demonstrated that the medium no longer contains a listed hazardous waste. This is referred to as a "contained in" demonstration. As stated at §350.2(h)(3), a person can use TRRP to demonstrate that an environmental medium no longer contains a listed hazardous waste and is therefore no longer considered to be a hazardous waste. Typically, the attainment of §350.32(a)(3), by demonstrating that an environmental medium does not contain COCs at concentrations in excess of the critical PCLs, will be sufficient to make the contained in demonstration. However, in certain circumstances the RCRA land disposal restrictions (LDRs) will continue to apply to an environmental medium that has been demonstrated to not contain hazardous waste. Additional details regarding the circumstances when the land disposal restrictions will apply to a TRRP response action are presented in the TNRCC guidance document entitled *TRRP Compatibility with RCRA* (RG-366/TRRP-3).

The Remedy Standard A response objective for characteristically hazardous waste is described at §350.32(a)(2). This paragraph requires the person to remove and/or decontaminate any environmental medium which is characteristically hazardous to the extent necessary such that it does not meet any of the hazardous waste characteristics (that is, ignitability, corrosivity, reactivity, and toxicity characteristics). The person must also demonstrate that this environmental medium attains the reduction of COCs to below the critical PCLs.

NAPL Response Objective for Remedy Standard A

In order to attain Remedy Standard A, a person must completely remove any NAPLs that are present in environmental media. The requirement to remove NAPLs "to the maximum extent practicable" does not apply here. NAPLs must be completely removed unless a number of conditions are satisfied. First, in order for the NAPL to remain, the PCLs for the COCs within the NAPL must be greater than the residual soil saturation limit or aqueous solubility limit, depending upon the medium involved, for that COC. In other words, taking into account the chemical, physical, and toxicological properties of the COC, it is not possible for the COC to be present at a toxic concentration. Second, the person must demonstrate that the NAPL will not result in an explosive atmosphere or vapor accumulation as is specified in §350.31(c). And third, in order for the NAPL to remain, the person must demonstrate that aesthetics are not an issue as described in §350.74(i). Even though a COC's concentration is below its PCL, it must not adversely impact environmental quality or public welfare, present objectionable characteristics such as taste or odor, or make a natural resource unfit for use. Additional details pertaining to NAPLs are provided in the TNRCC guidance document entitled *NAPL Evaluation and Recovery* (RG-366/TRRP-32).

Groundwater PCLE Zone Response Objective for Remedy Standard A

Subsection 350.32(f) specifies that the person cannot allow the groundwater PCLE zone to expand beyond its existing boundary. "Existing boundary" under Remedy Standard A means the location of the boundary of the groundwater PCLE zone at the time of submittal of the self-implementation notice (SIN) for self-implemented response actions and at the time of submittal of the RAP for non-self-implemented response actions. The response objectives for Remedy Standard A when stated bluntly are "clean it up and don't let it get any bigger while you're doing it." As an example of what is not allowed, a groundwater pumping system that would pull groundwater with COCs beyond the existing boundary of the groundwater PCLE zone before it is extracted for treatment could not be used as a response action under Remedy Standard A.

Remedy Standard B Response Objectives

For Remedy Standard B separate response objectives are presented to provide protection of human health and ecological receptors. The initial section below provides a summary of the general human health response objectives. The second section presents the response objectives that must be attained, when warranted, to protect ecological receptors. And the following sections provide a description of the groundwater and soil response objectives that Remedy Standard B response actions must meet. Use of the critical PCL, which is the lower of the human health PCL and, when necessary, the ecological PCL facilitates a person demonstrating attainment of both the human health and ecological response objectives for an affected property under Remedy Standard B.

Summary of Remedy Standard B General Human Health Response Objectives

The general human health response objectives for Remedy Standard B are summarized in Table 4. The person must meet the groundwater and soil response objectives that are described later in this document in addition to these general human health response objectives. The combination of these two sets of requirements provides the complete list of response objectives for Remedy Standard B response actions. The next section describes the circumstances when threats to ecological receptors, rather than human health considerations, will be the determining factor in establishing the response objectives that must be attained. The Remedy Standard B response objectives are described in §350.33.

Table 4. Summary of Remedy Standard B general human health response objectives

Response Objective	Rule Citation
Persons must, within a reasonable time frame given the particular circumstances of an affected property, remove, decontaminate, and/or control the surface soil, subsurface soil and/or groundwater human health PCLE zones, other environmental media, and hazardous and non-hazardous waste in accordance with the provisions of this section such that humans will not be exposed to concentrations of COCs in the exposure media in excess of the residential or commercial/industrial critical human health PCLs, as applicable at the prescribed, or any approved alternate human points of exposure (POEs) established for environmental media in accordance with §350.37.	§350.33 (a)(1) §350.33 (b)(2) §350.37
Remedy Standard B is not self-implementing. TNRCC's written approval of an APAR and a RAP is required before a person can implement a response action.	§350.33 (d)
Remedial alternatives must be appropriate considering the hydrogeologic characteristics of an affected property, COC characteristics, and the potential for unprotective exposure conditions to continue or result during the remedial period. MNA, or an in-situ technology, may be a decontamination or a control remedy depending upon the circumstances.	§350.33 (b)(2)
Class 1 groundwater PCLE zones must be removed and/or decontaminated to the critical groundwater PCL for each COC except in the circumstance when the affected property qualifies for a modified groundwater response.	§350.33(b)
An institutional control is required under Remedy Standard B for both residential and commercial/industrial land uses.	§350.31(g)

Summary of Remedy Standard B Ecological Receptor Response Objectives

As described in §350.33(a)(3), a person must use one of the approaches presented in Table 5 to respond to an affected property based upon threats to ecological receptors whenever:

- the COC concentrations within environmental media exceed the ecological PCLs but not the human health PCLs; or

- when there will be residual concentrations of COCs above the ecological PCLs following completion of a human health response action.

Whenever human health PCLs are exceeded, the response action for an affected property will be based upon the threats to human health. An exception is provided in the circumstance where a person adequately demonstrates that the threats to human health are minimal and that a human health-based response would have a significant and highly disproportionate effect on ecological receptors as explained at §350.33(a)(3). When the response action is to be based on ecological receptors, the person must use one of the two response objectives described in Table 5. Whenever a response action based on ecological receptors is performed in accordance with the first option listed in Table 5 under §350.33(a)(3)(A), the remedy must also attain the groundwater and soil response objectives described later in this document. However, for a response action within an environmental medium or media that is based on ecological receptors and that is performed in response to the second option in Table 5 under §350.33(a)(3)(B), there would be no requirement to attain the soil and/or groundwater response objectives, as applicable, for that affected environmental medium or media. However, if an additional response action, not based on threats to ecological receptors under §350.33(a)(3)(B), is required for another soil and/or groundwater medium at such an affected property, then the soil and/or groundwater response objectives, as applicable, for that affected environmental medium or media must be attained. A discussion of ecological risk management under the TRRP rule is presented in the TNRCC guidance document entitled *Guidance for Conducting Ecological Risk Assessments at Remediation Sites in Texas.*

Table 5. Remedy Standard B ecological receptor response objectives

Response Objective	Rule Citation
Persons must remove, decontaminate, and/or control the environmental media, and hazardous and non-hazardous waste in accordance with §350.33 such that ecological receptors will not be exposed to concentrations of COCs in the exposure medium in excess of the ecological PCLs at the POEs determined in accordance with §350.77.	§350.33(a)(3)(A)
After consultation with the Natural Resource Trustees and determined to be appropriate by the TNRCC, the person may conduct an ecological services analysis. The ecological services analysis must include an evaluation of the effects of reasonable and feasible remediation alternatives and a justification for leaving COCs in place above the ecological PCLs. Where appropriate, the ecological services analysis shall include a plan to provide compensatory ecological restoration. The ecological services produced by the restoration activity must exceed the future ecological services decreases potentially associated with the continued exposure to COCs and/or any selected response action at an affected property.	§350.33(a)(3)(B)

General Groundwater Response Objectives for Remedy Standard B

A person must achieve the general groundwater response objectives (human health and ecological) for Remedy Standard B presented in Table 6 unless the person demonstrates that an affected property meets the qualifying criteria for one, or a combination, of the modified groundwater response approaches described as: waste control unit (WCU); technical impracticability (TI); and/or plume management zone (PMZ). Figure 2 shows the process for determining the Remedy Standard B groundwater response objectives that will be applicable at a particular affected property. A person who uses one or more of the modified groundwater response approaches must fulfill the post-response action care obligations described in the approved RAP. A person who uses one, or a combination, of the modified groundwater response approaches that utilize a physical control(s) must provide financial assurance as described in §350.33(l) and (m).

This and the next section of this document, pertaining to modified groundwater objectives, describe the response objectives that apply to groundwater PCLE zones under Remedy Standard B. Possible approaches to demonstrate in the RAP that a proposed response action will conform to these requirements for groundwater PCLE zones are presented in the TNRCC guidance document entitled *Evaluation of Remedy Effectiveness* (RG-366/TRRP-31).

Table 6. General groundwater response objectives for Remedy Standard B

Response Objective	Rule Citation
Persons must use an active approach or MNA to reduce the concentration of COCs to the critical groundwater PCLs throughout the groundwater PCLE zone	§350.33(f)(1)(A)
Persons must prevent concentrations above critical groundwater PCLs from migrating beyond the existing boundary of the groundwater PCLE zone	§350.33(f)(1)(B)
Persons must prevent COCs from migrating to air at concentrations above $^{Air}Air_{Inh}$	§350.33(f)(1)(C)
Persons must prevent COCs from migrating to surface water at concentrations above the PCLs for groundwater discharges to surface water (^{SW}GW)	§350.33(f)(1)(D)
Persons must prevent human and ecological receptor exposure to the groundwater PCLE zone	§350.33(f)(1)(E)

Under the general groundwater response objectives for Remedy Standard B, a person must use either an active restoration approach or MNA to reduce the COCs to the critical groundwater PCLs throughout the groundwater PCLE zone. Restoration to this level must occur within a reasonable time frame and must prevent further expansion of the groundwater PCLE zone. Information regarding analysis and sampling

to demonstrate whether these groundwater response objectives are being attained is presented in the TNRCC guidance document entitled *Compliance Sampling and Monitoring* (RG-366/TRRP-30). Many different types of groundwater response actions and combinations of actions can be used to attain

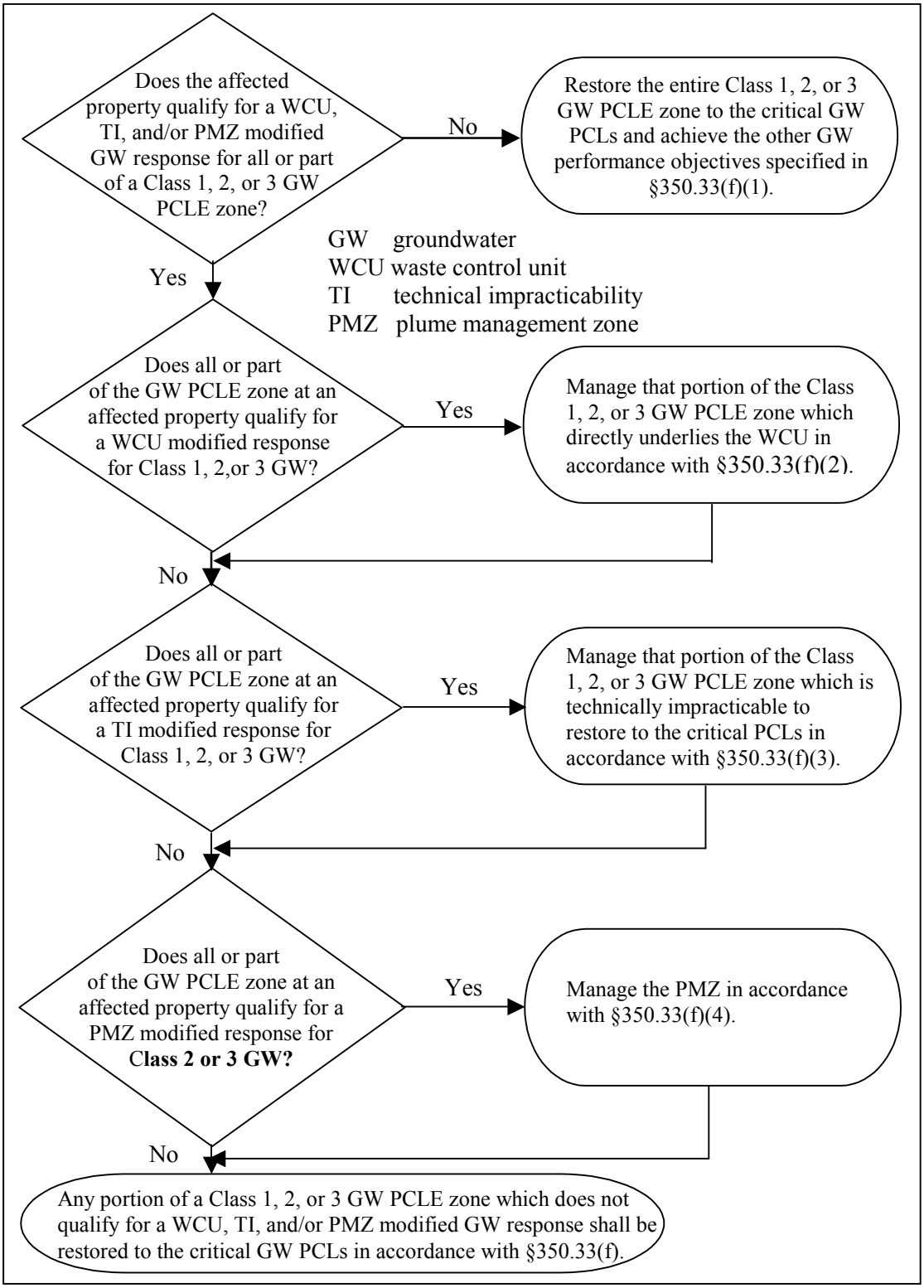

Figure 2. Process for determining Remedy Standard B groundwater response objectives.

the required performance. Figure 3 depicts a groundwater response action based upon removal. Examples of groundwater removal actions are groundwater pumping and disposal and also air sparging for volatiles. To be used alone, a removal technology must not only reduce the COCs to the critical groundwater PCLs but must also prevent the groundwater PCLE zone from expanding. Figure 3 depicts an affected property where groundwater extraction wells are being used to attain the performance objectives. The performance requirement that the PCLE zone cannot be allowed to expand is indicated by the "stop" included in the figure.

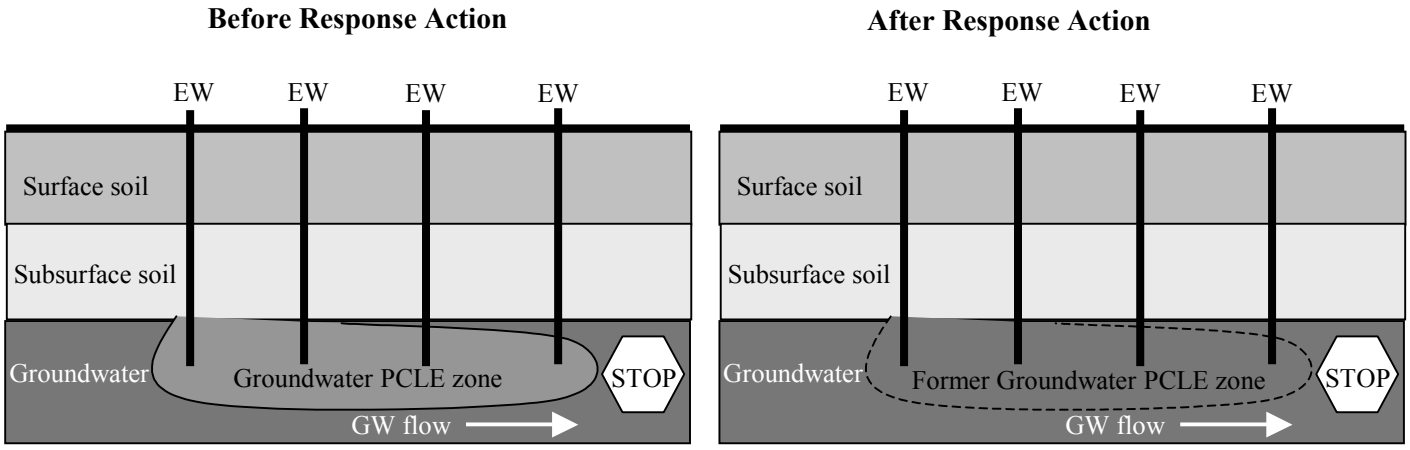

Figure 3. Example of Remedy Standard B groundwater response action based on removal (Groundwater Extraction Wells (EW))

Figure 4 depicts an affected property where decontamination is being used to treat groundwater. Two different treatment approaches are shown on Figure 4. First, depending upon the hydrogeologic conditions and the properties of the COCs, MNA may be used as the groundwater response action. The figure depicts the approach where amendments are added to the groundwater-bearing unit through wells in order to increase the rate of COC decomposition. In some instances, enhanced MNA may not be adequate by itself to prevent the expansion of the groundwater PCLE zone. A permeable reactive barrier is the other groundwater treatment technology depicted in Figure 4. The permeable reactive barrier is placed at the hydraulically downgradient limit of the groundwater PCLE zone. COCs amenable to treatment by this technology are decomposed as groundwater flows through the barrier. For a permeable reactive barrier, the rate of COC transport via groundwater flow must be sufficiently high for the person to demonstrate that the response action will be completed within a reasonable time frame considering the circumstances of a particular affected property. A permeable reactive barrier could also be used under Remedy Standard A provided it prevents groundwater PCLE zone expansion and results in the attainment of the groundwater response objectives within a reasonable time frame.

And finally, Figure 5 shows that control measures can be used as part of the groundwater response action under Remedy Standard B to achieve the general groundwater response objectives. Since the primary requirement is to reduce the concentration of COCs to the critical PCLs throughout the groundwater PCLE zone, a control measure cannot be used alone since it will not reduce the COC concentrations to the groundwater PCLs. Control measures, such as the slurry wall shown in Figure 5, may be used in combination with removal and/or decontamination response actions.

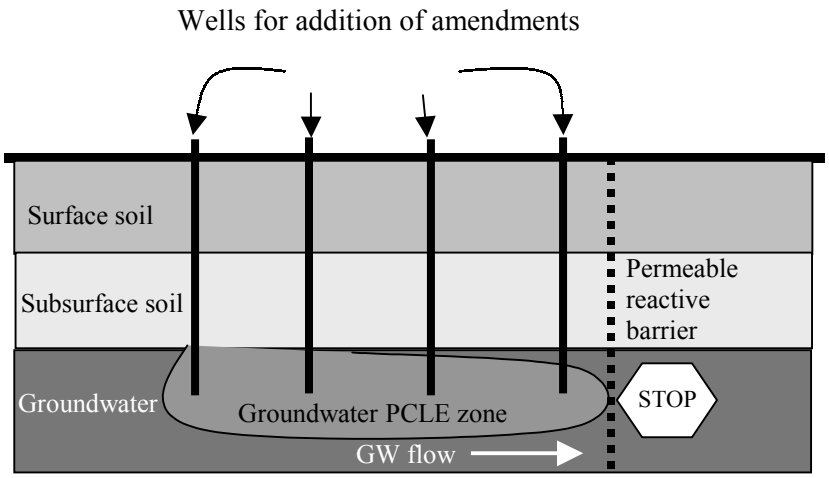

Figure 4. Example of Remedy Standard B groundwater response action based on decontamination (amendments, MNA and/or permeable reactive barrier)

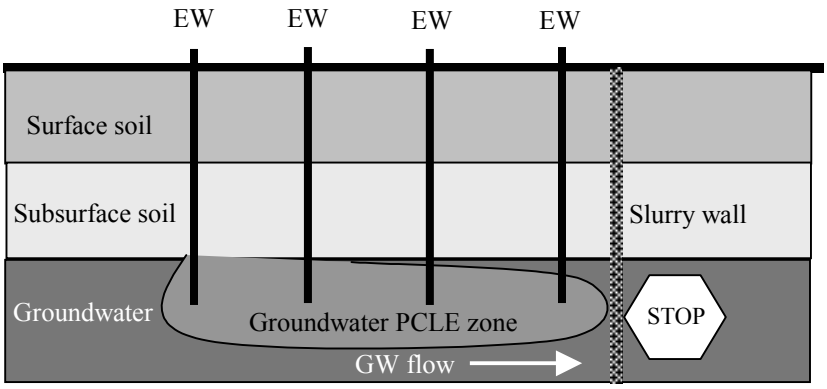

Figure 5. Example of Remedy Standard B groundwater response action where a control measure (slurry wall) is required to prevent the groundwater PCLE zone from expanding. EW is groundwater extraction well.

Modified Groundwater Response Objectives for Remedy Standard B

The person may demonstrate that an affected property meets the qualifying criteria for use of one, or a combination, of the modified groundwater response approaches described as: WCU, TI, and PMZ. These modified groundwater response approaches are intended to provide flexibility in appropriate circumstances. The TNRCC should agree to use of a modified groundwater response approach when a person adequately demonstrates that an affected property meets the qualifying criteria for a modified approach. Each of these modified groundwater response approaches requires the person to provide proof of the filing of an institutional control within the property deed records. This is an important requirement. Additional information pertaining to the proof of filing of an institutional control is provided in the TNRCC guidance entitled *Institutional Controls* (RG-366/TRRP-16).

Waste Control Unit

A WCU is defined at §350.4(a)(91) as a municipal or industrial solid waste landfill, including those RCRA regulated units classed as landfills, with a liner system (i.e., synthetic or clay) and an engineered cap that have been closed pursuant to an approved closure plan, previous regulations, or will be implemented pursuant to an approved RAP. Additional details concerning WCUs are found in the TNRCC guidance document entitled *Application of Remedy Standards A and B* (RG-366/TRRP-28).

As specified in §350.33(f)(2), WCU demonstrations can be used for Class 1, 2, and 3 groundwaters. In the circumstance where an existing or planned WCU overlies an existing groundwater PCLE zone, the person may propose in the RAP, and the TNRCC may approve, the exclusion of that portion of the groundwater PCLE zone which directly underlies the WCU from the requirement to meet the general groundwater response objectives described previously. The person should thoroughly describe the physical control and explain how it meets the definition of a WCU. Furthermore, the person should describe why a WCU modified groundwater response would be an appropriate action at the affected property. With the approval of a WCU modified groundwater response, the groundwater directly underlying the WCU does not have to be restored to the critical PCLs. Beyond the perimeter of the WCU, however, all of the general groundwater response objectives must be attained, unless otherwise modified by another groundwater response objective. The extent of the modified groundwater response is depicted in Figure 6. Deeper groundwater-bearing units underlying a WCU that do not contain a groundwater PCLE zone must be protected. Formation of a groundwater PCLE zone in such an unaffected unit is prohibited. Proof of compliance with the institutional control requirements must be submitted to the TNRCC within 120 days of approval of the RAP. This control provides notice of the existence and location of the groundwater PCLE zone beneath the WCU and prevents usage of and exposure to this groundwater.

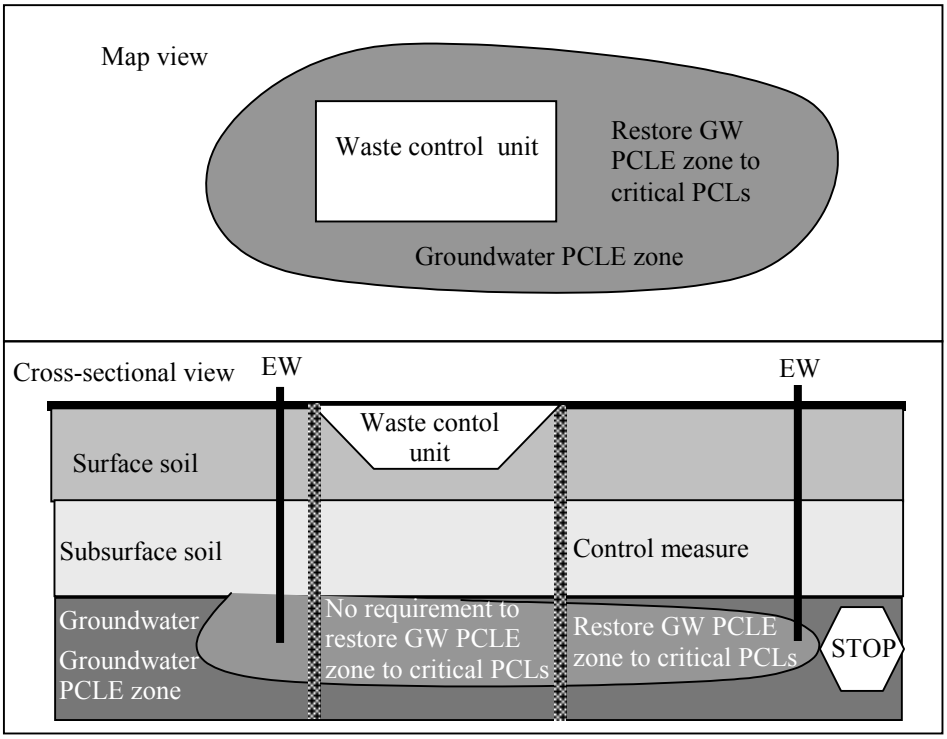

Figure 6. Example of Remedy Standard B Waste Control Unit Response Objectives. EW is groundwater extraction well.

Figure 6 depicts an example of a WCU and its associated response objectives under Remedy Standard B. The groundwater directly under the WCU does not need to be restored to the critical groundwater PCLs. The other part of the groundwater PCLE zone must be restored to the critical groundwater PCLs. Groundwater extraction wells are depicted as an example removal or decontamination method to attain this objective. In this example, a slurry wall, as a control measure, is installed to prevent COCs from migrating out of the WCU zone. Also, although not depicted in Figure 6, a WCU could be combined with a TI and/or PMZ modified groundwater response approach if the conditions at an affected property are appropriate.

Technical Impracticability

TI demonstrations as described in §350.33(f)(3) can be used for Class 1, 2, and 3 groundwaters. To use a TI approach a person must satisfy the requirements in Table 7. Figure 7 shows an example of a TI zone being applied under Remedy Standard B. The area outside of the TI zone must be restored to the critical groundwater PCLs. In this example, a control measure is used to prevent migration of COCs from the TI zone. Also, the groundwater PCLE zone must not expand.

Table 7. Groundwater technical impracticability

Response Objective	Rule Citation
Persons must demonstrate that it is not feasible from a physical perspective using currently available remediation technologies due either to hydrogeologic or chemical-specific factors to reduce the concentration of COCs throughout all or a portion of the groundwater PCLE zone to the applicable critical groundwater PCLs within a reasonable time frame. TI demonstrations shall be performed in accordance with the United States Environmental Protection Agency guidance titled "Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration (Office of Solid Waste and Emergency Response Directive 9234.2-25 or subsequent version), as amended, or other method approved by the TNRCC.	§350.33(f)(3)(A)
Persons must use removal or decontamination to reduce COC concentrations to the critical groundwater PCLs for any portion of the groundwater PCLE zone where it is technically practicable	§350.33(f)(3)(B)
Persons must prevent migration of COCs from that portion of the groundwater PCLE zone where restoration is technically impracticable	§350.33(f)(3)(C)
Persons must demonstrate that NAPLs have been reduced to the extent practicable, which involves conformance with the following criteria: • readily recoverable NAPLs have been removed; • the NAPLs will not generate explosive conditions; • the NAPLs will not discharge to the ground surface, to structures, or to other groundwater-bearing units; and • the lateral and vertical extent of NAPLs will not increase under natural conditions or sufficient NAPLs have been removed such that an active recovery system can effectively contain migration of NAPLs	§350.33(f)(3)(D) §350.33(f)(4)(E)
Persons must establish a PMZ for the area where COCs cannot be removed to the extent necessary to attain the critical groundwater PCLs and prevent COCs at concentrations above the critical groundwater PCLs from spreading beyond the existing boundary of the groundwater PCLE zone	§350.33(f)(3)(E)
Persons must submit proof of compliance with the institutional control requirements to the TNRCC within 120 days of approval of the RAP. The institutional control provides notice of the existence and location of the groundwater PCLE zone and prevents use of and exposure to groundwater from this zone until the COCs have reduced to the critical groundwater PCLs.	§350.33(f)(3)(F) §350.31(g)

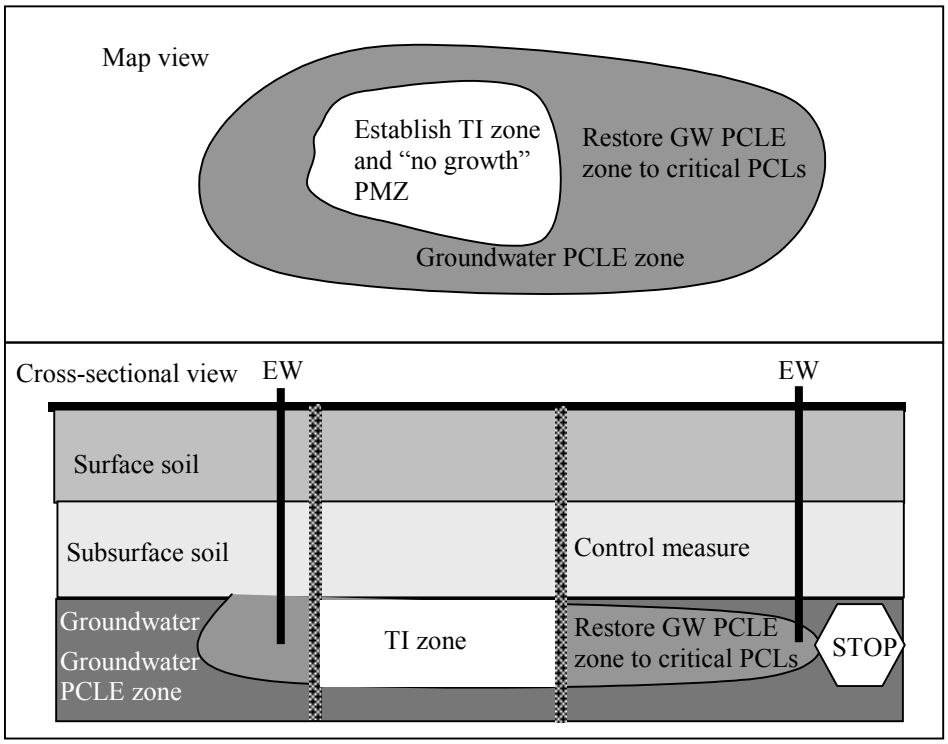

Figure 7. Example of Remedy Standard B technical impracticability response objectives. EW is groundwater extraction well.

Subparagraph 350.33(f)(3)(A) is explicit with regard to the performance that must be demonstrated in order for all or part of a groundwater PCLE zone to qualify as a TI zone. If a TI zone is approved, then the person must assure that the groundwater PCLE zone and PMZ conforms with the requirements listed above. The following paragraphs provide additional details regarding the required performance.

A TI demonstration must focus primarily on the physical perspective, meaning the engineering feasibility and reliability of available remediation technologies to restore all or part of a groundwater PCLE zone to the critical PCLs. Cost plays a subordinate role to protectiveness. Cost is not a major factor in the TI determination unless restoration to the critical PCLs would be inordinately expensive. The point at which the cost of restoring groundwater to the critical PCLs becomes inordinate must be determined based on the circumstances of the particular affected property. As with long restoration time frames, relatively high restoration costs may be appropriate in certain cases, depending on the nature of the COC release, the groundwater classification, and the current and likely future use of the groundwater.

Subparagraph 350.33(f)(3)(A) refers to "currently available remediation technologies". To meet the TI demonstration requirement, there must not be available groundwater remediation technologies that can successfully reduce the COCs to the critical PCLs in a reasonable period. A demonstration of technical impracticability must be performed in accordance with the USEPA *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (Office of Solid Waste and Emergency Response Directive 9234.2-25 or subsequent version), as amended, or other method approved by the TNRCC. The information required in the TI demonstration depends on the circumstances of the affected property and the state of groundwater remediation science at the time such an evaluation is made. In general, the TNRCC expects such a demonstration to consist of: (1) a review of technical literature to identify candidate technologies; (2) a screening of the candidate technologies to identify potentially applicable technologies; and (3) an analysis, using affected property hydrogeologic and COC data, of the capabilities of any of the applicable technologies to achieve the required cleanup standards. The person

must also demonstrate that any groundwater-bearing unit which does not contain a groundwater PCLE zone will not over time be affected by COCs above the critical PCL levels.

Determinations of TI will be based on characterization of the affected property and, where appropriate, remedy performance data. These data must be collected, analyzed, and presented so that the engineering feasibility and reliability of groundwater restoration are fully addressed in a logical and concise fashion. The request for a TI is made in the RAP and is presented in the context of the proposed response action for the affected property. Persons may seek a TI determination after implementation and monitoring of a partial or full-size groundwater restoration system. In this event, TNRCC expects the existing remedy to have been rigorously monitored. The response action should have been modified or enhanced, where appropriate, to demonstrate that best efforts have been made to achieve the required cleanup levels. The TNRCC does not consider failure to achieve desired cleanup standards due to an inadequate system design or operation to be sufficient justification for a determination of TI for a groundwater cleanup. The person may also seek a determination of TI prior to response action implementation. In this instance, assessment of the affected property must be especially thorough. Such assessment must clearly and convincingly demonstrate that attainment of the critical PCLs is not practicable.

Hydrogeologic limitations to groundwater remediation include conditions such as: complex stratigraphic or structural environment; groundwater-bearing units of very low permeability; certain types of fractured bedrock; and conditions that at present make extraction or in situ treatment extremely difficult. COC-related factors include a COC's potential to become either sorbed onto or lodged within the soil or rock comprising a groundwater-bearing unit. NAPLs are examples of COCs that may pose technical limitations to groundwater-bearing unit restoration. Dense NAPLs are more dense than water and are often particularly difficult to locate and remove from the subsurface. The property of dense NAPLs to sink through the water table and to penetrate to deeper portions of a groundwater-bearing unit(s) often makes them difficult to remediate. Additional details concerning the remediation of NAPLs under TRRP are presented in the TNRCC guidance document entitled *NAPL Evaluation and Recovery* (RG-366/TRRP-32). However, the presence of known remediation constraints, such as dense NAPLs, fractured bedrock, or other condition, is not sufficient by itself to justify a TI determination. Adequate affected property assessment data must be presented to demonstrate, not only that the constraint exists, but that the effect of the constraint on COC distribution and recovery potential poses a critical limitation to the effectiveness of available technologies.

Estimates of the time frame required to achieve groundwater restoration may be considered in a TI evaluation. While restoration time frames may be an important consideration in selecting a response action for an affected property, no single time frame can be specified during which restoration must be achieved to be considered "reasonable." Long restoration times, such as 100 years, may be indicative of hydrogeologic or COC-related constraints to remediation. While predictions of restoration time frames may be useful in illustrating the effects of such constraints, the TNRCC will base TI decisions on an overall demonstration of the extent of such physical constraints at an affected property, not on restoration time frame analyses alone. Such demonstrations should be based on detailed and accurate conceptual models that can also provide the bases for meaningful predictions of restoration time frames.

Plume Management Zones

To establish a PMZ in response to §350.33(f)(4) a person must satisfy the requirements described in Table 8. A person must actively monitor a PMZ to assure that the requirements in Table 8 are fulfilled. In particular, the PMZ must not result in a deeper groundwater-bearing unit that does not contain a groundwater PCLE zone being affected over time by COCs at concentrations greater than the critical PCLs applicable for that deeper groundwater-bearing unit. There are additional requirements which are described later and which depend on whether a removal and/or decontamination remedy or a removal, decontamination, and/or control response is used to attain these response objectives.

Table 8. Response objectives which apply to all plume management zones

Response Objective	Rule Citation
PMZs may not be established for Class 1 groundwater and may be established only for Class 2 and 3 groundwater-bearing units which already contain a groundwater PCLE zone	§350.33(f)(4)
Persons must demonstrate that a PMZ should be approved based upon consideration of • the potentially adverse effects on groundwater quality; and • the potentially adverse effects on hydraulically-connected surface water.	§350.33(f)(4)(A)
With a PMZ, the POE to groundwater is changed from throughout the groundwater PCLE zone to an alternate location at the downgradient extent of the PMZ established in accordance with §350.37(l) and (m) for Class 2 and 3 groundwater, respectively	§350.33(f)(4)(B)
In order to establish a PMZ, the person must: • comply with the institutional control requirements of §350.31(g) and provide proof of compliance within 120 days of RAP approval; • demonstrate that COCs will not migrate beyond the downgradient boundary of the PMZ with concentrations greater than the critical PCLs; • demonstrate through the performance of a field survey that there are no artificial penetrations, abandoned wells or wells with open hole completion which would allow COCs with concentrations in excess of the critical PCLs to migrate to an unaffected groundwater-bearing unit.	§350.33(f)(4)(C)
Person must establish groundwater attenuation monitoring points beginning at an appropriate hydraulically upgradient location within the groundwater PCLE zone and continuing down the approximate central flow path of the COCs to the downgradient extent of the PMZ. The attenuation monitoring points must satisfy the following requirements: • The number and location of attenuation monitoring points shall be demonstrated to be adequate to reliably verify over time the current and future conformance with the PMZ response objectives. The number and location of attenuation monitoring points shall depend upon a site-specific evaluation of the hydrogeologic conditions of an affected property, the fate and transport characteristics of the COCs, and the length and configuration of the PMZ. • The person shall calculate attenuation action levels for each COC at each attenuation monitoring point that must not be exceeded so that the critical groundwater PCLs will not be exceeded at the POE. The person shall periodically monitor the adequacy of the attenuation action levels. • The person shall monitor COCs in groundwater at the attenuation monitoring points in accordance with the approved schedule. If an attenuation action level is exceeded at its respective attenuation monitoring point or a critical groundwater PCL is exceeded at the groundwater POE, then the person shall take an active response measure.	§350.33(f)(4)(D)
The person shall reduce NAPLs which contain COCs in excess of PCLs within a PMZ to the extent practicable. The requirements for NAPLs are listed in Table 7.	§350.33(f)(4)(E)
The person shall have the continuing obligation to assess whether changes to local hydraulic gradients would increase the likelihood that COCs can migrate beyond the PMZ at concentrations above the critical PCL.	§350.33(f)(4)(F)

The primary function of a PMZ is to prevent exposure to groundwater within a PCLE zone. The most important characteristic of a PMZ is that the POE to groundwater is changed from throughout the PCLE zone to a downgradient receptor POE. This alternate POE location is some distance "x" downgradient of the groundwater PCLE zone boundary. This alternate POE location is established in accordance with §350.37(l) for Class 2 groundwater and §350.37(m) for Class 3 groundwater. Further details regarding the establishment of a POE for a PMZ are provided in the TNRCC guidance document entitled *Human Health Points of Exposure* (RG-366/TRRP-21).

The classification of the affected groundwater determines the eligibility criteria for a PMZ; however, the person must secure the TNRCC's permission to implement a PMZ. Such approval is not automatic. The person must clearly demonstrate that the COCs within a PMZ will not pose a substantial present or potential hazard to human health or the environment as long as the attenuation action levels are not exceeded at the respective attenuation monitoring points. This analysis must be based upon the potentially adverse effects on groundwater quality and hydraulically-connected surface water quality described at §350.33(f)(4)(A). Some of the required factors are: the physical and chemical characteristics of the COC, including its potential for migration; the quantity of groundwater and the direction of groundwater flow; the proximity and withdrawal rates of groundwater users; and the current and future uses of groundwater in the area. To apply for a PMZ, a person must provide a carefully prepared analysis of all of these factors in the RAP. This demonstration should contain the necessary surveys, assessments, and evaluations to build the case that the person can control the groundwater PCLE zone within the PMZ. Additional lines of support that may be used to make this demonstration include: ordinances which prohibit groundwater use, poor groundwater quality due to non-point sources, groundwater monitoring and water quality trends, and the adequacy of the hydrogeologic characterization.

Also, the groundwater PCLE zone must be removed, decontaminated, and/or controlled so that the critical PCLs for other environmental media, such as air, are not exceeded at their applicable POEs. For example, assume a highly volatile COC with relatively low water solubility is at an acceptable concentration based upon lateral transport to the groundwater POE. However, the volatile characteristics of this COC are such that its concentration exceeds the PCL for air in the human breathing zone. PCLs must be determined for all exposure pathways that are reasonably anticipated to be completed. A PMZ must be protective for all complete or reasonably anticipated to be complete exposure pathways.

Plume Management Zones – Types of Response Actions

A person may choose to attain the groundwater response objectives for a PMZ at an affected property by conducting a response action, if necessary, which makes use of removal and/or decontamination, removal and/or decontamination with controls, or controls only. When the PCLE zone extends beyond the limits of an institutional control and the POE to groundwater is located within the existing limits of the groundwater PCLE zone, a person may use MNA as a decontamination process to bring the PCLE zone into compliance provided the person can demonstrate that the groundwater PCLE zone is not expanding. The person must also demonstrate that the critical PCLs will be met at the POE within a reasonable time frame.

When a person chooses to use a removal and/or decontamination response approach the additional response objectives summarized in Table 9 must be attained. Figure 8 depicts an example PMZ where attainment of the response objectives is to be achieved via removal and/or decontamination processes. In the example depicted in Figure 8, MNA is being relied upon to assure that the critical groundwater PCLs are not exceeded at the alternate POE. In this example, the groundwater PCLE zone has reached steady-state conditions and is not migrating downgradient within the PMZ. In the event that the groundwater PCLE zone is migrating downgradient, the person cannot use MNA unless it can be demonstrated that the attenuation action levels and critical PCLs will not be exceeded at the attenuation monitoring points and alternate POE, respectively. Such determinations are typically based upon a combination of modeling outputs and groundwater monitoring data. In the event that natural attenuation factor outputs are inconsistent with groundwater monitoring data, the TNRCC will generally require the person to place more weight on the monitoring data. In any case, modeling outputs cannot be used as the sole reason to discount field evidence or monitoring data.

Table 9. Plume management zone – removal and/or decontamination response actions

Remedy Requirement	Rule Citation
Persons must remove and/or decontaminate the groundwater PCLE zone to the extent necessary so that the critical groundwater PCLs will not be exceeded at the POE and the attenuation action levels are not exceeded at their respective attenuation monitoring points, and so that the critical PCLs for other environmental media will not be exceeded at their applicable POEs	§350.33(f)(4)(F)(ii)(I)
Persons must fulfill any post-response action care obligations described in approved RAP	§350.33(f)(4)(F)(ii)(II)
Provided the person documents attainment of the PMZ response objectives, there are no post-response action care requirements.	§350.33(f)(4)(F)(ii)(III)

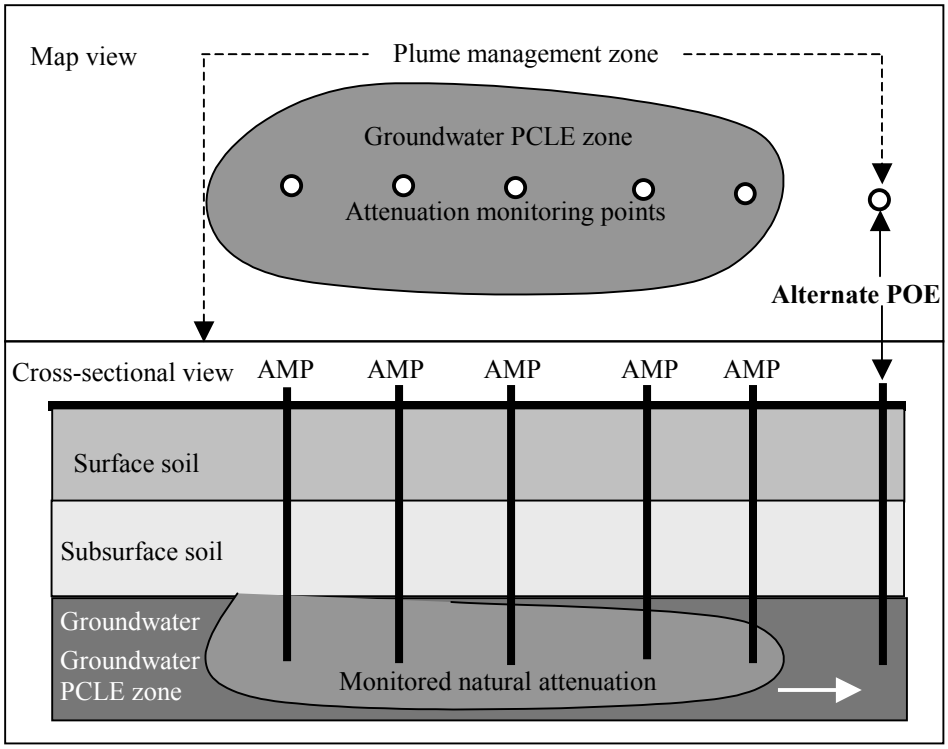

Figure 8. Example of Remedy Standard B plume management zone based on removal and/or decontamination. AMP is attenuation monitoring point.

In the event that a person chooses to attain the PMZ response objectives with a removal, decontamination, and/or control remedy then the additional requirements in Table 10 must be satisfied. Figures 9 and 10 illustrate the variety of response actions that can use a physical control measure as part of a PMZ and highlight the requirements in Table 10 regarding source area control.

Table 10. Plume management zone – removal, decontamination, and/or control or control only

Remedy Requirement	Rule Citation
Persons must remove, decontaminate, and/or control the groundwater PCLE zone to the extent necessary so that the critical groundwater PCLs will not be exceeded at the POE and so that the critical PCLs for other environmental media will not be exceeded at their applicable POEs	§350.33(f)(4)(F)(iii)(I)
Persons must use physical controls (for example, slurry walls, sheet piling, interceptor trenches, or hydraulic control wells) which are capable of reliably containing and preventing the expansion over time of the groundwater source area	§350.33(f)(4)(F)(iii)(II)
Persons must attain the attenuation action levels at the attenuation monitoring points for any portion of a groundwater PCLE zone outside of a physical control	§350.33(f)(4)(F)(iii)(III)
Persons must fulfill any post-response action care obligation described in approved RAP	§350.(f)(4)(F)(iii)(IV)
Persons must provide financial assurance for post-response action care in accordance with §350.33(l) and (m)	§350.33(f)(4)(F)(iii)(V)

Figure 9 depicts an affected property with a well-defined source area within the groundwater PCLE zone. The response action in this figure consists of a physical control, such as a slurry wall or sheet piling that surrounds the groundwater source area. At this affected property, this physical control effectively prevents migration of COCs from the source area to other parts of the groundwater PCLE zone. In this example, for areas outside of the physical control, MNA is adequate to prevent COCs above the critical PCLs from migrating to the alternate POE.

For the example affected property depicted in Figure 10, the groundwater source area is not well defined. The COCs are broadly distributed, fairly homogeneous in concentration, mobile, and persistent.

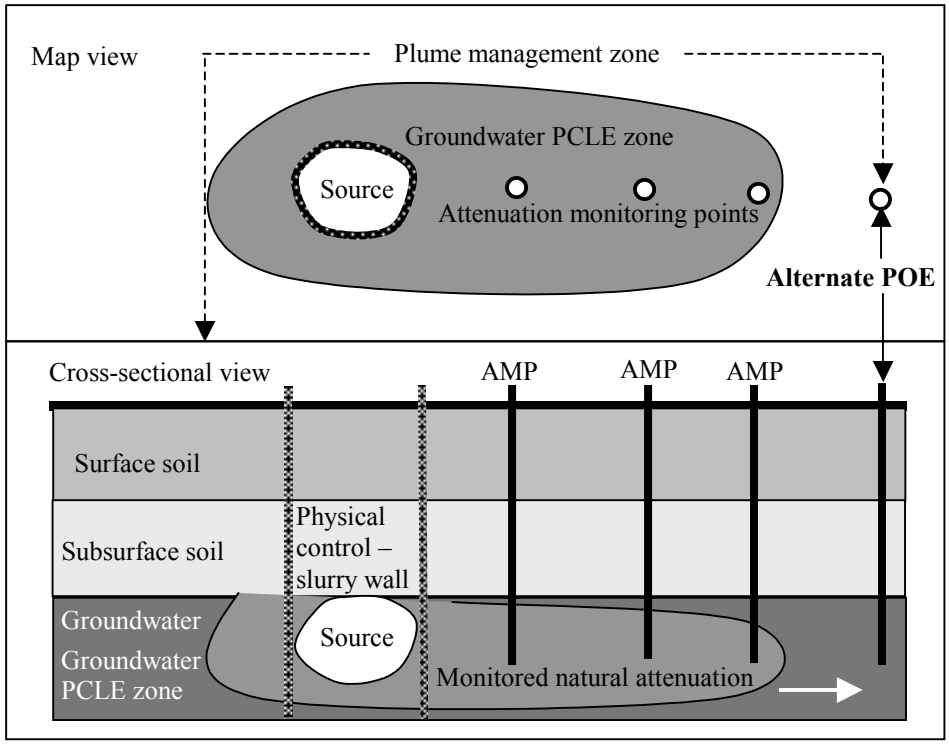

Figure 9. Example of Remedy Standard B plume management zone based on decontamination (monitored natural attenuation) and control (slurry wall). AMP is attenuation monitoring point.

Therefore, at this affected property, the groundwater source area is essentially the same as the groundwater PCLE zone. The person decides that the only way to prevent the COCs from reaching the alternate POE in concentrations above the critical PCLs is to place a physical control around the perimeter of the groundwater PCLE zone. This is acceptable since the groundwater source area will not expand. MNA is not being used as a part of the response action in this example.

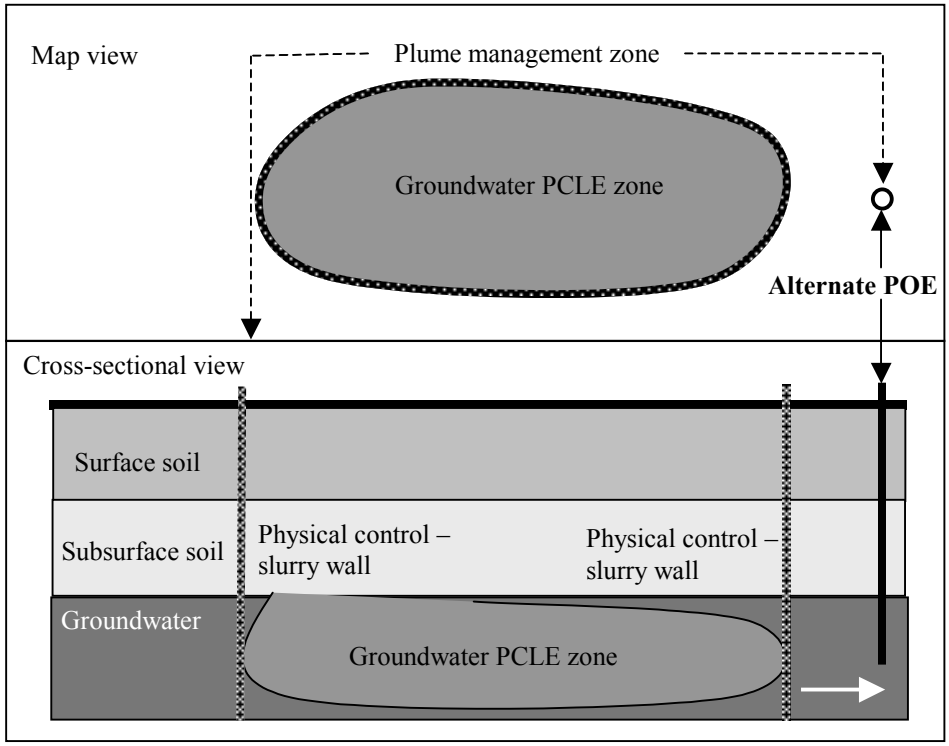

Figure 10. Example of Remedy Standard B plume management zone based on physical control (slurry wall).

Use of Physical Controls for Groundwater

This section describes the various uses of physical controls to address groundwater PCLE zones under Remedy Standard B. Whenever a physical control is used, the person is required to fulfill the post-response action care obligations described in the approved RAP. Such actions associated with the use of a physical control in a groundwater response action include, but are not limited to, monitoring of environmental media to verify response action effectiveness over time and the inspection, operation, and maintenance of the physical control to ensure its effectiveness and integrity over time. The degree of post-response action care is based, in part, upon an assessment of the long-term effectiveness of the response action. Particular attention is paid to developing an appropriate post-response action care plan for response actions, such as depicted in Figure 10, that use a physical control to contain an extensive PCLE zone.

Slurry walls are used here as a representative example for the other types of physical controls which could be used with groundwater PCLE zones. Remember that all response actions under Remedy Standard B, including slurry walls and other types of physical controls for groundwater, must be proposed in the RAP and require the prior approval of the TNRCC. As has been depicted in the previous figures, vertically-oriented controls, such as slurry walls, may be used to help attain the response objectives for a

groundwater PCLE zone under paragraphs §350.33(f)(1), (f)(2), (f)(3), and (f)(4) of the rule. Post-response action care for slurry walls, in particular, generally involves groundwater monitoring to verify that a slurry wall is effectively preventing the flow of the groundwater PCLE zone to areas beyond the wall. Rerouting flow of COCs around a slurry wall is not permitted. In addition, longer term groundwater monitoring is necessary to document that COCs will not break through the slurry wall over time. Since the groundwater response objectives are different under each of paragraphs §350.33(f)(1)-(4) of TRRP, the performance requirements for a slurry wall under these paragraphs are likewise different.

A person may use a slurry wall under §350.33(f)(1) provided that it is part of an overall plan to reduce the concentration of COCs to the critical PCLs throughout the groundwater PCLE zone. For instance, a person could install a slurry wall to keep the groundwater PCLE zone from spreading but would have to take other actions to restore the groundwater within the slurry wall to the critical PCLs.

A slurry wall may also be used as part of a WCU modified groundwater approach as presented in §350.33(f)(2). This approach allows exclusion of the affected groundwater directly beneath a WCU from the requirement to restore groundwater to the critical PCLs. This provision also emphasizes that beyond the perimeter of the WCU, restoration to critical PCLs must be attained. Thus, a slurry wall is most likely to be placed along the perimeter of a WCU to prevent COCs from migrating to a location where restoration to the critical PCLs would be required.

A slurry wall may be authorized in response to the TI modified groundwater response approach described in §350.33(f)(3). This paragraph allows a person to demonstrate that it is not feasible to reduce the concentration of COCs throughout all or a portion of the groundwater PCLE zone to the applicable groundwater PCLs within a reasonable time frame. However, this paragraph also requires the person to (1) reduce the concentration of COCs to the critical PCLs for any portion of the groundwater PCLE zone for which it is technically feasible and (2) prevent migration of COCs from that portion of the groundwater PCLE zone which satisfies the TI demonstration. Thus, a slurry wall would most likely be used under §350.33(f)(3) to prevent the migration of COCs away from the zone which qualifies for a TI.

Slurry walls are mentioned in §350.33(f)(4) regarding persons who choose to attain the PMZ groundwater response objectives by conducting a response action that uses removal and/or decontamination with controls or controls only. According to §350.33(f)(4)(F)(iii)(II) "the person may use physical controls (e.g., slurry walls, sheet piling, interceptor trenches, or hydraulic control wells) which are capable of reliably containing and preventing the expansion over time of the groundwater source area." Further, for any portion of the groundwater PCLE zone that is outside of such a physical control, the person must reduce the concentration of COCs when necessary to assure that the critical PCLs are not exceeded at the POE for the PMZ. Depending upon site-specific circumstances, a slurry wall could be designed to contain only the groundwater source area, the entire groundwater PCLE zone when there is no discrete groundwater source area, or perhaps other configurations just so long as the critical PCLs are not exceeded at the POE.

Surface and Subsurface Soil Response Objectives for Remedy Standard B

The response objectives under Remedy Standard B for surface and subsurface soil are discussed in the following sections. These include both the general surface and subsurface soil response objectives and the response objectives based on soil-to-groundwater threats.

General Surface and Subsurface Soil Response Objectives for Remedy Standard B

Subsection 350.33(a) presents the general surface and subsurface soil response objectives. The response action for soil must prevent the exposure of humans to concentrations of COCs in surface soil above the critical human health PCLs. The response action must also prevent the cross-media transfer of COCs so that humans are not exposed to COCs derived from surface or subsurface soils in other environmental media, for example, air or groundwater, at concentrations above the critical human health PCLs for that environmental medium. The response action must also prevent ecological receptors from being exposed to concentrations of COCs in excess of the ecological PCLs. This section of this guidance document discusses the response objectives that apply to surface and subsurface soil PCLE zones under Remedy Standard B. Possible approaches to demonstrate in the RAP that a proposed response action will conform to these requirements for soil PCLE zones are presented in the TNRCC guidance document entitled *Evaluation of Remedy Effectiveness* (RG-366/TRRP-31).

Surface and Subsurface Soil Optional Approaches for Remedy Standard B

There are two optional approaches from which a person may choose in order to satisfy the Remedy Standard B surface and subsurface soil response objectives. The person must select one of these two approaches in order to design a response action which will satisfy the performance objectives specified in §350.33(a)(1) – (2) and (a)(3)(A) (described previously) to address human health and/or ecological risks.

Under the first option described in §350.33(e)(1) and depicted in Figure 11, the person may decide to meet the surface and subsurface soil response objectives solely through use of removal and/or decontamination processes. As a result the person is required to fulfill any post-response action care obligations described in the approved RAP; but financial assurance is not required.

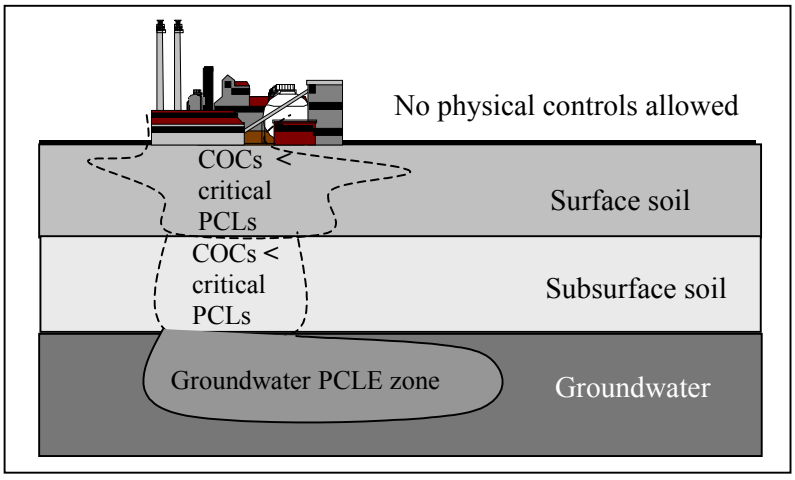

Figure 11. Remedy Standard B surface and subsurface soil response objectives under §350.33(e)(1) using removal and/or decontamination but not control measures. All surface and subsurface soil PCLE zones have been removed.

Under the second option described in §350.33(e)(2) and presented in Figure 12, the person may choose to attain the surface and subsurface soil response objectives by conducting a response action which uses removal and/or decontamination with controls or controls only. "Reliably contain" as used in the first of the following bullets does not necessarily mean zero release of COCs over time. Releases of COCs must

be minimized to the extent necessary such that the critical PCLs for the various environmental media are not exceeded over time. To take this approach, the person must:

- demonstrate that any physical control or combination of measures (for example, WCU, cap, slurry wall, treatment that does not attain decontamination, or a landfill) will reliably contain COCs within and/or derived from the surface and subsurface zone material over time;
- fulfill the post-response action care described in the approved RAP; and
- provide the required financial assurance.

Suppose that in the example presented in Figure 12 the physical control is adequate to prevent direct human contact, ingestion, soil-to-groundwater transfer, and ecological receptor exposure. However, one or more COC(s) at this affected property is highly volatile. The physical control is not sufficient to prevent COC concentrations from exceeding the air PCLs in the human breathing zone. In this event, the physical control must be modified. The physical control could be replaced with a different type of control with alternative properties or augmented with a supporting remedial measure, such as a vapor recovery system. The type of three dimensional control structure depicted in Figure 12 is generally only warranted when lateral transport of COCs or water through the soil remains an issue. The relevant soil exposure pathways at an affected property play an important role when determining the type and construction of a control measure for a soil PCLE zone. For example, in Figure 12 the design of a cap constructed to prevent human and ecological exposure to COCs from a surface and subsurface soil PCLE zone may be somewhat different depending upon the relevant exposure pathways.

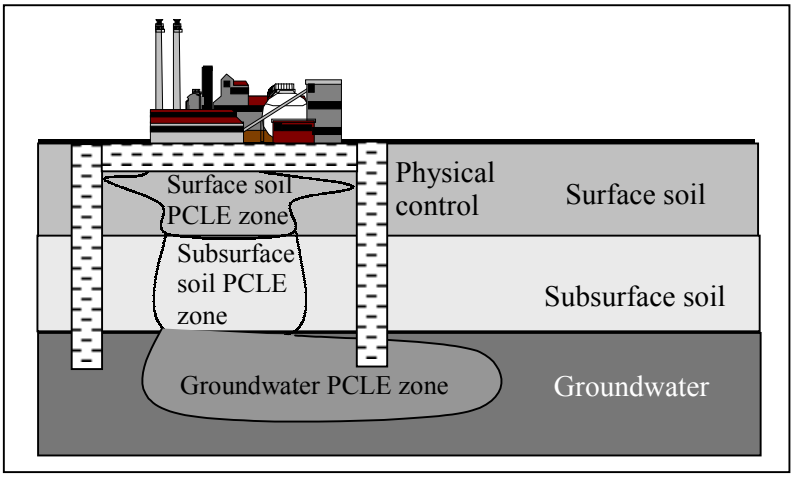

Figure 12. Remedy Standard B surface and subsurface soil response objectives under §350.33(e)(2) using removal and/or decontamination with controls or controls only. This is an example of the physical control measures that may be used. The vertically oriented physical controls addressing the soil PCLE zones may not be routinely warranted.

Several likely exposure pathways along with possible effects on the design for a cap are presented below:

- human ingestion of surface soils, dermal contact with surface soils, and ingestion of vegetables. Preventing physical access is the primary design criterion. This criterion could be satisfied by a clay-rich soil cap or concrete barrier.

- human inhalation of volatile COCs derived from a surface and/or subsurface soil PCLE zone. Typically there are two primary design criteria. These include preventing physical access to

affected surface soils and preventing exposure to COCs in vapors migrating from surface and subsurface soils. Generally, a cap will have a barrier constructed of material that is impermeable to vapor migration. A cap may include provision for vapor collection to prevent dangerous accumulation of COCs below the control.

- cross-media transfer of COCs from soil to groundwater in excess of the critical PCLs. Typically involves preventing physical access, water infiltration and the resulting transport of COCs to groundwater. May include modifying surface slope to direct infiltration away from PCLE zone.

- exposure of a burrowing ecological receptor. A concrete barrier could be used to prevent exposure of a burrowing receptor; however, such decisions are generally made on a site-specific basis.

Soil-to-Groundwater Response Objectives for Remedy Standard B

Under Remedy Standard B, the soil-to-groundwater response objectives depend upon both the classification of the groundwater-bearing unit underlying the soil PCLE zone and upon whether a PMZ has been approved for the uppermost groundwater-bearing unit.

Figure 13 depicts a setting where COCs are leaching from a soil PCLE zone into an underlying groundwater PCLE zone. For this example, assume that a PMZ has not been approved. The soil-to-groundwater response objective for Class 1, 2, and 3 groundwater prohibits any leachate from a surface or subsurface soil PCLE zone from resulting in a COC concentration in groundwater that exceeds the groundwater PCL. The leachate can have a higher concentration than the groundwater PCL but must not result in a concentration in groundwater which is greater than the groundwater PCL. Groundwater classification plays an important part in the implementation of this requirement. The PCL for a COC in Class 3 groundwater may be 100 times higher than the PCL for that COC in Class 1 or 2 groundwater (that is, compare ${}^{GW}GW_{Ing}$ and ${}^{GW}GW_{Class\ 3}$). As a result, for any given COC, the soil-to-groundwater PCL may be 100 times higher if the classification of the underlying groundwater is Class 3 than if it is Class 1 or 2.

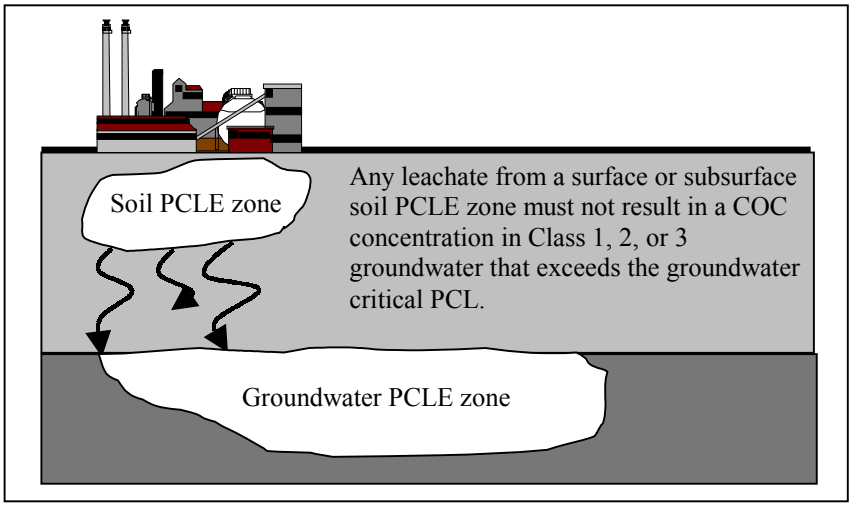

Figure 13. Soil-to-groundwater response objective for circumstance when no PMZ has been approved.

Figure 14 is the same setting as Figure 13 except that a PMZ has been designated in the uppermost groundwater-bearing unit. This is permissible when the unit is Class 2 or 3 groundwater that has previously been affected by COCs. For Class 2 groundwater, any leachate from a surface or subsurface soil PCLE zone must not result in either:

- an increase in COC concentrations in groundwater above those levels measured at the time of RAP submittal (see §350.33(a)(2)); or

- COC concentrations in groundwater at the POE of the PMZ in excess of the groundwater PCL.

For example, assume that at an affected property the existing concentration of a particular COC is 10 ppm in the Class 2 groundwater below the soil PCLE zone. Assume also that the person has demonstrated through the use of lateral fate and transport modeling that 25 ppm of the COC could remain in groundwater below the soil PCLE zone and not result in an exceedence of the critical PCL for the COC at the POE for the PMZ (assume 1 ppm). In this circumstance, in spite of the lateral transport calculations, the existing concentrations of COCs in groundwater cannot be allowed to increase. As a result, the soil response objective in this example would be based on not exceeding 10 ppm for the COC in the Class 2 groundwater. For affected properties similar to this example, groundwater monitoring is generally performed to demonstrate that the soil-to-groundwater response objective is attained over time. Some variation in the concentration of a COC in groundwater is expected during a time series of measurements. However, if any single measurement is significantly above the critical groundwater PCL or if there is a consistent upward trend in a COC concentration indicating that a PCL or attenuation action level is or will be exceeded, then an additional response action may be necessary to address leachate generation and the transport of COCs from the soil PCLE zone. These requirements are based on the potential future use of the Class 2 groundwater and the need to prevent its further deterioration as a potential groundwater supply.

And for Class 3 groundwater, any leachate from a surface or subsurface soil PCLE zone must not result in COC concentrations in groundwater at the POE of the PMZ in excess of the groundwater PCL.

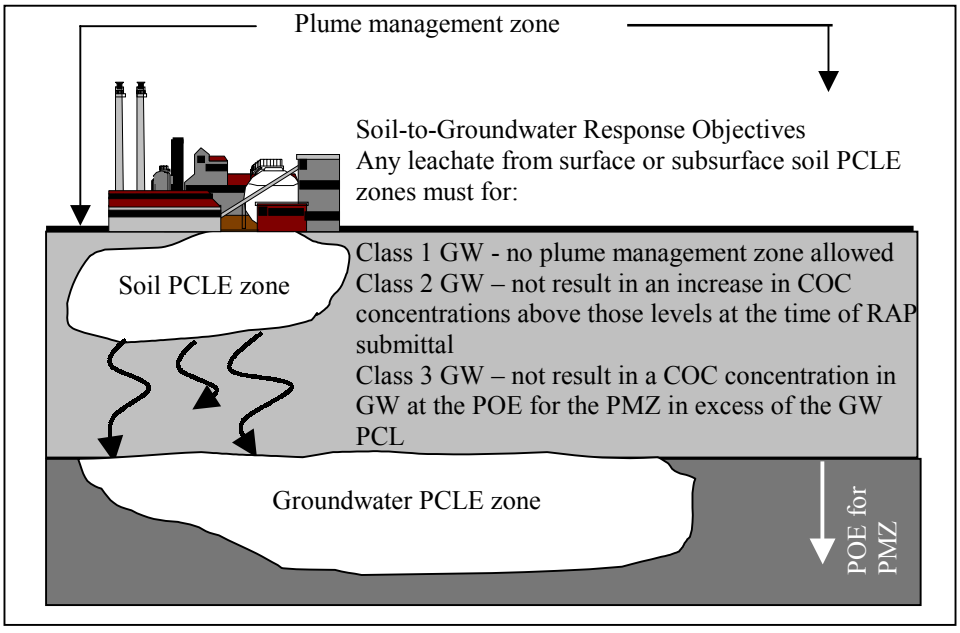

Figure 14. Soil-to-groundwater response objectives for circumstance when a PMZ has been approved for Class 2 or 3 groundwater.