Texas Natural Resource Conservation Commission

INTEROFFICE MEMORANDUM

To: PST Corrective Action Coordinators **Date:** March 6, 1997

From: Chet Clarke, Director of Programs
Petroleum Storage Tank Division

Subject: Clarifications and Amendments for Implementation of RG-36

The following clarifications should be exercised in the implementation of the guidelines in *Risk-Based Corrective Action for Leaking Storage Tank Sites* (RG-36) to facilitate Plan B evaluations.

1. <u>When to Conduct a Plan B Evaluation:</u>

New exit criteria have been established for post-Plan A, pre-Plan B evaluations (see February 10, 1997 TNRCC IOM - *Process for Closure Evaluation for Petroleum Hydrocarbon LPST Sites Exceeding Target Concentrations*). Plan B evaluation of a site should only be conducted after an evaluation of the site under the exit criteria. The exit criteria will close individual exposure pathways for LPST cases that either 1) do not exceed Plan A target concentrations, or 2) can be qualitatively determined to have no likely potential for current or future exposure. Case closure should be requested using a *Site Closure Request* form (TNRCC-0028) for LPST cases where all individual exposure pathways can be closed under the exit criteria. When specific exposure pathways cannot be eliminated under the exit criteria, then a Plan B evaluation of those exposure pathways may be warranted. Plan B should only be used to evaluate complete or potentially complete exposure pathways. This is a change from past practice. However, please note that some pathways closed under the exit criteria because concentrations did not exceed Plan A concentrations may have to be carried into the Plan B evaluation to address the additive effect from exposure through multiple pathways.

For example, upon analysis under the exit criteria it is determined that site soils are contaminated but the concentrations do not exceed limits protective for construction worker exposure. However, the groundwater concentrations are in excess of limits protective for construction worker exposure at the groundwater point of exposure (see Table 4 of this document for construction worker target concentrations). If there is soil contamination present at the same location as the groundwater point of exposure, then under Plan B the combined exposure to soils and groundwater should be evaluated.

2. <u>Relevant Exposure Pathways:</u>

When exposure pathways cannot be eliminated under the exit criteria, then a Plan B evaluation of the site may be warranted. Exposure pathways relevant to the source media and receptor types for Plan B are listed in Table 1. Mandatory exposure pathways are denoted with an "x" in the applicable column for the different receptors. Mandatory indicates that for the particular source media and receptor type, those exposure pathways must be considered. For example, if the human health exposure pathway for soils could not be eliminated under the exit criteria, then under Plan B the human health exposure pathway for soils must be evaluated as prescribed in Table 1. The term “mandatory” does not mean that those pathways must be evaluated under Plan B even though they have been eliminated under the exit criteria. Contingent exposure pathways are indicated with a “c” in the applicable column for the different receptors. Contingent exposure pathways must be considered when they are applicable for the site in question.

In Table 1, the terms “on-source” and “off-source” are used. On-source indicates that exposure occurs at the source area and no lateral contaminant transport via air dispersal or groundwater transport is involved. An example of an on-source exposure pathway is the ingestion of soil. Off-source indicates that the point of exposure can be at a location remote from the source area as a result of lateral contaminant transport processes. An example of an off-source exposure pathway is the air transport of emissions away from the source area to receptors located beyond the limits of the source area. These terms are significant when developing the conceptual exposure model for a site and in the selection of reasonable points of exposure. For various exposure pathways, exposures can occur at on-source or off-source locations, either of which can be located on-site or off-site. Ensure that when evaluating target concentrations for the various exposure pathways, the on-source and off-source aspects are addressed. In general, when the on-site, on-source land use is assumed to be residential, then off-site or off-source exposures will not need to be evaluated for that same exposure pathway. The reason for this is that the target concentrations protective for on-site, on-source residential exposures should be protective for associated off-site or off-source residential or commercial/industrial exposures. However, when the on-site, on-source land use is commercial/industrial, then associated off-source and/or off-site exposures need to be evaluated to ensure residents are protected.

<u>Groundwater Exposure Pathways</u>:

Target groundwater concentrations established to be protective of impacts to wells which supply drinking water or other domestic use should typically be based on the ingestion pathway. We will no longer require the evaluation of the shower inhalation exposure pathway or dermal contact with groundwater by resident or commercial/industrial workers as mandatory actions.

Require evaluation of construction worker exposure to groundwater (e.g., inhalation of groundwater volatiles and dermal exposure to groundwater) only when the groundwater is less than 15 feet, or within the depths of typical subsurface construction depths for an area, and when that exposure pathway cannot be ruled out qualitatively. For example, when the groundwater contaminants intercept subsurface utilities or other probable areas of current or future construction, then exposure may be considered feasible. When the groundwater is less than 15 feet in depth and affecting off-site Rights-of-Way, then contact with groundwater contaminants may be particularly feasible during the installation or maintenance of utilities. Default exposure factors are provided below in item 5 for construction worker exposures.

For Category IV groundwaters greater than 15 feet deep, consider the real probability that anyone will use the groundwater to be remote unless the receptor survey turns up actual demonstrated beneficial use. Focus primarily on the potential for that groundwater to discharge to a higher category groundwater, surface water, or create some other hazard such as volatilization of contaminants into buildings.

The Customized Texas RBCA software contains a model for the evaluation of volatile emissions from groundwater to indoor air. Input values for the building parameters will default into the evaluation unless site-specific values are used. Discretion should be used in decision making regarding target concentrations based on the default assumptions for this pathway as the default building parameter assumptions are likely overconservative for many buildings. As such, the target groundwater concentrations derived to be protective of this pathway may in many instances be the driver for the site unnecessarily. When qualitatively this is a pathway of concern and the target concentrations for this pathway are exceeded, field verification of vapor concentrations may be the logical next step. This pathway may be more appropriate for evaluation when there is a history of reported vapors, or when high concentrations are in close proximity to building foundations and there is reason to be believe that the foundation is sufficiently impermeable to prevent permeation of vapors through the foundation.

3. Selecting Reasonable Points of Exposure for Plan B Evaluations:

Soils: For human exposure to soils, the default closest location for a point of exposure (POE) should be considered on-site, at the source area. When on-source exposure pathways exist off-site (e.g., the release has contaminated off-site soils at depths of $\leq$ 15 feet such that off-site receptors could directly contact the contamination), ensure a POE is set at that closest property line to ensure that concentrations are protective for that off-site land use. When target concentrations for on-site exposures are based on a commercial/industrial land use assumption, POEs will also be needed at the closest residential property line (selected in the appropriate direction for the given pathway) to ensure any relevant off-source exposure pathways are protective for residents.

When engineering barriers such as impermeable surfaces are used as part of the remedial solution to prevent exposure to contaminated soils, then POEs should be set at the limit of the engineering barrier to ensure concentrations are protective beyond the limits of the barrier for the relevant land use.

For the evaluation of construction worker exposure, subsurface utility areas are minimum default POEs. Other areas where subsurface construction activities are planned or are likely to occur should also be evaluated.

Groundwater: The judgement of where to place a groundwater POE is very dependent on the exposure pathway of concern. At certain sites, ingestion of the groundwater may be of concern, at other sites incidental contact with the groundwater during construction activities may be of concern. Groundwater POEs are discussed in the context of different exposure pathways.

Groundwater Ingestion: Siting POEs in the context of groundwater ingestion is very dependent on the results of the water well survey (Are supply wells routinely installed in the area?), the nature of the affected groundwater zone (Is the affected groundwater a known local/regional water supply?), and land use. When the on-site land use is commercial/industrial, water is supplied to the site by a municipal supply (not an on-site water well), and there is not a history of commercial/industrial use of the groundwater, then a reasonable POE may be the closest downgradient residential property line. However, at sites where the impact has affected a known local/regional water supply based on either the water well survey results or the fact that a state-designated major or minor aquifer has been affected, then the POE may be best assumed at the downgradient on-site property line unless institutional controls will be emplaced out to the recommended POE to provide notice of the presence of contamination or restrict water use. In some instances it may be sensible to consider allowing the POE to be set across a roadway when the downgradient property line is adjacent to a roadway.

Incidental Contact with Groundwater During Construction: Subsurface utility areas, such as along Rights-of-Way are minimum POEs that should be considered. Other areas where subsurface construction activities are planned or are likely to occur such as along on-site subsurface utility runs should also be evaluated as possible locations for POEs when those utility areas require routine maintenance.

Inhalation of Volatile Emissions from Groundwater: When the concern is volatilization to outdoor air, then a POE at the source is probably the minimum requirement. When the on-site land use is commercial/industrial, then an additional POE may be needed at the closest residential property line to ensure protection for residents. When the concern is volatilization to indoor air, then the most appropriate location for the POE likely coincides with the foot print of the building in question.

Groundwater Discharge to Surface Water: As stated in RG-36, the POE for groundwater discharge to surface water should be set at a point upgradient of the surface water body. The standard should be met before the point of discharge to surface water. Surface water dilution should not be considered.

It is the responsibility of the responsible party and the Corrective Action Specialists to ensure that an adequate receptor survey has been conducted. Refer to *Guidance for Risk-Based Assessments in Texas* (RG-175) for criteria for acceptable receptor surveys. Also refer to the February 10, 1996 TNRCC IOM entitled *Guidance for Judging the Adequacy of Contaminant Delineation for Purposes of Determining if Further Corrective Action is Needed* for criteria to determine if the contaminant release has been adequately defined to evaluate threats to receptors. An inadequate release investigation compromises the ability to evaluate the appropriateness of proposed POE locations.

4. Point of Applicability for Risk Levels and Exposure Factors In Calculating Plan B Target Concentrations for Groundwater Pathways

Plan B provides the flexibility to set POEs at locations other than at the source area for the groundwater exposure pathways. Plan B also draws a distinction between current/actual and future potential exposures when selecting the applicable exposure factors (Reasonable Maximum Exposure (RME) and Most Likely Exposure (MLE)), and applicable risk levels for calculating target concentrations for the groundwater exposure pathways. Now that the new exit criteria allows qualitative elimination of incomplete exposure pathways, only complete or potentially complete groundwater pathways should be evaluated under Plan B. Therefore, assume actual or current exposure at the POE. If the POE is located away from the source area, then future potential exposure should be assumed for the area located between the source area and the POE. Health-based concentrations must be met at the POE. The health-based concentration for each carcinogen is to be based on a 10^{-6} risk level for Class A and B carcinogens, and a 10^{-5} risk level for Class C carcinogens. For noncarcinogens, the health-based concentrations are to be based on a hazard quotient of 1. Additionally, when multiple carcinogens or noncarcinogens are present at the POE, the cumulative risk and hazard index at the POE should not exceed 10^{-4} and 1 respectively. Note that for carcinogens it is highly unlikely that the cumulative risk level will be exceeded when the 10^{-6} risk level is met for each constituent. The Reasonable Maximum Exposure (RME) exposure factors for the particular land use are to be used for determining the health-based target concentrations to be met at the POE. For groundwater ingestion concerns, the health-based groundwater concentrations are the federal maximum contaminant levels (MCLs) if available for the particular chemicals of concern. Do not consider the risk level or hazard quotient associated with MCLs in determining the individual or cumulative risk. The performance criteria for chemicals of concern which have MCLs is that the MCLs are not to be exceeded at the groundwater ingestion POE. Do not require a target concentration for a chemical which is less than the MCL for that chemical.

Target concentrations must be set at the source area to be protective of the POE. In addition, between the POE and the source area, target concentrations should be based on a risk level and hazard quotient not to exceed 10^{-4} and 1 respectively. When multiple carcinogens and noncarcinogens are present, then the cumulative risk level and hazard index should not exceed 10^{-4} and 1 respectively. Most Likely Exposure (MLE) exposure factors may be assumed for residential land use. No MLE exposure assumptions have been adopted for commercial/industrial or construction worker exposures (some are included in the Customized Texas RBCA software and User's Manual, but these have not been adopted). Target concentrations for groundwater should not be required to fall below the MCL as a result of the cumulative evaluation.

Figure 1 illustrates how the risk levels and exposure factors are to be applied when groundwater POEs are located away from the source area. In Figure 1, current/actual exposure is assumed at the POE and future potential exposure is assumed between the source area and the POE (illustrated by the future potential POE located at the source). Note that the exposure factors must be consistent with the land use at the POE and the land uses between the source area and the POE.

5. <u>Default Construction Worker Exposure Factors</u>

Assume the following as an acceptable default exposure scenario for construction workers:

Averaging Time:	70 yr (carcinogen)
	0.24 yr (noncarcinogen) - soil
	0.06 yr (noncarcinogen) - groundwater
Body Weight:	70 Kg
Exposure Duration:	12 weeks - soil
	3 weeks - groundwater
Exposure Frequency:	5 events/week - soil
	5 days/week - groundwater
Inhalation Rate:	20 m^3/day
Soil Ingestion Rate:	480 mg/day
Soil -to-Skin Adherence Factor	0.12 mg/cm^2 -event

Skin Surface Area:	3300 cm^2 - soil
	6170 cm^2 - groundwater
Event Frequency:	2 events/day - groundwater exposure
t_{event}:	2 hrs/event

When evaluating construction worker exposure to soils, combine the dermal contact, soil ingestion, and inhalation of volatiles and particulates exposure pathways for the construction worker. When evaluating construction worker exposure to groundwater, consider both dermal contact with, and inhalation of, volatiles from the groundwater. When the construction worker is exposed to both the soil and the groundwater pathways, the target concentrations should be based on cumulative risk from the soil and groundwater pathways. The inhalation exposure pathways need to only be considered for those chemicals with a Henry's Law constant greater than 10^{-5} atm-m^3/mole and a molecular weight of less than 200 grams/mole.

When evaluating a source for inhalation exposure during construction, assume a surface area for the floor of the excavation of 240 ft^2 (22.3 m^2) and a width of 15.5 ft (4.7 m). The surface area of the four excavation walls must also be assumed when evaluating volatile emissions from soils. If all four walls are contaminated from ground surface to 15 feet in depth, then the additional surface area is 930 ft^2 (86.4 m^2) (Total surface area is 1170 ft^2 (108.7 m^2)). When the site-specific information indicates that the actual surface area would exceed these assumptions, then the target concentrations should be based on the actual surface areas.

For the evaluation of exposure due to volatilization from groundwater which is seeping into the floor of the excavation, note that this is really a surface water-to-air exposure pathway, and not groundwater volatilization through a vadose zone as addressed in the Customized Texas RBCA software. For this surface water-to-air exposure pathway, use the equations presented in Tables 2 and 3 as appropriate for carcinogens and noncarcinogens and assume a source dimension equivalent to the surface area of the excavation floor. The equations use an overall mass transfer coefficient K (m/s) to transfer the chemical from the water to the air. The overall mass transfer coefficient is derived from the methodology employed in the US EPA document *Air Emissions Models for Waste and Wastewater,* Chapter 5, pages 5-1 thru 5-16, for quiescent impoundments. A default wind speed of 0.225 m/s was assumed for the model, which represents 10% of the 2.25 m/s wind speed for the mixing zone as assumed in RG-36 for purposes of the VF and PEF calculations. The RG-36 wind speed was reduced by 90% to account for the reduced wind speed in the excavation. This same windspeed was used to set the target soil concentrations presented in Table 4. A water depth was assumed as 1 m, based on a construction depth of 15 feet and an average groundwater depth of 12 feet for LPST sites. An area of 22.3 m^2 was assumed. The values for diffusivity of ether in water, viscosity of air, and density of air were as assumed in the US EPA document. Chemical properties were as provided in RG-36. Please note that the specific equation used for these calculations is valid for wind speeds less than 3.25 m/s. For greater wind speeds, other equations must be used as explained in the US EPA document on page 5-14.

Precalculated overall mass transfer coefficients (K) are provided in Table 4 for the volatile compounds listed in RG-36. Also provided in Table 4 is the surface water-to-air target groundwater concentrations, the dermal contact target groundwater concentrations, and the target groundwater concentrations for combined dermal and inhalation exposure for construction workers as well as the target soil concentrations.

Reference-

US EPA, 1994. *Air Emissions Models for Waste and Wastewater*. EPA-453/R-94-080A, Office of Air Quality Planning and Assessments.

This document can be obtained from the US EPA bulletin board system. The document is on the Chief BBS under Emission Est Software/Water&Chemdata/ereport1.zip &ereport2.zip. EPA Internet access : Telnet: ttnbbs.rtpnc.epa.gov
ftp: ttnftp.rtpnc.epa.gov
http://ttnwww.rtpnc.epa.gov

When evaluating construction worker exposure, a "representative concentration" can be used in lieu of the maximum concentration for the volatilization source term when adequate site data is available to support a statistical evaluation. This will provide some balance for the use of toxicity factors based on chronic exposure assumptions for a subchronic exposure scenario.

6. Equations for Dermal Contact with Soil and Groundwater

Tables 5 through 8 provide the dermal exposure equations for soil and groundwater and the default input parameters. Chemical-specific values for the inputs for the dermal equations and calculated target concentrations for soil and groundwater are provided in Table 9. Also please note that for volatile compounds (compounds with vapor pressures greater than or equal to 1 mm Hg), the ABS_d value is set to zero. An ABS_d of zero is based on the tendency of the volatile compounds in soil to volatilize rather than sorb through the skin. **Please note that the current version of the Customized Texas RBCA software does not include the term Event Frequency (EV) in the groundwater dermal contact equation. Instead, Screen 4.2 requires the user to provide an input value for *Groundwater Dermal Exposure Time (hr/day)*. The Screen 4.2 input is actually used in the software as the t_{event}. Input into Screen 4.2 the t_{event} value (2). The protective concentration for dermal contact with groundwater calculated by the software (RBSL value) should then be divided by the EV value (2).**

7. Adjustment of Oral Toxicity Data to Assess Dermal Exposures

Page 30 of RG-36 mentions the fact that it is not appropriate to use unadjusted oral toxicity values when evaluating dermal exposure. TNRCC toxicologists recommend the adjustments should be made as follows.

For carcinogens:

$$SF_d = SF_o/ABS_{GI}$$

For noncarcinogens:

$$RfD_d = (RfD_o)(ABS_{GI})$$

Where:

SF_d = Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$
SF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$
ABS_{GI} = Gastrointestinal Absorption Fraction (unitless)
RfD_d = Dermal reference dose (mg/kg-day)
RfD_o = Oral reference dose (mg/kg-day)

Adjustment of the oral toxicity value is significant only when the ABS_{GI} is < 50%. Use the ABS_{GI} data presented in Bast and Borges (1996) when making the adjustment. The ABS_{GI} for chemicals listed in RG-36 are provided in Table 9.

Bast, C.B., Borges, H.T., 1996. Derivation of Toxicity Values for Dermal Exposure. *The Toxicologist* 30(2):152.

8. <u>Toxicity Values:</u>

For the inhalation pathways, use the RfDi values as listed below in lieu of the RfC values contained within RG-36. RfDi values **and not RfC** values should be used in the equations listed in RG-36. Note that these revised target concentrations are so large that this error should not have affected any case management decisions for these chemicals.

Constituent	RfDi (mg/kg-day)	Revised Target Soil Concentration Ingestion + Inhalation (mg/kg)	
		Residential	Com/Ind
Dichloro(1,2)benzene	5.71e-02	6.60e+03	6.51e+04
Ethylbenzene	2.86e-01	7.56e+03	1.04e+05
Methyl Ethyl Ketone	2.86e-01	3.78e+04	1.61e+05
Toluene	1.14e-01	1.15e+04	3.82e+04
Xylene	2.00e-01	4.81E+04	6.56E+04

Please note that Appendices VI and VII of the December 16, 1996 Texas Risk Reduction Program Concept Document contain extensive toxicity and chemical properties information that can be used for evaluations of chemicals not addressed in RG-36. Please note however that RfC values are listed and not RfDi values.

9. <u>Use of the Plan A Soil-to-Groundwater Concentrations:</u>

The Plan A soil-to-groundwater protective concentrations should not be used as the driving criteria for needing additional corrective action when groundwater sampling data indicates that the target groundwater concentrations are met, and there is no reason to expect that the groundwater concentrations should get worse (e.g., old release, no continuing source, or groundwater monitoring data shows stable or declining concentrations). The Plan A soil-to-groundwater protective concentrations are more appropriate as an initial *screen* when groundwater has not been impacted.

Additionally, other more sophisticated models than the simple equilibrium partitioning approach used in RG-36 may yield more realistic target concentrations for this soil-to-groundwater pathway.

10. Land Use Evaluations

Target concentrations for residential and commercial/industrial land use are addressed in RG-36. The definitions for residential and commercial/industrial land use are presented in 30 TAC 334, Subchapter G, 334.202. Base the use of the affected property (on-site and off-site) on the current land use. Rights-of-way along roads and streets should be considered commercial/industrial. The future use of land should be considered the same as the current unless a planned change in future land use is already known. It is the responsibility of the responsible party and Corrective Action Specialist to ensure land use is accurately represented and that land use changes planned at the time of the risk evaluation have been identified. Vacant land should be considered residential unless the site is clearly located in a commercial/industrial area, or there are documented plans to use the property for commercial/industrial use as defined in 30 TAC 334, Subchapter G, 334.202.

11. Use of Fate and Transport Models for Groundwater Plume Evaluations:

Contaminant fate and transport models should only be used when necessary. Contaminant fate and transport model evaluations are not needed to estimate exposure point concentrations for the direct contact groundwater pathways when there is adequate site groundwater monitoring data to document that the contaminant plume is steady state or declining, and the POE is not affected by concentrations which exceed health-protective limits. If the plume is steady state or declining, then there is potential for exposure only if there is a current or likely future POE within the limits of the contaminant plume. Points of exposure beyond the limits of steady state or declining plumes generally should not be considered as potential receptors.

Modeling of direct contact groundwater pathways may be of greater value early in the process to determine if receptors are likely within or beyond the extent of contamination to aid in the determination of the adequacy of plume delineation. Modeling of groundwater may also be of merit when the stability of the contaminant plume is uncertain, and an evaluation is needed to estimate an exposure point concentration that can be later verified through a monitoring program. Please note that the lateral transport models contained within the Customized Texas RBCA software are simple steady state models, and as such are not suitable for all scenarios. Other lateral transport models may be more appropriate. All modeling conclusions should be substantiated through monitoring data which may or may not already be available. When modeling outputs and monitoring data conflict, decisions should be based on the monitoring data.

Figure 1. Setting Risk Levels and Exposure Factors

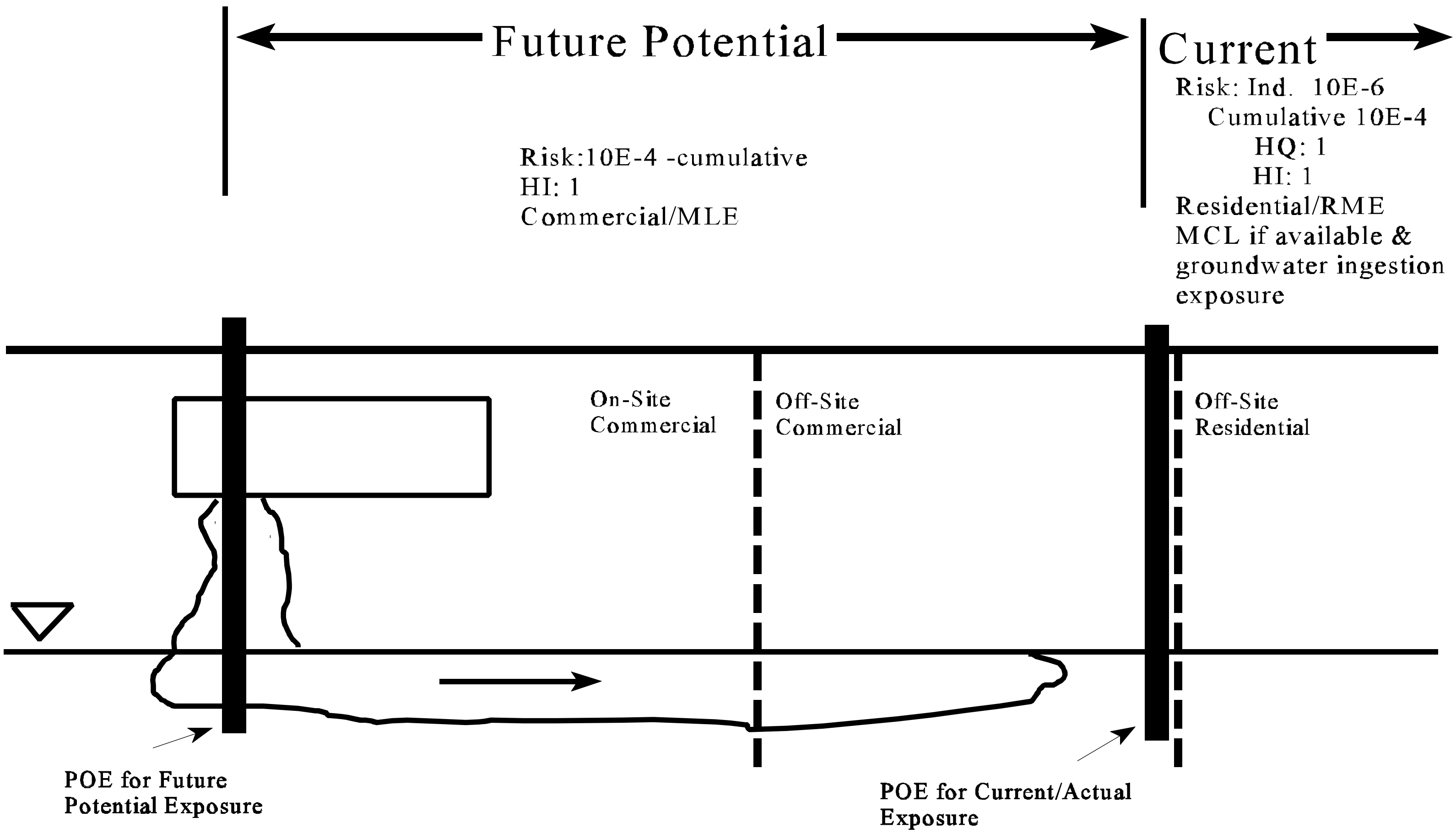

Table 1. Mandatory and Contingent Exposure Pathways

Source Medium and Exposure Pathway	Receptors				
	Residential		Worker		Construction Worker
	On-Source	Off-Source	On- Source	Off-Source	
Groundwater					
Ingestion	x	x	x	x	
Inhalation +Dermal Contact					x
Inhalation of Outdoor Air	c	c	c	c	
Inhalation of Volatiles Indoors	c		c		
Soils					
Ingestion + Inhalation[1] + Dermal Contact (0-15 feet)[2]	x		x		x
Inhalation of Outdoor Air (0-15 feet)[2]		x		x	
Inhalation of Volatiles Indoors	c		c		
Inhalation from Subsurface Soils (>15 feet)[2]	c	c	c	c	c
Surface Water[3]					
Ingestion	x	x	x	x	

1 Inhalation of volatiles and particulates. All others marked "inhalation" refer to inhalation of volatile emissions only.
2 Soils depth.
3 State Surface Water Regulations are the primary basis for setting the target concentration for surface waters. The target concentrations set forth in the regulations are to be used if available for the particular chemical and water body.
4 Combine the risk across exposure pathways within the same media and/or across media as appropriate to account for each exposure pathway acting on a single receptor.

Table 2. Equation for Evaluation of Protective Groundwater Concentration for Construction Worker Inhalation of Volatile Emissions from Groundwater Discharging to a Construction Excavation

$$C\ (mg/L) = \frac{TR \times BW \times AT \times 365\ days/yr}{SF_i \times IR_a \times K \times 1000\ L/m^3 \times EF \times ED} \times \frac{W \times \mu_{air} \times \delta_{air}}{A}$$

Parameter	Definition (units)	Default
TR	Target Cancer Risk (unitless)	For POE: 10^{-6} for Class A and B Carcinogens 10^{-5} for Class C Carcinogens
BW	Body Weight (kg)	70
AT	Averaging Time (yr)	70
SF_i	Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	chemical-specific
IR_a	Inhalation Rate (m^3/day)	20
K	Overall Mass Transfer Coefficient (m/s)	chemical-specific
EF	Exposure Frequency (days/wk)	5
ED	Exposure Duration (weeks)	3
W	Width of Contaminated Area (m)	4.7
μ_{air}	Wind velocity in excavation (m/s)	0.225
δ_{air}	Air mixing zone height (m)	2
A	Area of excavation floor (m^2)	22.3

Table 3. Equation for Evaluation of Protective Groundwater Concentration for Construction Worker Inhalation of Noncarcinogens from Groundwater Discharging to a Construction Excavation

$$C\ (mg/l) = \frac{HQ \times BW \times RfD_i \times AT \times 365\ days/yr}{IR_a \times K \times 1000\ L/m^3 \times EF \times ED} \times \frac{W \times \mu_{air} \times \delta_{air}}{A}$$

Parameter	Definition (units)	Default
HQ	Hazard Quotient (unitless)	1
BW	Body Weight (kg)	70
RfD_i	Inhalation Reference Dose (mg/kg-day)	chemical-specific
AT	Averaging Time (yr)	0.06
IR_a	Inhalation Rate (m^3/day)	20
K	Overall Mass Transfer Coefficient(m/s)	chemical-specific
EF	Exposure Frequency (days/wk)	5
ED	Exposure Duration (weeks)	3
W	Width of Contaminated Area (m)	4.7
μ_{air}	Wind velocity in excavation (m/s)	0.225
δ_{air}	Air mixing zone height (m)	2
A	Area of excavation floor (m^2)	22.3

Table 4. Target Concentrations for Construction Worker Exposure

Constituent	Target Soil Concentrations for combined Inhalation, Ingestion, and Dermal Contact Exposure (mg/kg)	Target Groundwater Concentrations				
		K (m/s)	Inhalation (mg/l)	Dermal (mg/l)	Combined Inhalation and Dermal (mg/l)	Target Concentration for T, E, and X**
Acenapthene	1.01e+04	1.32e-06	2.20e+01	2.33e-01	**2.31e-01**	
Acetone	2.13e+04	6.92e-07	7.00e+01	6.02e+02	**6.27e+01**	
Anthracene	5.90e+04	2.39e-06	6.09e+01	3.24e+00*	**3.08e+00***	
Benzene	1.20e+01	3.25e-06	5.98e+00	8.01e+00	**3.42e+00**	
Benzo(a)anthracene	6.27e+01	Not Volatile	-----	1.00e-03	**1.00e-03**	
Benzo(b)fluoranthene	6.15e+01	1.60e-07	5.81e+00*	5.05e-04	**5.05e-04**	
Benzo(k)fluoranthene	6.02e+02	1.20e-09	7.72E+03*	5.05e-03*	**5.05e-03***	
Benzo(a)pyrene	6.30e+00	Not Volatile	-----	5.05e-05	**5.05e-05**	
Chrysene	6.23e+03	Not Volatile	-----	1.00e-01*	**1.00e-01***	
Dibenz(a,h)anthracene	6.32e+00	Not Volatile	-----	2.32e-05	**2.32e-05**	
Dichloro(1,2)benzene	6.62e+02	2.53e-06	1.09e+01	4.44e+00	**3.16e+00**	
Dichloro(1,3)benzene	1.89e+04	2.63e-06	1.64e+01	4.39e+00	**3.46e+00**	
Dichloro(1,4)benzene	2.59e+04	2.57e-06	9.16e+01*	2.40e+01	**1.90e+01**	
Ethylbenzene	1.35e+03	2.59e-06	5.35e+01	4.97e+00	**4.55e+00**	1.52e+00
Fluoranthene	6.73e+03	Not Volatile	-----	6.07e-02	**6.07e-02**	
Flourene	7.87e+03	1.09e-06	1.78e+01*	6.81e-01	**6.56e-01**	
Formaldehyde	4.26e+04	Not Volatile	-----	3.30e+02	**3.30e+02**	
Indeno(1,2,3-cd)pyrene	6.32e+01	Not Volatile	-----	2.30e-04	**2.30e-04**	
Methyl Ethyl Ketone	1.24e+03	7.77e-07	1.78e+02	1.90e+03	**1.63e+02**	
Naphthalene	7.87e+03	2.39e-06	8.12e+00	1.92e+00	**1.55e+00**	

Constituent	Target Soil Concentrations for combined Inhalation, Ingestion, and Dermal Contact Exposure (mg/kg)	Target Groundwater Concentrations				
		K (m/s)	Inhalation (mg/l)	Dermal (mg/l)	Combined Inhalation and Dermal (mg/l)	Target Concentration for T, E, and X**
Pyrene	5.04e+03	Not Volatile	-----	4.55e-02	**4.55e-02**	
Toluene	2.76e+02	2.77e-06	2.00e+01	1.91e+01	**9.76e+00**	3.25e+00
Xylene	4.33e+02	2.75e-06	3.53e+01	9.09e+01	**2.54e+01**	8.47e+00

* Denotes target concentration exceeds pure component solubility limit.
** Target concentrations for ethylbenzene, toluene and xylene to equate to a Hazard Index of 1, assuming a Hazard Quotient of 0.33 for each. The Hazard Quotients can be partitioned in a different manner so long as the Hazard Index does not exceed 1.
Please note that for some compounds the target concentrations may be below analytical detection limits, and are therefore not measureable for purposes of demonstrating conformance with the target concentrations. In these situations, the method PQL will suffice.

TABLE 5. EQUATION FOR DERMAL CONTACT WITH CARCINOGENIC CHEMICALS OF CONCERN IN GROUNDWATER[1]

C_c (mg/L) =	$$\frac{TR \times BW \times AT \times 365\ days/yr \times 1000\ cm^3/L}{SF_d \times EF \times EV \times ED \times SA \times Z}$$
$Z_{inorganics}$ (cm/event) =	$Kp \times t_{event}$
$Z_{organics}$ (cm/event) =	$$If\ t_{event} < t^*,\ then\ 2\ K_p \sqrt{6\tau \frac{t_{event}}{\pi}}$$ $$If\ t_{event} > t^*,\ then\ K_p\ [\frac{t_{event}}{1+B} + 2\tau(\frac{1+3B}{1+B})]$$

Parameter	Definition (units)	Default[2]
TR	Target Cancer Risk (unitless)	For POE: 10^{-6} for Class A and B Carcinogens 10^{-5} for Class C Carcinogens
BW	Body Weight	70
AT	Averaging Time (yr)	70
SF_d	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	chemical-specific
EF	Exposure Frequency (days/wk)	5
EV[3]	Event Frequency - (events/day)	2
ED	Exposure Duration (weeks)	3
SA	Skin Surface Area (cm^2) - 50th percentile (hands+forearm+feet+lower legs)	6,170
Z	Dermal Factor (cm/event) - Organic Inorganic	chemical-specific chemical-specific
Kp	Dermal Permeability Coefficient (cm/hr)	chemical-specific
t_{event}[3]	Duration of Event (hr/event)	2
t^*	(hr)	chemical-specific
τ	lag time (hr/event)	chemical-specific
B	Relative Contribution of Permeability Coefficient (unitless)	chemical-specific

1 Equation modified from EPA, 1992
2 Default parameter values are the same for all receptor scenarios
3 Please note that the current version of the Customized Texas RBCA software does not include the term Event Frequency (EV) in the groundwater dermal contact equation. Instead, Screen 4.2 requires the user to provide an input value for *Groundwater Dermal Exposure Time (hr/day).* The Screen 4.2 input is actually used in the software as the t_{event}. Input into Screen 4.2 the t_{event} value (2). The protective concentration for dermal contact with groundwater calculated by the software (RBSL value) should then be divided by the EV value (2)

TABLE 6. EQUATION FOR DERMAL CONTACT WITH NONCARCINOGENIC CHEMICALS OF CONCERN IN GROUNDWATER[1]

$$C_{nc}\ (mg/L) = \frac{THQ \times BW \times RfD_d \times AT \times 365\ days/yr \times 1000\ cm^3/L}{EF \times EV \times ED \times SA \times Z}$$

$$Z_{inorganics}\ (cm/event) = Kp \times t_{event}$$

$$Z_{organics}\ (cm/event) = \text{If } t_{event} < t^*, \text{ then } 2\ K_p \sqrt{6\tau \frac{t_{event}}{\pi}}$$

$$\text{If } t_{event} > t^*, \text{ then } K_p \left[\frac{t_{event}}{1+B} + 2\tau\left(\frac{1+3B}{1+B}\right)\right]$$

Parameter	Definition (units)	Default[2]
HQ	Hazard Quotient (unitless)	1
BW	Body Weight (kg)	70
RfD_d	Dermal Reference Dose (mg/kg-day)	chemical-specific
EF	Exposure Frequency (days/wk)	5
EV[3]	Event Frequency (events/day)	2
AT	Averaging Time (yr)	0.06
ED	Exposure Duration (wk)	3
SA	Skin Surface Area (cm^2) - 50th percentile (hands+forearm+feet+lower legs)	6,170
Z	Dermal Factor (cm/event) Organic Inorganic	chemical-specific chemical-specific
Kp	Dermal Permeability Coefficient (cm/hr)	chemical-specific
t_{event}[3]	Duration of Event (hr/event)	2
t^*	(hr)	chemical-specific
τ	lag time (hr/event)	chemical-specific
B	Relative Contribution of Permeability Coefficient (unitless)	chemical-specific

1 Equation modified from EPA, 1992
2 Default parameter values are the same for all receptor scenarios
3 Please note that the current version of the Customized Texas RBCA software does not include the term Event Frequency (EV) in the groundwater dermal contact equation. Instead, Screen 4.2 requires the user to provide an input value for *Groundwater Dermal Exposure Time (hr/day).* The Screen 4.2 input is actually used in the software as the t_{event}. Input into Screen 4.2 the t_{event} value (2). The protective concentration for dermal contact with groundwater calculated by the software (RBSL value) should then be divided by the EV value (2).

TABLE 7. EQUATION FOR DERMAL CONTACT WITH CARCINOGENIC CHEMICALS OF CONCERN IN SOIL[1,2]

$C_{c\text{-}adj}$ (mg/kg) =	$$\frac{TR \times AT \times 365\ days/yr}{SF_d \times 10^{-6}\ kg/mg \times EF \times DF_{adj} \times ABS_d}$$	
C_c (mg/kg) =	$$\frac{TR \times BW \times AT \times 365\ days/yr}{SF_d \times 10^{-6}\ kg/mg \times EF \times ED \times SA \times AF \times ABS_d}$$	
Parameter	**Definition (units)**	**Default[3]**
TR	Target Cancer Risk (unitless)	For POE: 10^{-6} for Class A and B carcinogens 10^{-5} for Class C carcinogens
BW	Body Weight (kg) Child Worker	 15 70
AT	Averaging Time (yr)	70
SF_d	Dermal Cancer Slope Factor $(mg/kg/day)^{-1}$	chemical-specific
ED	Exposure Duration Child Adult Construction Worker Worker	 6 yr 33 yr 12 weeks 25 yr
EF	Exposure Frequency Resident Construction Worker Worker	 350 events/yr 5 events/wk 250 events/yr
SA	Skin Surface Area (cm^2) - 50th percentile (head+forearms+hands) Child Worker	 2,900 3,300
AF	Soil to Skin Adherence Factor (mg/cm^2-event) Child Workers	 0.2 0.12
ABS_d[4]	Dermal Absorption Fraction (unitless)	chemical-specific
DF_{adj}	Age-Adjusted Dermal Factor (mg-yr/kg-event) (Residential Land Use)	300

[1] Equations modified from EPA, 1989
[2] $C_{c\text{-}adj}$ for the residential land-use scenario and C_c for all worker scenarios
[3] For carcinogens at residential sites, use age-adjusted exposure factors.
[4] The factor ABS_d is the same as RAF_d in the Customized Texas RBCA software when the oral toxicity factor is adjusted for dermal exposure as shown in item 7 of this document.

TABLE 8. EQUATION FOR DERMAL CONTACT WITH NONCARCINOGENIC CHEMICALS OF CONCERN IN SOIL[1,2]

$$C_{nc}\ (mg/kg) = \frac{THQ \times BW \times AT \times 365\ days/yr}{1/RfD_d \times 10^{-6}\ kg/mg \times EF \times ED \times SA \times AF \times ABS_d}$$

Parameter	Definition (units)	Default[3]
HQ	Hazard Quotient (unitless)	1
RfD_d	Dermal Reference Dose (mg/kg/day)	chemical-specific
BW	Body Weight (kg) Child Workers	 15 70
AT	Averaging Time (yr) Child Construction Worker Site Worker	 6 0.24 25
ED	Exposure Duration Child Construction Worker Site Worker	 6 yr 12 weeks 25 yr
EF	Exposure Frequency Child Construction Worker Site Worker	 350 events/yr 5 events/wk 250 events/yr
SA	Skin Surface Area (cm^2) (head+forearms+hand) Child (0-6 years) - 50th percentile Workers	 2,900 3,300
AF	Soil to Skin Adherence Factor (mg/cm^2-event) Child (0-6 years) Workers	 0.2 0.12
ABS_d[4]	Dermal Absorption Fraction (unitless)	chemical-specific

[1] Equation modified from EPA, 1989
[2] Exposure parameters should correspond to a child for the residential scenario and an adult for all worker scenarios
[3] Default parameter values are the same for all receptor scenarios unless indicated otherwise
[4] The factor ABS_d is the same as RAF_d in the Customized Texas RBCA software when the oral toxicity factor is adjusted for dermal exposure as shown in item 7 of this document.

Table 9. Chemical-Specific Input Values for Dermal Equations

Constituent	ABS_d	ABS_{gi}	B	Kp	Sf_d	RfD_d	t	t^*	Z
Acenapthene	1.00e-01	3.10e-01	1.42e+00	1.93e-01	-----	1.86e-02	7.63e-01	4.89e+00	6.61e-01
Acetone	0	1.00e+00	5.82e-05	5.74e-04	-----	1.00e-01	1.98e-01	4.75e-01	1.37e-03
Anthracene	1.00e-01	1.00e+00	2.21e+00	1.90e-01	-----	3.00e-01	1.07e+00	5.82e+00	7.66e-01
Benzene	0	1.00e+00	9.84e-03	1.65e-02	2.90e-02	-----	2.62e-01	6.29e-01	4.16e-02
Benzo(a)anthracene	1.30e-01	3.10e-01	3.32e+01	6.42e-01	2.36e+00	-----	2.16e+00	1.03e+01	3.69e+00
Benzo(b)fluoranthene	1.30e-01	3.10e-01	1.29e+02	1.20e-+00	2.36e+00	-----	3.03e+00	1.43e+01	8.14e+00
Benzo(k)fluoranthene	1.30e-01	3.10e-01	1.29e+02	1.20e+00	2.36e-01	-----	3.03e+00	1.43e+01	8.14e+00
Benzo(a)pyrene	1.30e-01	3.10e-01	1.29e+02	1.20e-+00	2.36e+01	-----	3.03e+00	1.43e+01	8.14e+00
Chrysene	1.30e-01	3.10e-01	3.32e+01	6.42e-01	2.36e-02	-----	2.16e+00	1.03e+01	3.69e+00
Dibenz(a,h)anthracene	1.30e-01	3.10e-01	4.98e+02	2.17e+00	2.36e+01	-----	4.36e+00	2.06 e+01	1.77e+01
Dichloro(1,2)benzene	0	1.00e+00	1.91e-01	5.17e-02	-----	9.00e-02	6.90e-01	2.82e+00	1.68e-01
Dichloro(1,3)benzene	0	1.00e+00	1.91e-01	5.17e-02	-----	8.90e-02	6.90e-01	2.82e+00	1.68e-01
Dichloro(1,4)benzene	0	1.00e+00	1.91e-01	5.17e-02	2.40e-02	-----	6.90e-01	2.82e+00	1.68e-01
Ethylbenzene	0	1.00e+00	1.07e-01	6.09e-02	-----	1.00e-01	3.89e-01	1.01e+00	1.67e-01
Fluoranthene	1.00e-01	3.10e-01	8.57e+00	3.54e-01	-----	1.24e-02	1.50e+00	7.27e+00	1.69e+00
Flourene	1.00e-01	1.00e+00	1.04e+00	1.31e-01	-----	4.00e-02	9.03e-01	7.67e+00	4.86e-01
Formaldehyde	0	1.00e+00	2.24e-04	2.21e-03	-----	2.00e-01	1.33e-01	3.20e-01	5.02e-03
Indeno(1,2,3-cd)pyrene	1.30e-01	3.1e-01	4.98e+02	2.23e+00	2.36e+00	-----	4.24e+00	2.00e+01	1.80e+01
Methyl Ethyl Ketone	0	1.00e+00	1.80e-04	1.05e-03	-----	6.00e-01	2.41e-01	5.78e-01	2.61e-03
Naphthalene	1.00e-01	1.00e+00	1.48e-01	5.60e-02	-----	4.00e-02	5.29e-01	1.81e+00	1.72e-01
Pyrene	1.00e-01	3.10e-01	8.57e+00	3.54e-01	-----	9.30e-03	1.50e+00	7.27e+00	1.69e+00
Toluene	0	1.00e+00	3.47e-02	3.32e-02	-----	2.00e-01	3.19e-01	7.66e-01	8.69e-02
Xylene	0	1.00e+00	1.22e-01	6.68e-02	-----	2.00e+00	3.89e-01	1.14e+00	1.82e-01
Note: ABS_d is the same as RAF_d in the Customized Texas RBCA software if the oral toxicity value has been adjusted for dermal as discussed in item 7 of this document.									