March 2005

RRD OPERATIONAL MEMORANDUM NO. 1

SUBJECT: TECHNICAL SUPPORT DOCUMENT - ATTACHMENT 9
PART 201 GROUNDWATER PROTECTION CRITERIA
PART 213 TIER I RISK-BASED SCREENING LEVELS

Developed under R 299.5722

Key definitions for terms used in this document:

NREPA:	**The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended**
Part 201:	**Part 201, Environmental Remediation, of NREPA**
Part 213:	**Part 213, Leaking Underground Storage Tanks, of NREPA**
MDEQ:	**Michigan Department of Environmental Quality**
RRD:	**Remediation and Redevelopment Division**
Criteria or criterion:	**Includes the cleanup criteria for Part 201 of NREPA and the Risk-Based Screening Levels, as defined in Part 213 of NREPA and R 299.5706a(4)**
Facility:	**Includes "facility" as defined by Part 201 of NREPA and "site" as defined by Part 213 of NREPA**
DWC:	**Drinking water criteria or criterion**
GCC:	**Groundwater contact criteria or criterion**
GSI:	**Groundwater surface water interface criteria or criterion**
GWPC:	**Groundwater protection criteria or criterion**
SWP:	**Soil-water partition**
SWPV:	**Soil-water partition value or values**
TSD:	**Technical Support Document**

This TSD presents the methodology for the development of the generic soil criteria protective of groundwater, or the GWPC. This methodology is used to assess the potential for hazardous substances in soil to leach and impact groundwater at concentrations greater than the applicable generic drinking water, groundwater surface water interface, and groundwater contact criteria. This TSD replaces the Environmental Response Division, Operational Memorandum No. 18, TSD, Part 201 Generic Soil/Water Partitioning Criteria, dated August 23, 1999 and the Storage Tank Division, Operational Memorandum No. 4, Attachment 7, Part 213 Risk-Based Screening Levels for Soil/Water Partitioning, dated April 1999.

To assure that soils do not pose a threat of aquifer contamination, the concentration of a hazardous substance in soil leachate must be below the applicable Part 201 groundwater criterion for that hazardous substance, considering all relevant pathways (R 299.5722(1)). Leach testing is not required to make this demonstration if the total concentration of a hazardous substance in soil does not exceed the generic soil GWPC (R 299.5722(2)). For each soil leaching pathway evaluated, the highest of 20 times (20X) the lowest applicable generic groundwater criterion and the SWPV, if available, becomes the GWPC for a given hazardous substance (R 299.5722(1)). If a SWPV is not available for a hazardous substance, then the 20X value becomes the GWPC. For hazardous substances with soil protection criteria greater than their respective soil saturation (C_{sat}) concentration, the C_{sat} becomes the criterion unless a facility-specific C_{sat} concentration is established using facility-specific soil characteristics (R 299.5718(2)).

The GWPC were developed pursuant to Sections 20120a(1)(a), (b), and (d); 20120a(3) and (9); and Sections 21304a(1) and (2) of NREPA; and R 299.5722. In addition to the Part 201 Administrative Rules (R 299.5746 and R 299.5748), the GWPC are presented in Attachment 1 of Operational Memorandum No. 1: Part 201 Generic Cleanup Criteria/Part 213 Risk-Based Screening Levels. These criteria are presented in columns 11, 12, and 13 of the residential and commercial I soil criteria table and in columns 12, 13, and 21 of the industrial and commercial II, III, and IV soil criteria table. The GWPC represent soil concentrations of contaminants in units of micrograms per kilogram (µg/kg) or parts per billion (ppb), unless otherwise noted.

THE SWP METHODOLOGY

The SWP methodology is based on assumptions related to the fate and transport of contaminants migrating from subsurface soil to groundwater. Generally, the migration of contaminants from soil to groundwater can be broken down into two stages:

1. Contaminant release from soil into the soil pore water and pore air (i.e., contaminant release into soil leachate).

2. Contaminant transport through the soil and groundwater to a receptor point (e.g., a drinking water well).

The United States Environmental Protection Agency (U.S. EPA) Soil Screening Guidance (SSG; U.S. EPA, 1996) provides a generic equation that accounts for both of these processes. The same equations are used in the risk-based corrective action screening methodology applied at petroleum release sites (American Society for Testing and Materials (ASTM), 1995). The SWP methodology is considered suitable for generic statewide application because it utilizes simple conservative assumptions about the release and transport of contaminants in the subsurface and also has the flexibility to allow for facility-specific adjustments if adequate data are available.

The SWP methodology presented in the SSG incorporates a linear equilibrium SWP equation to estimate hazardous substance release from soil into soil leachate by relating the concentration of hazardous substance adsorbed to soil organic carbon (f_{oc}) to the concentration in the soil leachate. As hazardous substances in soil leachate move through soil and groundwater, they are subjected to physical, chemical, and biological processes that can reduce the hazardous substance concentration at the receptor. The SWP methodology addresses only one of these attenuation processes which is contaminant dilution in groundwater. By incorporating a simple water-balance equation, a dilution attenuation factor (DAF) is calculated to account for soil leachate dilution in groundwater. The DAF is expressed as the ratio of the soil leachate concentration to the acceptable groundwater concentration. This DAF is used to calculate the target soil leachate concentration (C_w), which is the product of the applicable groundwater cleanup criterion and the DAF. This concentration is based on the most restrictive of the relevant groundwater exposure pathways that requires protection (i.e., drinking water, groundwater surface water interface, or groundwater contact). For example, if the DWC for a particular hazardous substance is 0.05 mg/L and the DAF is 16, C_w would be 0.80 mg/L. Once established, C_w is used in the SWP equation to determine the hazardous substance concentration in soil protective of the relevant groundwater exposure pathway.

Several parameters within the U.S. EPA SWP equation have been modified by the MDEQ after consultation with soil and groundwater modeling experts within the MDEQ. The water- and air-filled soil porosity default values have been changed to 0.16 L_{water}/L_{air} and 0.09 L_{air}/L_{soil}, respectively, to reflect a percentage of the effective porosity (assumed to be 25%) rather than total porosity. More specifically, 65% of effective porosity is attributed to water-filled porosity and 35% of effective porosity is attributed to air-filled porosity. The basis for this modification is presented in MDEQ 1995 and 1996. The DAF utilized for the SWPV has been changed from 20 to 16 to more accurately reflect conditions at Michigan sites. The chemical-specific dimensionless Henry's Law Constant (H') are multiplied by a temperature adjustment factor (TAF) of one-half (0.5) to account for reduced volatility of a hazardous substance under lower annual average soil temperatures of 10° Celsius in Michigan (Howe *et al*., 1987). Except for mercury, inorganic hazardous substances do not exhibit a significant vapor pressure. As a result, H' is assumed to be 0 when calculating a SWPV for inorganics. The U.S. EPA (1996) provides background information for the remaining parameters and the corresponding assumptions used in the SWP equation.

The SWP methodology was designed for use during the early stages of a site investigation when there may be limited information on soil and aquifer characteristics and the nature of contamination. Therefore, this methodology is based on conservative, simplifying assumptions about the release and transport of hazardous substances. These assumptions are implicit to the application of the SWP methodology. The assumptions are listed below (U.S. EPA, 1996).

1. The source is infinite (i.e., steady state concentrations will be maintained in groundwater over the exposure period of interest).

2. Contaminants (hazardous substances) are uniformly distributed throughout the zone of contamination.

3. Soil contamination extends from the ground surface to the water table (i.e., adsorption sites are filled in the unsaturated zone beneath the area of contamination).

4. There is no chemical or biological degradation in the unsaturated zone.

5. Equilibrium SWP is instantaneous and linear in the contaminated soil.

6. The receptor well (or GSI, or excavation) is at the edge of the source (i.e., there is no dilution from recharge downgradient of the site) and is screened within the plume (or intersects the plume).

7. The aquifer is unconsolidated and unconfined (surficial).
8. Aquifer properties are homogenous and isotropic.

9. There is no attenuation (i.e., adsorption or degradation) of contaminants (hazardous substances) in the aquifer.

10. Nonaqueous phase liquids are not present at the site.

The SWP Equation

The SWP equation is presented below. The SWP equation is the same for organic and inorganic hazardous substances. However, the soil-water distribution coefficient (K_d) values for organics and inorganics are derived differently. The K_d for organic compounds is largely influenced by the soil organic carbon. Unlike organic compounds, K_d values for metals (inorganics) are affected by a variety of soil conditions with the most significant being pH, oxidation-reduction conditions, iron oxide content, soil organic matter content, cation exchange capacity, and major ion chemistry (U.S. EPA, 1996).

There is a wide range of K_d values for metals reported in the literature. With the exception of lead and copper, the K_d values for metals were obtained from the SSG (U.S. EPA, 1996). The K_d values for lead and copper were not provided in the SSG and were developed by the MDEQ under contract with Research Triangle Institute (Truesdale, 1999).

The SWP equation follows:

$$SWPV = C_w\left[K_d + \left(\frac{\theta_w + \left(H' \times TAF \times \theta_a\right)}{\rho_b}\right)\right]$$

where,

SWPV	Soil-water partitioning value	= µg/kg (ppb), chemical-specific
C_w	Target soil leachate concentration; applicable Part 201 groundwater criterion x 16 (i.e., DAF)	= µg/L (ppb)
K_d	For inorganics: Soil-water distribution coefficient for inorganic compounds For organics: $K_d = K_{oc} \times f_{oc}$	= L/kg, chemical-specific
K_{oc}	Soil organic carbon-water partition coefficient for organic compounds	= L/kg, chemical-specific
f_{oc}	Fraction of organic carbon in soil	= 0.002 (i.e., 0.2% for subsurface soil)
θ_w	Soil water-filled porosity	= 0.16 L_{water}/L_{air}
θ_a	Soil air-filled porosity	= 0.09 L_{air}/L_{soil}
H'	Dimensionless Henry's Law Constant, where $H' = HLC \times 41$ where 41 is a conversion factor. (NOTE: For calculation of the SWPV for inorganic hazardous substances, H' equals 0)	= unitless, chemical-specific
HLC	Henry's Law Constant	= atm-m^3/mol, chemical-specific
TAF	Temperature adjustment factor	= 0.5 (H' adjusted to Michigan annual average soil temperature of 10° Celsius)

ρ_b	Dry soil bulk density	= 1.5 kg/L

20X VALUE

Both the 20X and the SWP approaches are used to predict soil leachate concentrations of hazardous substances. The 20X value for soil is derived by multiplying the applicable groundwater criterion (DWC, GSI, or GCC) by 20. Before the SWP methodology was adopted, a 20X approach was used to determine the level of hazardous substance in soil that was protective of groundwater. The multiplier of 20 comes from the dilution factor inherent to the toxicity characteristic leach procedure.

Chemical-specific information necessary to develop the SWPV is not available for all hazardous substances, resulting in the ability to generate only 20X values for some hazardous substances. When both a SWPV and a 20X value are available, the higher of the two becomes the GWPC.

APPLICATION AND IMPLEMENTATION

The GWPC are not calculated for hazardous substances designated with a footnote “NLL” (i.e., “not likely to leach”) in the criteria tables. The generic GWPC are *not* applicable to hazardous substances present in non-soil matrices such as slag, tailings, wood, coal tar, and other solid or semi-solid material. In these instances, a site-specific evaluation such as leach testing is necessary. In addition, the generic GWPC are *not* applicable if the exposure pathway is not a relevant pathway at the facility or if the exposure it addresses (e.g., drinking water ingestion, dermal contact with groundwater, etc.) is reliably restricted by a restrictive covenant, or institutional control, or other mechanism allowed for under Part 201 and the associated Administrative Rules.

Drinking Water Protection Criteria

The migration of contaminants from soil to groundwater **is a relevant pathway** for any facility where groundwater is in an aquifer. This pathway is **also relevant** for groundwater that is not in an aquifer but may transport a hazardous substance into an aquifer at a concentration that exceeds the Part 201 generic residential and commercial I DWC (R 299.5710(1)(b)). The GWPC are not applicable if ingestion of the groundwater is, or will be, reliably restricted (Section 21310a and Sections 20120b(4) and (5) of NREPA; R 299.5710(1)(a) and (2)).

Restrictions on groundwater use for drinking at a facility do not preclude the need to comply with appropriate soil cleanup criteria to assure that groundwater will comply with the residential criteria at the property boundary. This is necessary to assure protection of off-property resource uses (e.g., drinking water, groundwater contact, surface water impacts), unless those off-property uses are also reliably restricted.

The soil criteria protective of commercial II, III, IV, and industrial DWC are applicable to property that is zoned or being used for purposes consistent with these land use categories provided that a notice of approved environmental remediation, notice of corrective action, or restrictive covenant limits the property use to industrial or commercial, as appropriate. It must be documented that the source property is not used for residential purposes or any other non-conforming use that presents greater potential for exposure than assumed in the development of the generic criteria. Both commercial/industrial and residential DWC are presented in the drinking water protection criteria column (column 21) of the industrial and commercial soil criteria table (Table 3) of Operational Memorandum No. 1.

GSI Protection Criteria

The soil leaching pathway for GSI protection (GSIP) **is relevant** for all land uses if an investigation or the application of best professional judgment leads to the conclusion that groundwater is reasonably expected to vent to surface waters in concentrations that exceed the generic GSI criteria (R 299.5716(1)).

If mixing zone criteria have been established for a specific hazardous substance pursuant to R 299.5716(7) and (8), then the SWPV for protection of the GSI can be determined by substituting the mixing zone-based GSI criterion as the applicable Part 201 groundwater criterion when calculating C_w in the SWP equation. The SWPV is then compared to 20X the mixing zone-based GSI criterion and the greater of the two becomes the GSIP criterion. The GSIP criteria calculated directly from generic or mixing zone-based GSI criteria do not need to be met at all points at the facility if a demonstration is made that an alternative soil concentration will not leach hazardous substances to the groundwater at levels that result in an exceedance of the generic or mixing zone-based criteria at the GSI. Predictions of any fate and transport modeling used as part of such a demonstration must be confirmed by field measurements.

For more information on the development and application of the Part 201 generic GSI or mixing zone-based criteria, please refer to MDEQ, 2004.

GCC Protection Criteria

The soil leaching pathway for GCC protection **is relevant** for all land uses unless the depth to groundwater exceeds the depth at which utilities exist or may be constructed or exceeds the depth at which subsurface work is likely to occur (R 299.5712).

Options for Part 201 Facility-Specific Generic Closure/Part 213 Tier II Site-Specific Unrestricted Closure

A party may modify the ρ_b, f_{oc}, and chemical-specific TAF for the Henry's Law Constant to develop a Part 201 facility-specific generic SWPV. A Tier II site-specific unrestricted closure is the Part 213 equivalent of a Part 201 facility-specific generic closure. Because these parameters do not vary significantly over time, options for Part 201 facility-specific generic closures and Part 213 Tier II site-specific unrestricted closures do not require land and resource use restrictions to address criteria modifications.

Refer to RRD Operational Memorandum No. 2 for methodologies to measure ρ_b, moisture content, and f_{oc}.

Additional alternatives that would allow for a facility or site-specific generic closure include:

1. Soil leach testing may be performed to determine site-specific leachate concentrations of hazardous substances for comparison to the applicable groundwater criteria. For further information on the requirements for leach testing and compliance with the GWPC, refer to R 299.5722(1), (2), and (3); and RRD Operational Memorandum No. 2, Attachment 2.

2. Saturated zone fate and transport models may be used to calculate a facility-specific DAF to account for source size and attenuation in the aquifer. Predictions from any fate and transport modeling must be confirmed by field measurements.

This memorandum is intended to provide guidance to foster consistent application of Part 201 and the associated Administrative Rules. This document is not intended to convey any rights to any person nor itself create any duties or responsibilities under law. This document and matters addressed herein are subject to revision.

REFERENCES

ASTM (American Society for Testing and Materials), 1995. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Sites. E 1739-95.

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