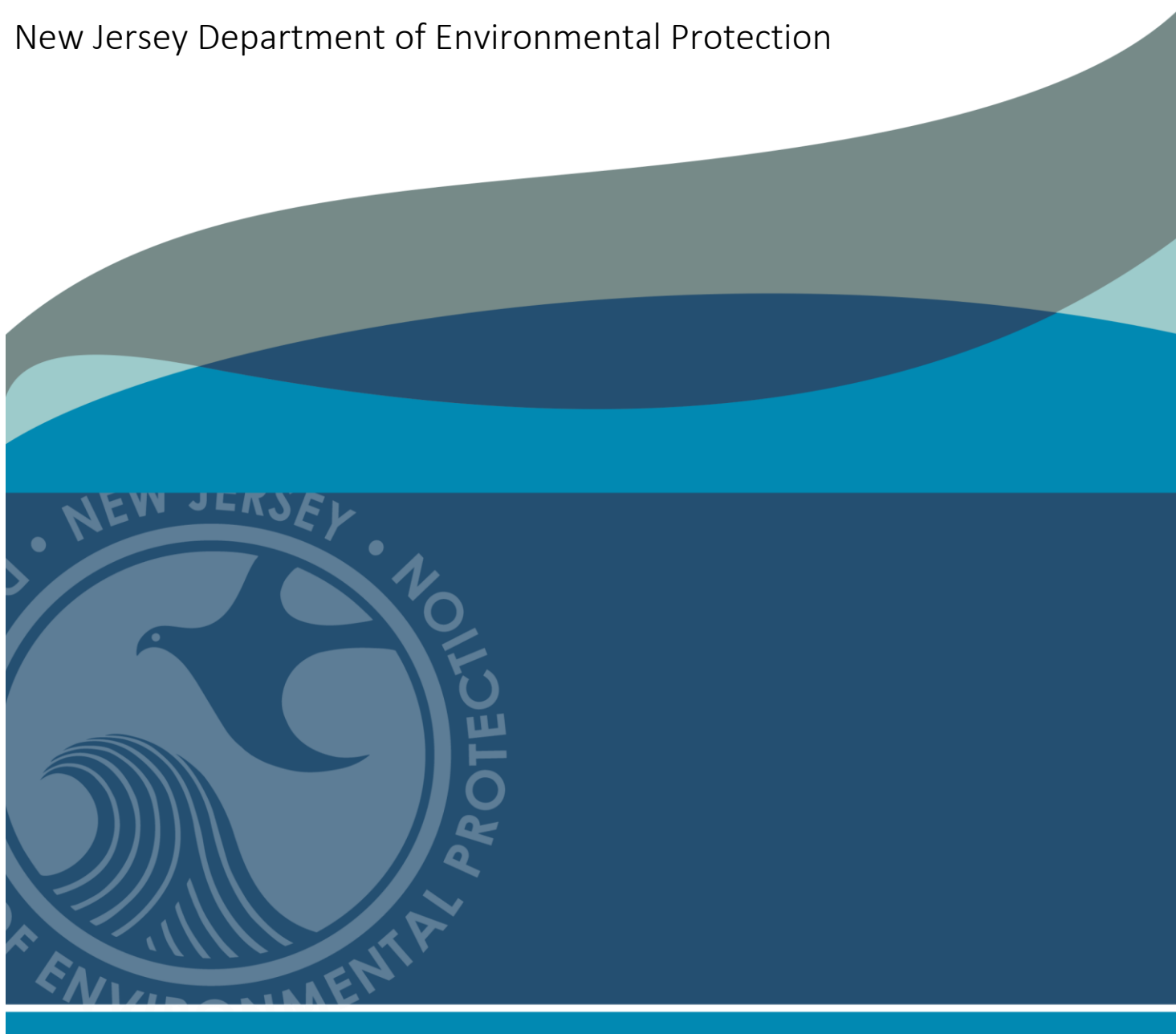


# PFAS Soil and Soil Leachate Remediation Standards Basis & Background

for the Migration to Ground Water Exposure Pathway for Perfluorononanoic Acid (PFNA), Perfluorooctanoic Acid (PFOA), Perfluorooctane Sulfonate (PFOS) and Hexafluoropropylene Oxide Dimer Acid and its Ammonium Salt (GenX)

Contaminated Site Remediation & Redevelopment

New Jersey Department of Environmental Protection



**June 2023**  
**Version 1.1**

## **Introduction**

The Migration to Ground Water (MGW) exposure pathway was analyzed for four per- and polyfluoroalkyl substances (PFAS): perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), and hexafluoropropylene oxide dimer acid and its ammonium salt (GenX). Soil and soil leachate remediation standards for the MGW exposure pathway aim to prevent unacceptable risk to human health from the ingestion of contaminated ground water, caused by the migration of contaminants from the unsaturated zone soil to the ground water. Soil Remediation Standards for the Migration to Ground Water (SRS-MGW) exposure pathway represent the acceptable concentrations of contaminants in the unsaturated zone soil that do not result in an exceedance of the New Jersey Ground Water Remediation Standards (GWRS) when soil moisture passing through this soil drains down into the underlying saturated zone. The Soil Leachate Remediation Standards for the Migration to Ground Water (SLRS-MGW) exposure pathway represent the acceptable concentrations of contaminants in the unsaturated zone soil aqueous phase that do not result in an exceedance of the New Jersey GWRS when this soil water drains down to and dilutes into the underlying saturated zone. Generic SRS-MGW could not be developed for PFNA, PFOA, PFOS, and GenX and instead must be determined on an area of concern (AOC) or site-specific basis. Interim SLRS-MGW were developed.

The procedure for calculating SRS-MGW and SLRS-MGW is based on the procedures outlined in N.J.A.C. 7:26D. Standards are calculated using the New Jersey Class II-A GWRS (N.J.A.C. 7:9C). The GWRS are intended to be protective of human health for chronic (lifetime) exposure to contaminated ground water. They are based on a 1 in one million lifetime cancer risk level for carcinogens and a Hazard Quotient of 1 for noncarcinogens, as mandated by the Brownfield and Contaminated Site Remediation Act (N.J.S.A. 58:10B-1 et seq.).

## **Soil Remediation Standards for the Migration to Ground Water Pathway**

SRS-MGW are calculated using a modified version of the USEPA Soil Screening Level Equation (USEPA, 1996a, Equation 22). This equation, shown below, calculates a migration to ground water criterion ( $MGW_c$ ) which is then compared to the soil reporting limit and soil saturation limit ( $C_{sat}$ ) to determine the SRS-MGW. A full explanation can be found in Appendix 4 of N.J.A.C. 7:26D. The input parameters for this equation include a chemical specific soil-water partition coefficient ( $K_d$  value). For PFNA, PFOA, and PFOS, a three to five order of magnitude difference in  $K_d$  values has been reported in the scientific literature (Rovero et al. 2021). This variability stems from the complexity of PFAS-soil adsorption mechanisms and thus it is presently not possible to accurately define a generic  $K_d$  value for use in standard development. For GenX, very limited data on soil-water partitioning are available at this time. As a result, a generic SRS-MGW could not be developed for PFNA, PFOA, PFOS, or GenX. Note that chemical-specific  $C_{sat}$  values cannot presently be calculated for PFAS compounds due to the variability in  $K_d$  values. However, calculated  $MGW_c$  are not expected to default to  $C_{sat}$ .

$$MGW_c = GWRS * \frac{mg}{1000 \mu g} * \left\{ K_d + \frac{\theta_w + (\theta_a * H')}{\rho_b} \right\} * DAF$$

Parameter	Definition	Units	Default
$MGW_c$	Migration to ground water soil criterion	mg/kg	Chemical specific
$GWRS$	New Jersey ground water remediation standard	µg/L	Chemical specific
$K_d$	Soil-water partition coefficient	L/kg	Chemical specific
$\theta_w$	Water-filled soil porosity	$L_{water}/L_{soil}$	0.23
$\theta_a$	Air-filled soil porosity	$L_{air}/L_{soil}$	0.18
$H'$	Henry's law constant	unitless	Chemical specific
$\rho_b$	Dry soil bulk density	kg/L	1.5
$DAF$	Dilution-Attenuation Factor	unitless	20

In lieu of a generic SRS-MGW value, SRS-MGW for PFNA, PFOA, PFOS, and GenX must be determined on an AOC/site-specific basis using the Synthetic Precipitation Leaching Procedure (SPLP) and the Department's SPLP Calculator. Once SPLP testing and sample concentration analyses have been completed, the SPLP Calculator will generate an AOC/site-specific  $K_d$  value and an AOC/site-specific SRS-MGW. Therefore, the process by which to apply for an Alternative Remediation Standard (ARS) should be utilized as described in the Remediation Standards at N.J.A.C. 7:26D-8.

### Soil Leachate Remediation Standards for the Migration to Ground Water Pathway

SLRS-MGW were calculated for PFNA, PFOA, PFOS, and GenX by multiplying the New Jersey GWRS by a Dilution-Attenuation Factor ( $DAF$ ) of 20. This approach is consistent with that found in the Remediation Standards at N.J.A.C. 7:26D.

$$MGW_{leachate} = GWRS * DAF$$

Parameter	Definition	Units	Default
$MGW_{leachate}$	Soil leachate remediation standard	µg/L	Chemical specific
$GWRS$	New Jersey ground water remediation standard	µg/L	Chemical specific
$DAF$	Dilution-Attenuation Factor	unitless	20

Proposed interim soil leachate remediation standards for PFNA, PFOA, PFOS, and GenX are listed below. The standards are used by comparing them to field leachate concentrations, which are calculated using SPLP results and the Department’s SPLP calculator. A detailed explanation can be found in Section 6 of the Alternative Remediation Standards Technical Guidance for Soil and Soil Leachate for the Migration to Ground Water Exposure Pathway document.

**Interim SRS-MGW and SLRS-MGW for the Migration to Ground Water Exposure Pathway**

<b>Contaminant</b>	<b>CAS No.</b>	<b>Soil Remediation Standard - MGW (mg/kg)</b>	<b>Soil Leachate Remediation Standard - MGW (µg/L)</b>	<b>Soil Leachate Remediation Standard - MGW (ppt)</b>
<b>PFNA</b>	<b>375-95-1</b>	<b>AOC/Site-specific</b>	<b>0.26</b>	<b>260</b>
<b>PFOA</b>	<b>335-67-1</b>	<b>AOC/Site-specific</b>	<b>0.28</b>	<b>280</b>
<b>PFOS</b>	<b>1763-23-1</b>	<b>AOC/Site-specific</b>	<b>0.26</b>	<b>260</b>
<b>GenX</b>	<b>13252-13-6 &amp; 62037-80-3</b>	<b>AOC/Site-specific</b>	<b>0.40</b>	<b>400</b>

**References**

Rovero, M., Cutt, D., Griffiths, R., Filipowicz, U., Mishkin, K., White, B., Goodrow, S., Wilkin, R. T., Limitations of Current Approaches for Predicting Groundwater Vulnerability from PFAS Contamination in the Vadose Zone. *Groundwater Monitoring & Remediation* **2021**, 41(4), 62-75.

USEPA (1996). Soil Screening Guidance: Technical Background Document, May 1996. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response: Washington, DC, EPA/540/R-95/128.