



Site-Specific Numerical Soil Standards Model Parameters

This document provides guidance to qualified professionals for determining site-specific model parameters for use in deriving site-specific numerical soil standards (SSSs) under [Protocol 2 “Site-Specific Numerical Soil Standards”](#).

Site-specific model parameters are used in the ministry’s Groundwater Protection Model (GPM) to derive SSSs for the site-specific factors protective of groundwater use.

Specific guidance on how to run the ministry’s GPM can be found in Technical Guidance 13, “Groundwater Model” (revisions expected by November 1, 2017).

1.0 Groundwater Protection Model

The ministry’s GPM is used in the “SSS Model Type” to back-calculate a SSS that is protective of the applicable water use in the shallowest unconfined aquifer. A schematic illustrating the GPM is found in Appendix 1.

The GPM takes into account four different model processes from source to receptor: (1) soil-leachate partitioning at the source, (2) unsaturated transport of leachate to the groundwater table, (3) mixing at the groundwater table, and (4) saturated transport to the receptor. A conceptual model illustrating the four processes is found in Appendix 2.

The model parameters used in the GPM can be divided into four major categories: (1) source dimensions, (2) infiltration, (3) hydrogeology, and (4) physical/chemical properties. Available model parameters and their use in the four GPM model processes are listed in Appendix 3.


2.0 Parameter sensitivity

A parameter sensitivity analysis was completed to define and prioritize a list of model parameters that are considered most sensitive to the calculated SSSs under Protocol 2 [1]. This analysis provides a focused assessment on which model parameters may be considered for potential modification when deriving SSSs on a site.

Parameter sensitivity varies for each matrix substance and will specifically vary for organic and inorganic substances. The most important difference is that only organic matrix substances will degrade in the unsaturated zone, whereas inorganic matrix substances are unaffected by unsaturated transport. A detailed review of the sensitivity analysis is found in [1].

Based on the relative quantified change in SSS derived from the GPM, the model parameters were ranked from highest to lowest relative sensitivity for organic and inorganic substances, Table 1.

Table 1. Ranking of model parameter sensitivity

Sensitivity	Organics	Inorganics
<p>Highest</p>  <p>Lowest</p>	Depth to water	Soil pH
	Infiltration	Infiltration
	Source depth	Partitioning coefficient (K_d)
	Fraction of organic carbon (f_{oc}) and partitioning coefficient (K_{oc})	Transport distance
	Transport distance	Hydraulic conductivity and gradient
	Biodegradation rate	

Due to the significant attenuation of degradable organic substances in the unsaturated zone, the GPM is highly sensitive to parameters used to calculate unsaturated zone attenuation (i.e. depth to water table, source depth, sorption and biodegradation). The infiltration rate, which is used to calculate the dilution factor when leachate mixes at the groundwater table, is also a sensitive parameter for both organic and inorganic substances. Source dimensions influence both the unsaturated zone thickness relevant for organics and the transport distance to receptor and, thus, are also sensitive parameters. Remaining hydrogeological parameters like porosity, bulk density, hydraulic conductivity, gradient, and pH_{water} are less sensitive model parameters in the GPM.

3.0 Site-specific model parameters

SSSs are derived using the Modified GPM method by substituting the model default parameters with site-specific values. As per Protocol 2, parameters related to source dimensions, infiltration and hydrogeology can

be modified within the acceptable parameter ranges provided in Table 2 of the protocol. The methods provided for modifying model parameters include using look-up regional data, literature data or site-specific data determined by site investigations (Protocol 2, Table 1).

Based on the sensitivity of model parameters, decisions can be made regarding which default parameters to modify with site-specific values. One strategy for modifying model parameters is to start by modifying the infiltration rate using data from the look-up table in Protocol 2, Appendix 1. If further modification is sought, the hydrogeological parameters can be modified using either literature values (an option for selected parameters only) or site-specific data obtained during site investigations. Finally, depth to water table and/or transport distance to receptor can be modified. This step requires site-specific data to determine the source dimensions.

Where site-specific conditions warrant modification outside the parameter ranges provided, the rationale and supporting data must be provided in an application for a director's approval.

Although a variety of approaches are possible, one approach for modifying parameters is shown in the flowchart of Appendix 4.

Parameter categories are discussed in detail below.

3.1 Infiltration

Infiltration is a moderately sensitive parameter when deriving SSSs for both organic and inorganic matrix substances. A water balance approach defines the infiltration rate, I , where the amount of infiltration into the ground is defined as the difference between the precipitation, P , in the form of rainfall and snowfall and the sum of the evapotranspiration,

ET and surface water runoff, RO. The following expression summarizes the infiltration equation:

$$I = P - (ET + RO)$$

Look-up infiltration data has been derived for the province [2]. The look-up table and figure in Protocol 2, Appendix 1 provides infiltration rates for available urban centres.

The following method is recommended in determining which infiltration value to use on a site:

- If the site is located within a 20 km radius of a listed urban centre, use the infiltration value listed for that centre.
- If the site is located outside a 20 km radius and in between two listed urban centres, and does not cross an infiltration contour on the infiltration figure, use the infiltration rate for the urban centre closest to the site. An average of the two infiltration rates can be calculated in situations where the site is located equidistant from the two stations.
- If the site is located at a horizontal distance greater than the 20 km radius from a listed urban centre and one or more infiltration rate contours are crossed, use an infiltration rate corresponding to the closest infiltration rate contour to the site.
- If the site is located between two contour intervals, the infiltration rate can be estimated to the nearest 100 mm/year. For example, the town of Sechelt, which is located midway between the 800 mm/year and 600 mm/year contours, would be considered to have an annual infiltration rate of 700 mm/yr.

If a site-specific infiltration rate (e.g. using on-site infiltrometer test) is to be used, an application for a director's approval can be made.

3.2 Hydrogeology

Hydrogeological parameters can be modified to reflect site-specific conditions in the GPM.

The less sensitive hydrogeological parameters, including total porosity, effective porosity, dry bulk density and pH of groundwater, can be modified using sourced literature values or actual site-specific values. For PCP, site-specific data is required to modify pH_{water} for the site-specific factor protective of aquatic life.

Site-specific hydrogeological parameter values are determined through in-situ field investigations. Technical guidance on site investigations can be found in [Technical Guidance 8 "Groundwater Investigation and Characterization"](#). Further, [Technical Guidance 6 "Assessment of Hydraulic Properties for Water Use Determinations"](#) provides additional guidance for assessing aquifer properties.

Laboratory analyses of representative soil samples are required to determine site-specific values for pH of soil, dry bulk density, ρ_b , and fraction of organic carbon, f_{oc} . [Technical Guidance 1 "Site Characterization and Confirmation Testing"](#) provides guidance on how to conduct soil sampling to determine a representative soil sample. The selection of pH for running the GPM is described in Protocol 28 "2016 Standards Derivation Methods", chapter titled *Generic Numerical Standards*.

Field investigations are required to determine the hydraulic conductivity, K and the hydraulic gradient, i. Similarly, site-specific aquifer thickness, d_a , can be determined if desired, however the parameter is not a sensitive parameter in the GPM. Since saturated transport in the GPM is simulated in the shallowest unconfined groundwater flow system, the

hydraulic conductivity, gradient, and thickness should be measured and represent conditions in the unconfined flow system. For sites where there are perched water tables or where the hydraulic conductivity, gradient and aquifer thickness cannot be determined, the default model parameters values will need to be used.

The depth to water table, d , is a sensitive model parameter for organic substances. The distance to water table can only be modified from its default value of 3 m (i.e. no unsaturated zone) if site-specific source dimensions are determined as described in Protocol 2, Section 5.1.1.

The transport distance to the receptor, x , is a sensitive model parameter for both organic and inorganic substances. The transport distance can only be modified from its default value of 10 m if the site-specific source dimensions are determined and groundwater meets the requirements described in Protocol 2, Section 5.1.3.

3.3 Source dimensions

The horizontal and vertical extent of the source dimensions are defined by the length, X , width, Y , and depth, Z . Due to the variability in chemical behaviour and mobility of different contaminants in the subsurface, the approach used to define the dimensions of the source is different for different types of contamination. Specifically, the method used to define the dimensions of a petroleum hydrocarbon contamination source is different than that used to define an inorganic contamination or chlorinated hydrocarbon source.

Site-specific measurements are required to modify the default source dimensions using the criteria listed in Protocol 2, Section 5.1.1. Site-specific source dimensions are a requirement on

sites where the parameters “distance to water table” and “distance to receptor” are modified. Further details on source definition are provided below and in the document “Defining the Contaminant Source Zone Protocol 2 Groundwater Model” [3].

Petroleum hydrocarbon source

Petroleum hydrocarbon sources are almost exclusively a consequence of NAPL releases. Partially NAPL-saturated soils and soils with residual NAPL can serve as long-term sources of groundwater contamination. The presence of NAPL at a site is defined in [Protocol 16 “Determining the Presence and Mobility of Nonaqueous Phase Liquids and Odorous Substances”](#) for both LNAPL and DNAPL, and the definitions and methods described in the protocol can be used to define the horizontal extent and depth to which the LNAPL/DNAPL occurs.

Defining the horizontal and vertical extent of residual NAPL in soil is somewhat more complicated, since residual saturation levels can vary significantly (e.g., less than 1% to greater than 20%). The recommended approach for defining the extent of residual NAPL is to use soil analytical data for key petroleum hydrocarbon substances as surrogates to define the source dimension variables. Protocol 2 uses VH_s , EPH_{s10-19} and EPH_{s19-32} as surrogates for residual NAPL in soil.

If non-petroleum hydrocarbon substances are present in addition to a petroleum hydrocarbon source, site-specific source dimensions for those substances are determined as described below.

Inorganic source definition

For inorganic sources, the source dimensions are defined using the applicable Schedule 3.1 Part 1 matrix soil standard for a given contaminant of

concern, COC, or the substance concentrations in regional/ local background soil as defined in [Protocol 4 “Determining Background Soil Quality”](#).

Other COCs

For non-petroleum hydrocarbon volatile organic sources and other COCs, the source dimensions are defined based on the applicable Schedule 3.1 Part 1 matrix soil standards.

3.4 Physical/chemical properties

Model parameters contained within the physical/chemical category are restricted and cannot be modified using the Modified GPM method under Protocol 2. However, should alternative, scientifically defensible values be available for modifying these parameters, an application for a director’s approval including rationale and supporting documentation can be made.

4.0 References

[1] Core 6 Environmental, 2017. *Results of a Sensitivity Analysis of the Omnibus Groundwater Model.*

[2] Core 6 Environmental, 2017. *Estimation of Regional Infiltration Rates in British Columbia Protocol 2 Groundwater Model.*

[3] Core 6 Environmental, 2017. *Defining the Contaminant Source Zone Protocol 2 Groundwater Model.*

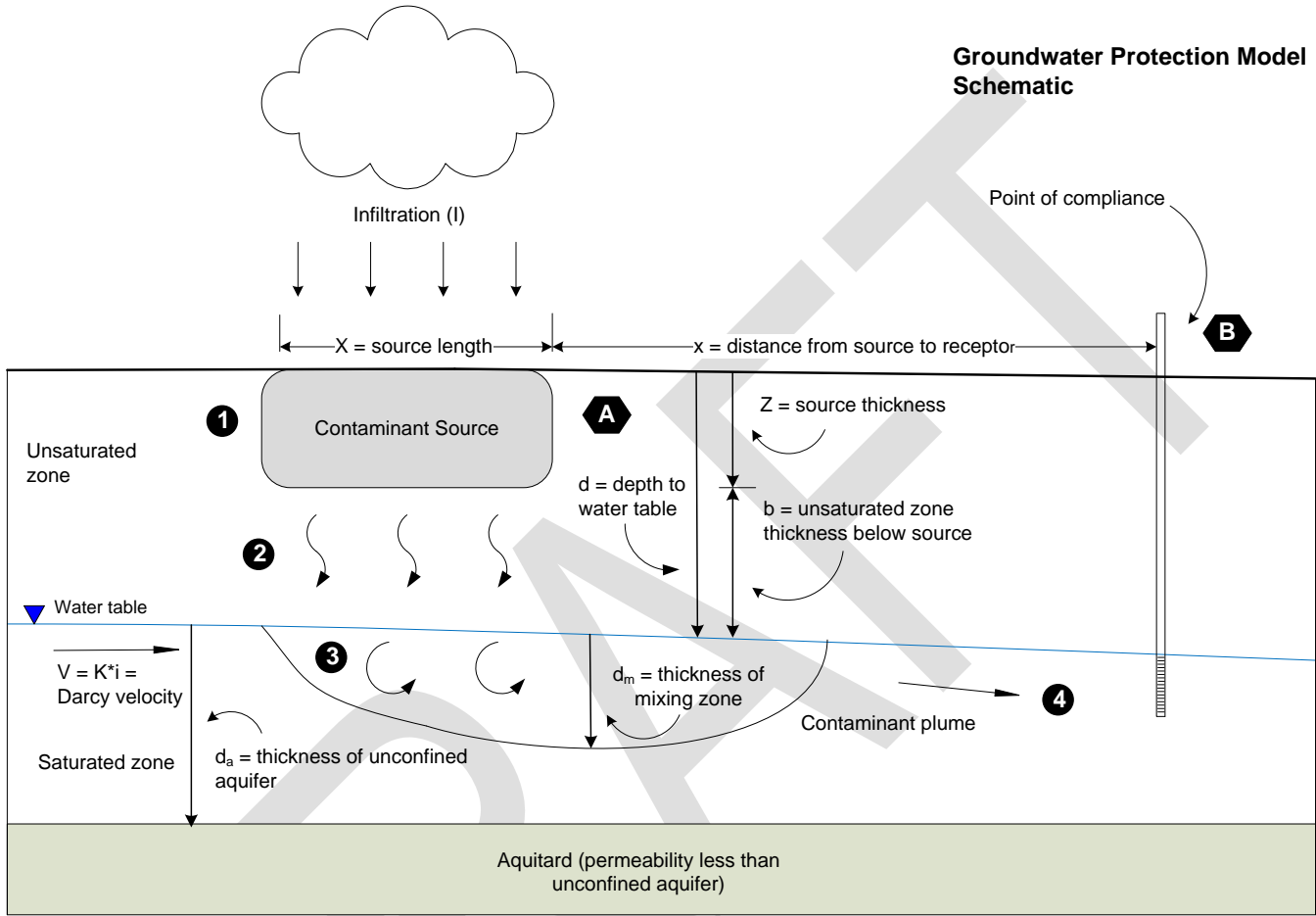
Note: This document is solely for the convenience of the reader. It does not contain and should not be construed as legal advice. The current legislation and regulations should be consulted for complete information.

For more information, please direct inquiries to site@gov.bc.ca.

Revision history

Approved Date	Effective Date	Document Version	Notes
	November 1, 2017	1.0	Draft for stakeholder consultation

Appendix 1 - Schematic of the GPM



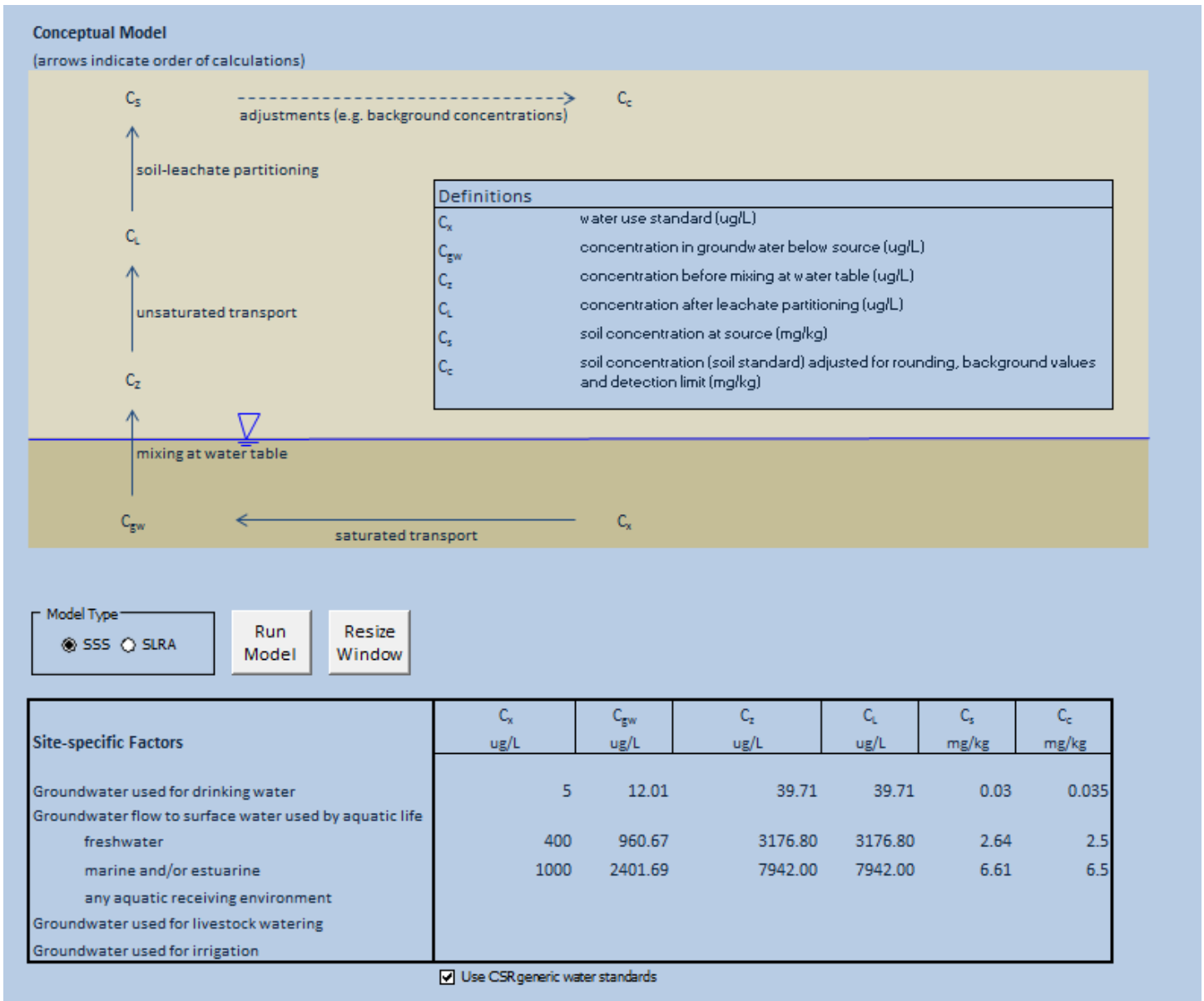
LEGEND

- ① Leachate concentration due to partitioning
- ② Unsaturated zone contaminant fate and transport
- ③ Mixing of leachate and groundwater flux at water table
- ④ Saturated zone contaminant fate and transport

- Ⓐ Substance soil concentration at source (C_s)
- Ⓑ Substance groundwater concentration at receptor (C_x)

Schematic only.
Not to scale.

Appendix 2 – Conceptual model of the GPM



Appendix 3 – Active model parameters in the GPM

Parameter set	Definition	Symbol	Unit	Saturated transport	Mixing	Unsaturated transport	Partitioning
Source dimension	Source length	X	m		X		
	Source width	Y	m	X			
	Source depth	Z	m			X (organic)	
Infiltration	Infiltration	I	m/yr		X	X (organic)	
Hydrogeology	Total porosity	n	-	X			X
	Water filled porosity	n_w	-			X (organic)	X
	Effective porosity	n_e	-	X			
	Fraction of organic carbon	f_{oc}	-	X (organic)		X (organic)	X (organic)
	Hydraulic conductivity	K	m/s	X	X		
	Hydraulic gradient	i	-	X	X		
	Depth to water table	d	m			X (organic)	
	Aquifer thickness	d_a	m		X		
	Dry bulk density	ρ_b	g/cm ³	X		X (organic)	X
	pH of soil	pH _{soil}	pH units	X (PCP)			X (inorganic)
	pH of groundwater	pH _{water}	pH units	X (PCP)			
	Distance to receptor	x	m	X			
Physical/chemical	Half-life	$t_{1/2s}$	days	X (organic)		X (organic)	
	Distribution coefficient	K_{oc}/K_d	L/kg	X		X (organic)	X
	Henry's Law constant	H	-				X
	Number of days frozen	D_{fr}	days/yr			X (organic)	

Appendix 4 - Step-wise Modified GPM Method

