

US EPA ARCHIVE DOCUMENT

**Model and Scenario Development Guidance for Estimating Pesticide  
Concentrations in Groundwater Using the Pesticide Root Zone  
Model**

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## Purpose

This guidance describes the methods for developing scenarios for the PRZM-GW model. PRZM-GW is an implementation of the Pesticide Root Zone Model (Suarez, 2006) in which a pesticide moves downward into an aquifer according to the NAFTA conceptual model (see below). *Scenarios* are the subset of input parameters that describe the spatial characteristics of the PRZM-GW parameters. These include weather, soil, and crop characteristics.

## Groundwater Conceptual Model

**Figure 1** depicts the conceptualization of the groundwater scenario that evolved from meetings between the USEPA and Canada's PMRA and from the 2005 N-Methyl Carbamate SAP meetings (USEPA, 2005a, 2005b). The model represents vulnerable private drinking water wells in the vicinity of agricultural environments. In this conceptualization, the pesticide is applied to the soil surface or plant canopy, and precipitation or irrigation drive pesticide into the soil. Meteorological, crop, biological, chemical, and management processes affect the transport of the pesticide as it moves through the soil and into a saturated zone. Horizontal surface movement of a pesticide (via runoff or erosion) and subsequent removal is assumed negligible for this model.

The saturated zone of the conceptual model is a shallow unconfined aquifer with a water table depth that corresponds to the scenario location. The well-screen extends from the aquifer surface to 1 meter below the surface, but this length is also adjustable according to common practices. The default well-screen length of 1 meter was chosen to sample the higher concentrations expected to be closest to the water table; however, this can be adjusted based on site-specific data. Pesticide concentrations in the well are taken as the average concentration in the screened zone.

The conceptual model includes meteorological events that can significantly affect pesticide transport, including precipitation, evaporation, snow, temperature, and wind. These weather processes vary and are simulated with daily resolution. Daily resolution is required by risk assessment applications within OPP's and PMRA's Health Effects Division.

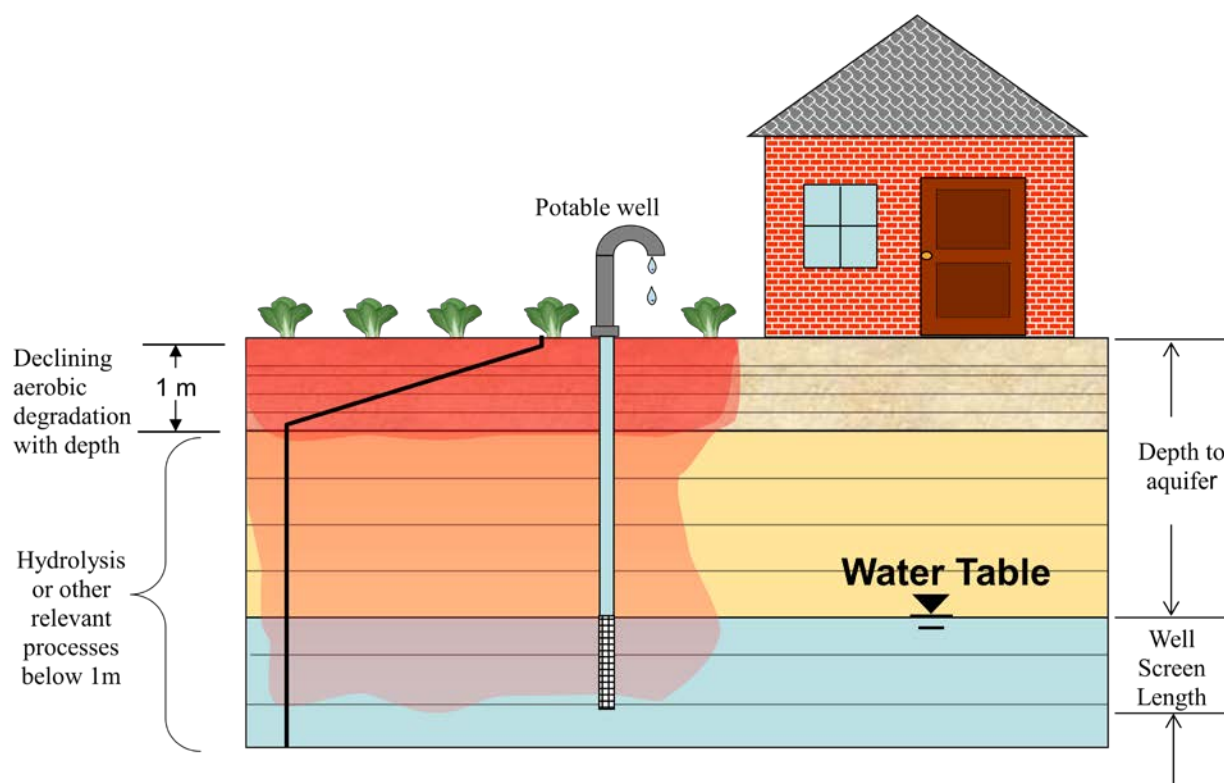
Soil temperature variations with depth and time have important implications on transport and are thus included in the model. Temperature simulations on and below the field are more important for groundwater simulations than for surface water simulations. In a groundwater simulation, the entire duration of the simulation occurs on or below the field; whereas in a surface water simulation the relevant pesticide is in the field's zone of relevance (top 2 cm) for much shorter periods and will be less likely to be in that surface zone during periods of extreme cold when temperature effects will be significant. It is likely that in many scenarios temperature in the subsurface could be quite different from surface temperatures or from the laboratory experiment temperature of the degradation experiments.

Crop descriptions are needed only in regard to how they impact hydrology (*i.e.*, water balance) or pesticide transport. In most cases, parameterization of pesticide hold up and wash off of foliage will be difficult due to lack of data, thus prudence should be considered in attempting to

simulate these processes. A description of canopy coverage and root depth is incorporated to capture the most relevant plant influences on pesticide transport.

Agricultural management practices that could dramatically affect pesticide transport such as irrigation or well setbacks are included in the conceptual model. Because irrigation provides significant amounts of water and is an important transport driver, irrigation is included in those areas where it is used. Simulation of other management practices such as soil manipulation, tile drainage, and pesticide application methods may be desirable but are not considered in the present conceptualization because there is a lack of consensus regarding their importance to transport. Such processes may be considered in subsequent versions if more evidence of their impact becomes available.

The conceptual model includes consideration for pesticide degradation in the soil profile. In general, degradation occurs faster in the top of the profile and decreases at lower depths. As depicted in **Figure 1** (by the black line on the left of the figure), the pesticide fate conceptualization uses the pesticide's aerobic soil degradation rate in the top 10 cm, and a linearly declining rate with depth to 1 meter, below which only abiotic processes are assumed to occur. In some cases, there may be evidence that certain pesticides behave differently than this depiction. The conceptual model does not preclude alternative degradation schemes when there is compelling evidence that a pesticide may behave differently than the default conceptualization.



**Figure 1. General Groundwater Scenario Concept for Estimating Pesticide Concentrations in Drinking Water.** The black line through the soil profile represents the decline in degradation with respect to the depth.

## Implementation of the Conceptual Model into PRZM

PRZM is a one-dimensional, finite-difference vertical-transport model that accounts for pesticide fate. PRZM can simulate specific site, pesticide, and management properties, including field properties (organic matter, water holding capacity, bulk density, general hydrology), pesticide application parameters (application rate, frequency, incorporation, and methods), and pesticide environmental fate and transport properties (aerobic soil metabolism half-life, soil-water partitioning coefficients, foliar degradation and dissipation). PRZM is the standard EPA model for simulating transport of pesticides off of a field and into a surface water body.

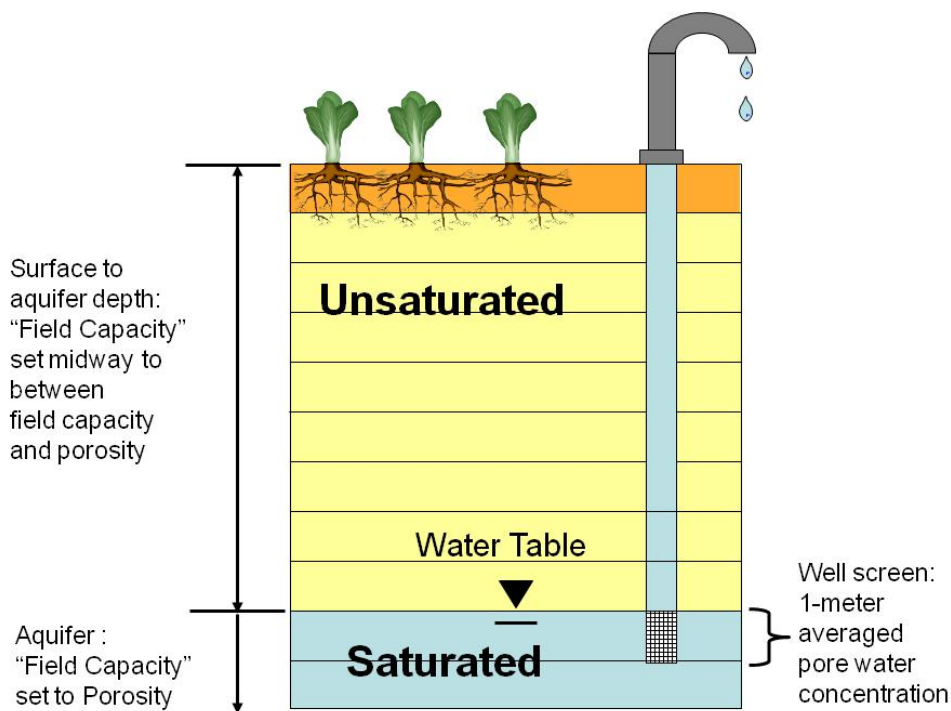
In order to use PRZM to simulate transport to groundwater rather than to surface water, environmental scenarios need to be developed to represent the conceptual model. These scenarios will differ from surface water scenarios in particular for a few key parameters, including field capacity, irrigation, dispersion, near surface degradation, the non-consideration of erosion and runoff, temperature simulation, and relevant output. The basis for these changes is described below. Detailed guidance for selection of these and other parameters is included in the section—Groundwater Scenario Development Guidance.

### *Field Capacity*

Although PRZM was not originally developed to simulate saturated conditions, a review of the model's structure and coding showed that saturated conditions can be effectively simulated by redefining the *field capacity* parameter. Soil compartments in PRZM are maintained at “field capacity” unless losses occur by evapotranspiration. Below the zone of evapotranspiration (which occurs at the bottom of the defined root zone or at a minimum defined evaporation depth), PRZM maintains the water content at “field capacity.” Thus, a saturated zone can be created in PRZM by setting the scenario's field capacity parameter (called THEFC in PRZM) equal to the porosity. By doing this, a constant water table can be simulated (**Figure 2**).

PRZM-GW output concentrations are calculated from the spatial average over the depth from the top of the saturated zone to the bottom of the well screen (1 meter default). Depending on precipitation and evapotranspiration characteristics of the particular scenario, this spatial averaging represents the temporal average of six months to greater than one year (*i.e.*, 1 meter of aquifer can hold six months of water from the FL scenarios to greater than a year for eastern Washington scenarios; scenarios described later). Note that during this time period, degradation within the aquifer still occurs, and thus this conceptualization is more realistic with regard to concentrations that may be pulled from a well than the temporal averaging described by the FOCUS group, in which post-breakthrough degradation does not occur.

In addition, analysis of prospective groundwater (PGW) studies indicates that actual water retention in the soil profile is better characterized by a value between field capacity and saturation. Therefore, the soil profile water holding capacity (*field capacity* in PRZM) should be set to a value that is the midpoint between field capacity and saturation. In this way, the travel time to the aquifer will be better simulated.



**Figure 2. PRZM Scenario to Simulate a Fixed Water Table**

In **Figure 2**, note the unique adjustments to PRZM groundwater scenarios: "field capacity" is set to porosity to simulate a saturated zone; well-screen of 1 meter is the default length.

### ***Irrigation***

Irrigation may be an important contributor to vertical pesticide transport and in many scenarios may be the dominant water source. When a scenario specifies irrigation, it is handled according to OPP guidance on PRZM irrigation (USEPA/OPP, 2007), which modifies the guidance provided in the PRZM manual. PRZM irrigation guidance that appears in the PRZM manual may be inappropriate for deeply rooted plants such as orchard trees. PRZM attempts to satisfy water demand to the bottom of the root zone, whereas in reality water demand would only be satisfied as a result of irrigation to several centimeters depth. Thus too much irrigation would occur unless preventative measures are taken. This should be considered in scenario development if irrigation is to be simulated. Guidance is provided for this case later in the parameter selection section of this document.

### ***Dispersion***

Dispersion (whether numerical or explicitly modeled) has an especially important impact on pesticide concentrations when there is a limited degradation zone that applies only over a short

distance, such as in this groundwater conceptual model. In these cases, dispersion will quickly remove the pesticide from the degradation zone into areas of low or no degradation. Thus, higher dispersion leads to higher pesticide concentrations, the opposite of what would be expected for a conservative non-degrading tracer. This characteristic is analogous to the efficiency difference between plug flow and completely mixed reactors, which is well known in chemical and environmental engineering fields. Thus, it is important to standardize the discretization within PRZM.

In PRZM, the vertical discretization is the dominant means of applying dispersion, which is caused by PRZM's use of backwards spatial differencing for the pesticide transport finite differencing. Although backward differencing is effective for elimination of oscillation at boundaries, it produces high but quantifiable numerical dispersion. Additional numerical dispersion also results from the fully implicit discretization of the temporal term (1 to 2 cm), but users have no control over this characteristic (Young and Carleton, American Geophysical Union Meeting 2012). For a backward finite difference, dispersivity is equal to one half of the spatial discretization.

EFED evaluation of PGW studies shows dispersivity values much greater than the 2.5 cm used by the European Union, as described in the FOCUS guidance. In an analysis of bromide tracers in PGW studies [see **Figure 3**; (Young and Carleton, American Geophysical Union Meeting 2012)], dispersivity increased with depth and ranged from about 10 cm at 1 m, increasing to around 40 cm at 5 m. In order to capture the dispersivity in the PRZM scenarios, the scenarios use discretization of 1 cm for the top 10 cm. For the next 10 cm, discretizations are 5 cm. From 20 cm to 1 m, discretizations are 20 cm. The standard scenarios use discretizations of 50 cm for all depths below 1 m, but the PRZM-GW user interface allows other discretizations if the user has justification for alternate schemes.



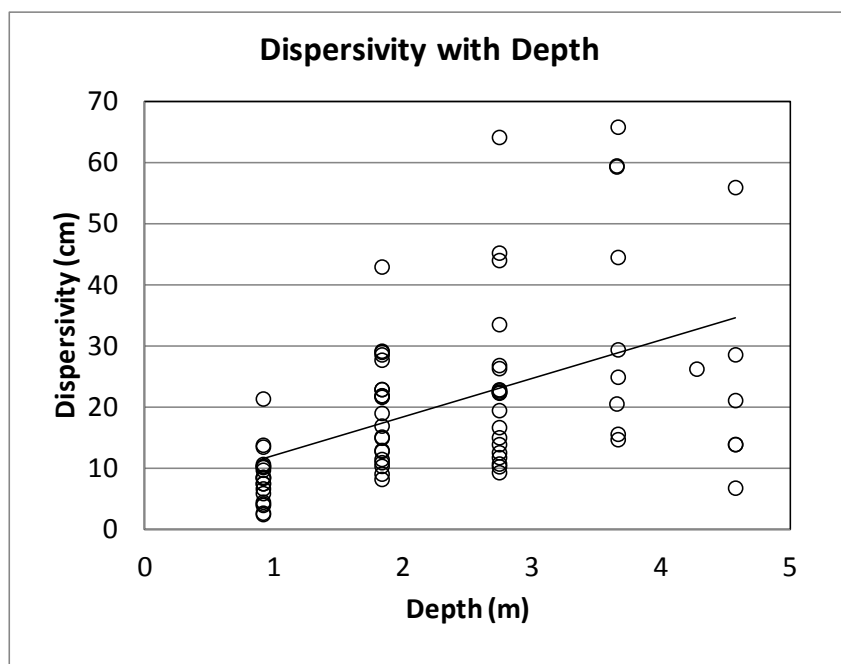
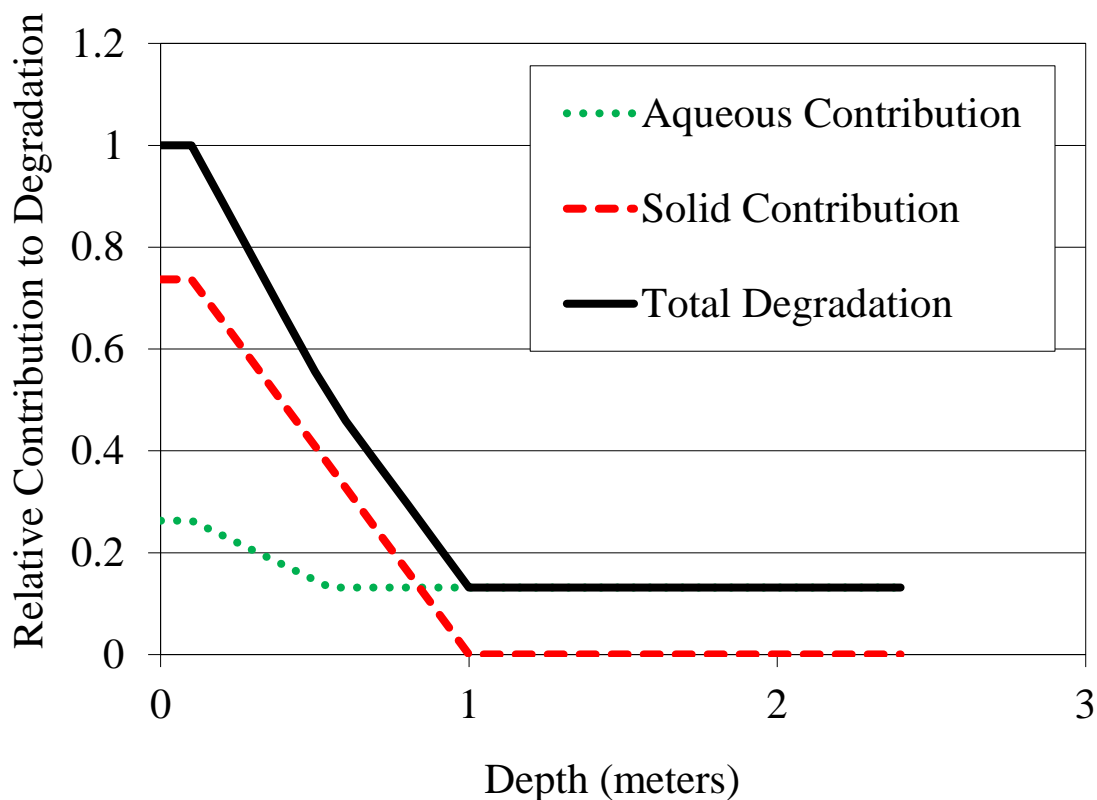


Figure 3. Dispersivity Determined from Bromide Tracers at 21 PGW Sites (Young and Carleton, American Geophysical Union Meeting 2012)

### *Near Surface Degradation*

Aerobic soil metabolism is modeled as declining with depth and becomes zero at 1 m below the surface. Because typically submitted soil degradation studies do not allow differentiation of water-phase from solid-phase degradation, only total system degradation is typically known. Thus the rates of both solid phase and water phase degradation should be set identically and should decline at the same rate with depth.

For the groundwater conceptualization, this can cause some difficulties when hydrolysis is significant, especially when the degradation rate in water drops below the hydrolysis rate, creating apparent inconsistencies. In order to overcome this problem, the following recommendations apply: (1) both solid and aqueous degradation rates (represented initially by aerobic soil metabolism rate) are to decline in a linear fashion with depth; (2) if the aqueous degradation rate drops below the hydrolysis rate, then the hydrolysis rate will be used for the aqueous degradation rate, while the solid degradation rate remains unaffected by the hydrolysis rate and continues to decline with depth. An example of the use of these recommendations is given in **Figure 4**. **Figure 4** shows that the aqueous-phase degradation rate does not decline below the hydrolysis rate, while the sorbed-phase rate continues to decline.



**Figure 4. A Depiction of Declining Degradation with Depth in the Presence of Hydrolysis**

In this case, the hydrolysis rate is 0.15 times the aerobic soil metabolism rate. Hypothetical partitioning conditions with the compound distributed in water and solids is the ratio of 2.8:1

### ***Temperature***

The temperature routine in PRZM allows for heat transfer between the bottom boundary of the simulation (set at a constant temperature) and the soil surface. The temperature routine requires that solar radiation be included in the meteorological file. Solar radiation has not previously been included in the surface water meteorological files; nevertheless, all current weather files have included solar radiation. Thus, standard weather files will work correctly. There are a few other parameters that are needed to run the temperature routine, which are new to the standard scenario development (e.g., albedo, emissivity), and which are not readily available for specific scenarios. Without further specific information regarding this parameterization, typical values should be chosen as specified in the guidance below.

## Selection of Scenario Locations

Appropriate scenario locations should be created in regions that are vulnerable to groundwater contaminations. This includes areas where the depth to groundwater is shallow (<100 feet), where there is high net leaching (or high rainfall with respect to evaporation), and where specific characteristics of the location may make a pesticide more prone to persistence (*e.g.*, high or low pH depending on the pesticide).

## Groundwater Scenario Development Guidance for PRZM

Guidance is presented in Table 1 on how to develop PRZM scenarios for groundwater estimates. The output of these model runs are contained in the PRZM “zts” file, which will give the daily spatially averaged (vertically over 1 m) aqueous concentration. These values represent high-end drinking water concentrations from a rural well. The scenario file can be constructed in the following manner:

**Table 1. Groundwater PRZM Scenario Building Guidance**

PRZM Record	Parameter	Input Value	Note
1	TITLE	text	Text notes
2	HTITLE	text	Text notes
3	PFAC - Pan factor	See note	PRZM 3 Manual, Figure 5.9 (Suarez, 2006). Select the value for the specific region based on the location of the crop scenario.
	SFAC - Snow melt factor (cm/°C day)	See note	For row crops, use 0.36 For orchard crops, use 0.16 Where snow persists less than a day, use 0.  See PRZM 3 Manual, Table 5.1 (Suarez, 2006).
	IPEIND - Pan factor flag	0	Pan data is read from weather file.
	ANETD – Minimum Depth to which evaporation is extracted (cm)	See note	PRZM Manual Figure 5.2 (Suarez, 2006). Use the mid-point of the range of values based on the location of the scenario. If a region crosses one or more boundaries, select the average of the midpoints.
	INICRP - Initial crop flag	0	Indicates no crop before first emergence date.

	ISCOND - Surface condition of initial crop	1	For groundwater scenarios, this parameter is a placeholder and will not affect the results.
	DSN - Weather data (5 values)	Leave blank	Specifies reading weather data from sources other than the standard weather files.
6	ERFLAG - Erosion flag	0	The erosion routine is not used in the groundwater scenarios.
8	NDC - Different crops in a simulation	1	Simulates 1 crop
9	ICNCN - Crop number of the different crop	1	Simulates 1 crop
	CINTCP - Max interception storage of crop (cm)	See note	PRZM 3 Manual (Suarez, 2006) Table 5.4 provides intercept storage for a limited number of crops. For orchard crops, the value ranges from 0.25 to 0.30.
	AMXDR - Max rooting depth of crop (cm)	See note	<p>This parameter controls depth within the soil profile from which water can be removed to satisfy potential evapotranspiration.</p> <p>When irrigation is used, this parameter also controls the amount of water that is supplied during an irrigation event. Enough water will be applied to fill the profile to a depth of AMXDR up to field capacity. Root depth is set to satisfy irrigation requirements in preference to actual root depth. Depth of irrigation can be obtained from agriculture extension agents or extension bulletins.</p>
	COVMAX - Max aerial canopy coverage (%)	See note	Extension agents, USDA crop profiles, or other authoritative sources can provide this information.
	ICNAH - Surface condition of crop after harvest	1	This parameter is a placeholder as it is not relevant for groundwater scenarios and only affects runoff.
	CN - Curve number for runoff (3 values)	10	CN is set to the low value of 10 to essentially eliminate runoff.
	WFMAX - Max dry weight of crop at full canopy (kg/m <sup>2</sup> )	0	WFMAX is a placeholder since it is not used in groundwater scenarios.

	HTMAX - Max height of canopy at maturation (cm)	See note	HTMAX, a placeholder for volatilization, is currently not implemented.  Values for selected crops in PRZM Manual (Carsel et al., 1998) Table 5-16 and Table A-1.
10	NCPDS - Number of cropping periods	See note	This parameter will be the same as the number of years in the met files.
11	EMD/EMM/TYREM - Day, month and year of crop emergence	See note	Sources of information include crop profiles, extension agents, and Table 5.9 in the PRZM manual (Suarez, 2006)
	MAD/MAM/TYRMAT - Day, month and year of crop maturation	See note	See sources of information above.
	HAD/HAM/IYRHAR - Day, month and year of crop harvest	See note	See sources of information above.
	INCROP - Crop number associated with NDC	1	Only one crop is modeled.
12	PTITLE - Label for pesticide title	See note	Pesticide specific text notes.
13	NAPS - Total number of pesticide applications	See note	Pesticide specific. Typically this value is the number of years times the number of applications per year.
	NCHEM - number of pesticides in the simulation	1	Simulation for one pesticide only.
	FRMFLG - Flag for testing ideal moisture conditions for pesticide applications	0	Not used.
	DKFLG2 - Flag to allow bi-phasic half-life	0	Not used.
15	PSTNAM - Pesticide name for output file	See note	Pesticide specific text notes.
16	APD/APM/IAPYR - Day, month and year of pesticide application	See note	Pesticide specific.
	WINDAY - Number of days soil moisture	0	Not used.
	CAM - Chemical application method	See note	Pesticide specific.
	DEPI - Depth of pesticide application	See note	Pesticide specific.
	TAPP - Application rate (kg/ha)	See note	Pesticide specific.
	APPEFF - Application efficiency to target	1.0	The conceptual model for groundwater represents a large area

			such that any losses out of the system ( <i>e.g.</i> , spray drift) are negligible.
	DRFT - Spray drift fraction to pond or reservoir	0.0	Irrelevant to the groundwater scenario.
17	FILTRA - Filtration parameter	0.0	This method is not used.
	IPSCND - Condition for deposition of foliar pesticide after harvest	See note	Pesticide specific. See USEPA OPP (2002).
	UPTKF - Plant uptake factor	0	Not used.
18	PLVKRT - Pesticide Volatilization decay from plant foliage ( $\text{days}^{-1}$ )	0	Not used.
	PLDKRT - Pesticide decay rate on plant foliage ( $\text{days}^{-1}$ )	0	Not used.
	FEXTRC - Foliar extraction coefficient for pesticide washoff per cm of rainfall	0.5	Default value is 0.5. In some rare cases, data may be available to better assess this value.
19	STITLE - Label for soil property title	See note	User defined text notes.
20	CORED - Flag for total depth of soil core (cm)	1000 cm	<p>The depth to GW is scenario specific. The default is a 10-meter soil profile, with the last meter simulated as a saturated zone.</p> <p>USDA Soil Data Mart or Soil Landscapes of Canada are the primary data sources for soil properties for the GW scenarios.</p> <p>In many cases, soil characterizations will not be available for depth below 1 meter. In these cases, the deepest known profile can be extended using reasonable judgment regarding the physical properties soils (<i>e.g.</i>, reductions in organic carbon content with depth).</p>
	BDFLAG - Flag for bulk density	0	Not used.
	THFLAG - Field capacity	0	Not used.
	KDFLAG - Soil/pesticide adsorption coefficient	1	This parameter will ensure that partitioning is taken from Record 30.

	HSWTZ - Drainage flag	0	Not used.
	MOC - Methods of characteristic	0	Not used.
	IRFLAG - Irrigation flag	Crop and site specific	Set the flag to 0 for no irrigation, 1 for year-round irrigation, or 2 for irrigation during the cropping period only.
	ITFLAG - Soil temperature simulation flag	1	Use temperature simulations
	IDFLAG - Thermal conductivity and heat capacity flag	1	Calculate thermal properties
	BIOFLAG - Biodegradation flag	0	Not used.
26	DAIR - Diffusion coefficient in air	0	Not used.
	HENRYK – Henry's Law Constant	0	Not used.
	ENPY - Enthalpy of vaporization	0	Not used.
Record 27 is used only if IRFLAG (Record 20) = 1 or 2			
27	IRTYP – Irrigation type	Set to 3 or 4	See USEPA/OPP (2007).
	FLEACH – leaching factor	See note	See USEPA/OPP (2007).
	PCDEPL – fraction of water capacity trigger for irrigation	See note	See USEPA/OPP (2007).
	RATEAP – maximum rate at which irrigation is applied (cm/hr)	See note	See WQTT Advisory Note: Irrigation Guidance for Developing PRZM Scenarios
30	PCMC	4	Setting this to 4 will make the following parameter (SOL) a K <sub>oc</sub> value
	SOL (mL/g)	Set to K <sub>oc</sub>	This parameter is the K <sub>oc</sub> value. It is pesticide specific. See USEPA OPP (2002).
31	ALBEDO	0.20	0.20 is a typical value for crops in the PRZM manual, Table 5.21. Use the same value for all 12 instances of ALBEDO.
	EMMIS emissivity	0.97	This value is taken from Table 5.22 of the PRZM manual
	ZWIND wind reference height	10.	Met data is taken at 10 meters.
32	BBT groundwater temperature	See note	Enter temperature of ground at 10 m below surface. Various sources,



			including USGS, can be used. Enter typical value for all 12 instances.  If ground temperature data are not available, annual average air temperature from the associated weather file can be used.
<b>32A</b>	QFAC (Q10 value)	2	Standard assumption in EPA/OPP
	TBASE (reference temperature of degradation values)	See note	Pesticide specific. Enter the temperature at which the degradation values were derived
<b>33</b>	NHORIZ - Total number of horizons	8	USEPA: For the upper horizons, use USDA Soil Data Mart.  PMRA: Use Soil Landscapes of Canada  Resolution need not be less than 1 cm in the top portion of the profile and not less than 20 cm in the remaining profile.  The top profile is resolved into 1 cm increments in order to allow for accurate applications of pesticides into the soil surface.  Below 20 cm, discretization is increased to 20 cm in order to simulate realistic dispersion.  See Appendix 1 for guidance.
<b>34</b>	HORIZN - Horizon number	1 to 8	See Appendix 1.
	THKNS - Horizon thickness (cm)	Fixed	See Appendix 1.
	BD - Bulk density (g/cm <sup>3</sup> )	See note	Use the USDA Soil Data Mart or Soil Landscapes of Canada. Use the midpoint of the reported range.
	THETO - Initial soil water content (cm <sup>3</sup> /cm <sup>3</sup> )	See note	Use the field capacity (see below)
	AD - Soil drainage parameter	0	Not used.
	DISP - Pesticide hydrodynamic solute dispersion coefficient	0	Dispersion will be simulated by numerical dispersion as implemented through spatial discretization.

	ADL - Lateral soil drainage parameter	0	Not used.
36	DWRATE/DSRATE/DGRATE - Dissolved, adsorbed, and vapor phase pesticide decay rates. (Day <sup>-1</sup> )	Pesticide specific	See Appendix 1 for guidance on converting laboratory degradation rates to rates that decline with depth. Also see USEPA OPP (2002) for values used for pesticide properties.
37	DPN - Thickness of compartments in horizon (cm)	Fixed	See Appendix 1.
	THEFC - Field capacity in the horizon (cm <sup>3</sup> /cm <sup>3</sup> )	See note	For the soil profile, use the 33 kPa water content in the soil data. Input the midpoint between the field capacity and porosity. For the saturated zone, set field capacity to porosity.
	THEWP - Wilting point (cm <sup>3</sup> /cm <sup>3</sup> )	See note	Use the 15-bar or 1500 kPa water content in the soil data. Use the midpoint of the reported range. This parameter has no effect at depths below the evapotranspiration zone.
	OC - Organic carbon (%)	See note	Use the organic carbon value, percent converted to a fraction, reported in the soil data. Use a depth-weighted average of all the soil horizons in the PRZM layer.
	KD - Partition coefficient (ml/g)	See note	This value is chemical specific. See USEPA OPP (2002). If Koc is used, this parameter has no effect. Refer to input parameter guidance.
38	SPT (initial temperature of profile)	See note	Use BBT value from Record 32.
	SAND	See note	Use the USDA Soil Data Mart or Soil Landscapes of Canada. Use the midpoint of the reported range.
	CLAY	See note	Use the USDA Soil Data Mart or Soil Landscapes of Canada. Use the midpoint of the reported range.
	THCOND	0	Automatically calculated
	VHTCAP	0	Automatically calculated
40	ILP - Flag for initial pesticide level	0	Assume no prior pesticide applications.
	CFLAG - Conversion flag for initial pesticide levels	0	Assume no prior pesticide applications.
42	Archaic Parameters		Place Holders: Copy from previous

			run
<b>45</b>	Archaic Parameters		Place Holders: Copy from previous run
<b>46</b>	PLNAME	DCON	Specifies dissolved (Pore water) concentration
	INDX	Set to 1	Only 1 chemical is simulated.
	MODE	TAVE	Specifies vertical spatial averaging
	IARG	65	Output will be the spatial average of DCON from the water table to 1 meter below the water table. Specifies upper bound.
	IARG2	69	Output will be the spatial average of DCON from the water table to 1 meter below water table. Specifies lower bound.
	Const	1.0e3	Provides conversion to ppb.

## References

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USEPA, 2005a. N-Methyl Carbamate Pesticide Cumulative Risk Assessment: Pilot Cumulative Analysis, February 15 - 18, 2005, Docket Number: OPP-2004-0405

USEPA, 2005b. Preliminary N-Methyl Carbamate Cumulative Risk Assessment, August 23 - 26, 2005, Docket Number: OPP-2005-0172

USEPA OPP, 2002 . *Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides* , available on the OPP Water Models web page at <http://www.epa.gov/oppefed1/models/water/index.htm>.

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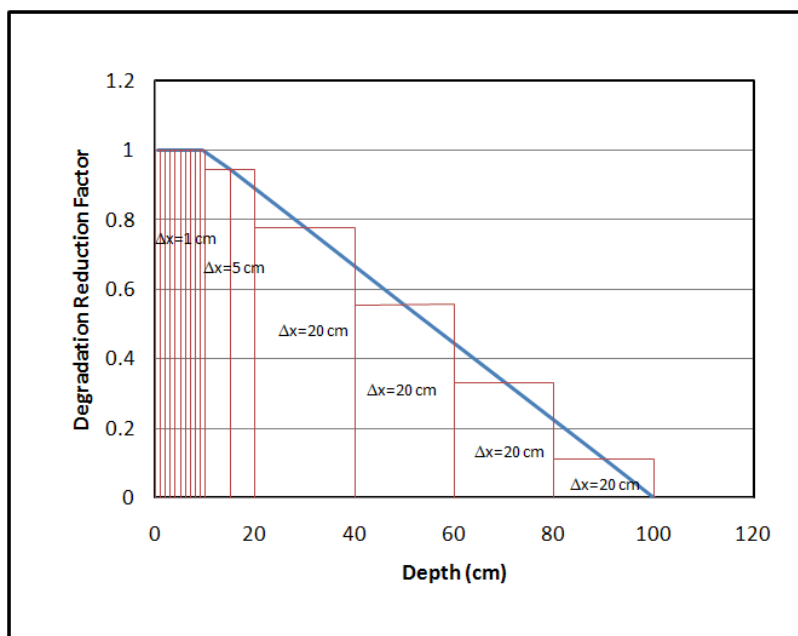
## Appendix 1

### Guidance on Setting up Degradation in the Profile

The PRZM implementation of the groundwater conceptual model uses eight soil layers as shown in **Table A1** and also depicted in **Figure A1**. The first layer is 10 cm and is discretized at 1 cm increments to allow some precision in defining root depths and evaporations zones and pesticide incorporation into the soil. The next layer is 10 cm thick and is discretized at 5 cm increments. The next four layers are all 20 cm and contain one compartment. These first six layers make up the top 1 meter of soil and represent the aerobic degradation zone. Degradation in the top meter declines proportionally with depth after the first 10 cm. Degradation reduction factors are given in the table below. The degradation rate in each layer is to be multiplied by the respective factor from the table. The next layer represents the depth between the aerobic zone and the water table. This layer is also discretized at 50 cm intervals. The eighth layer represents the water table and also has 50 cm discretization. Aerobic degradation does not occur in the seventh and eighth layers; however, hydrolysis is not precluded in these or any other horizons.

**Table A1. Degradation Reduction Factors and Discretizations for Layers and Nodes in PRZM Standard Groundwater Scenarios**

Layer	Multiplication Factor for Aerobic Degradation Rate	Depth (cm)	$\Delta x$ (cm)	Nodes
1	1.0	0 to 10	1	1 to 10
2	0.94	10 to 20	5	11 to 12
3	0.78	20 to 40	20	13
4	0.55	40 to 60	20	14
5	0.33	60 to 80	20	15
6	0.11	80 to 100	20	16
7	0	100 to 900	50	17 to x
8	0	900 to 1000	50	x+1 to x+2



**Figure A1. Degradation Reduction Factors and Discretizations for Layers and Nodes in PRZM Standard Groundwater Scenarios**