5.0 CALPUFF DISPERSION MODELLING

The CALPUFF model was used to predict maximum short-term (24-hour) and annual average ground-level concentrations at various receptor locations within the computational domains. The model was executed in a one-way nested grid to account for the cumulative contribution from sources in the US (Tier I), Ontario (Tier II) and Toronto (Tier III) to the SRLB study area. The CALPUFF computational domain is the area in which the transport and dispersion of puffs are considered for the calculation of ground level concentrations. Dispersion modelling was carried out using CALPUFF over a computational domain equal to the CALMET meteorological grid for Tier I and Tier II, respectively

Tier I and Tier II model runs were executed to generate hourly concentrations over each of their respective computational grids. From these computational grids, the 29 PAC concentrations were extracted from the grid cells which overlap with SRLB airshed as shown in Figure 5-1. Summing the Tier I and Tier II cells generates the background concentration which would be entering the City of Toronto. These are effectively 36 x 36 and 12 x 12 overlays of background contaminants that get added to the 1 x 1 of Tier III. This was carried out as part of a customized post-processing system. The contribution of the Tier III emissions to the SRLB airshed were modelled directly onto SRLB since the area of interest is within the City. A discrete receptor grid of 550 receptors was arranged over SRLB (Figure 5-2) to capture the maximum concentrations that occur from the combination of Tier I, Tier II and Tier III, respectively for all 29 PACs.

The following is a summary of the modelling setup.

5.1 Model Set-up

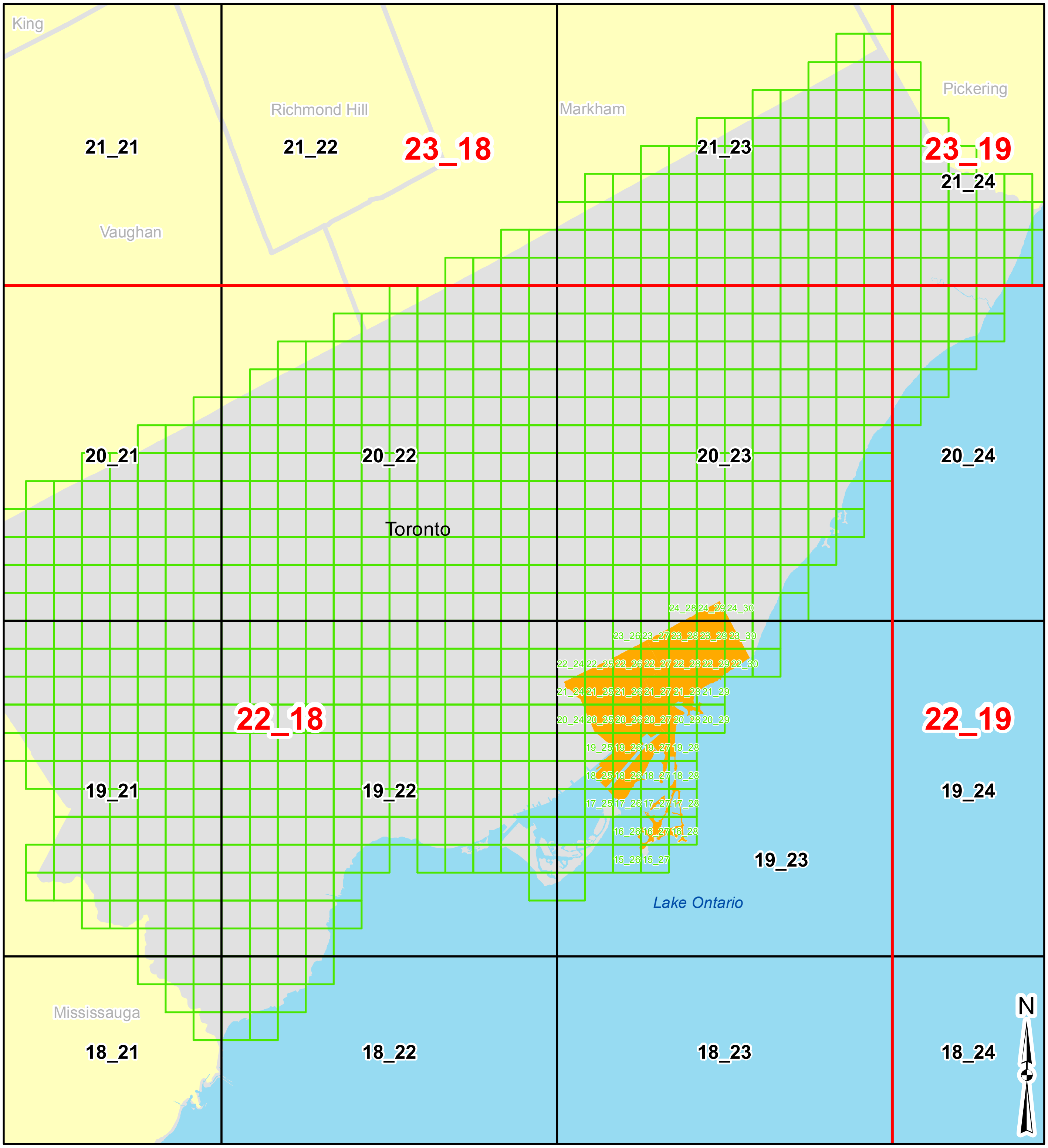
5.1.1 Meteorological Data

Meteorological data such as mixing heights, stability and winds determine the transport and dispersion of pollutants within the CALPUFF model. Hourly three- dimensional meteorological fields for 2006 were prepared using the CALMET model, as described in Section 4.0.

5.1.2 Emissions and Source

CALPUFF was used to model the dispersion of emissions from Tier I, Tier II and Tier for all applicable PACs to assess the contribution to air quality in SRLB. Details regarding emission rates and other sources characteristics considered in the modelling are found in Section 3.0.

Time varying hourly emissions of all 29 PACs for industrial, residential, mobile, biogenic and agricultural source data (for 2006) were inputted into CALPUFF as separate input files. Each source file can be run separately and summed at the completion of a year's run with the aid of a post-processor.



LEGEND

- Tier 3 Grid
- Tier 2 Grid
- Tier 1 Grid
- South Riverdale / The Beaches

5 2.5 0 5 10

SCALE 1:200,000 KILOMETRES

PROJECT

TORONTO AIRSHED MODELLING

TITLE

TIER I AND TIER II OVERLAPPING GRIDS ON SOUTH RIVERDALE/BEACHES

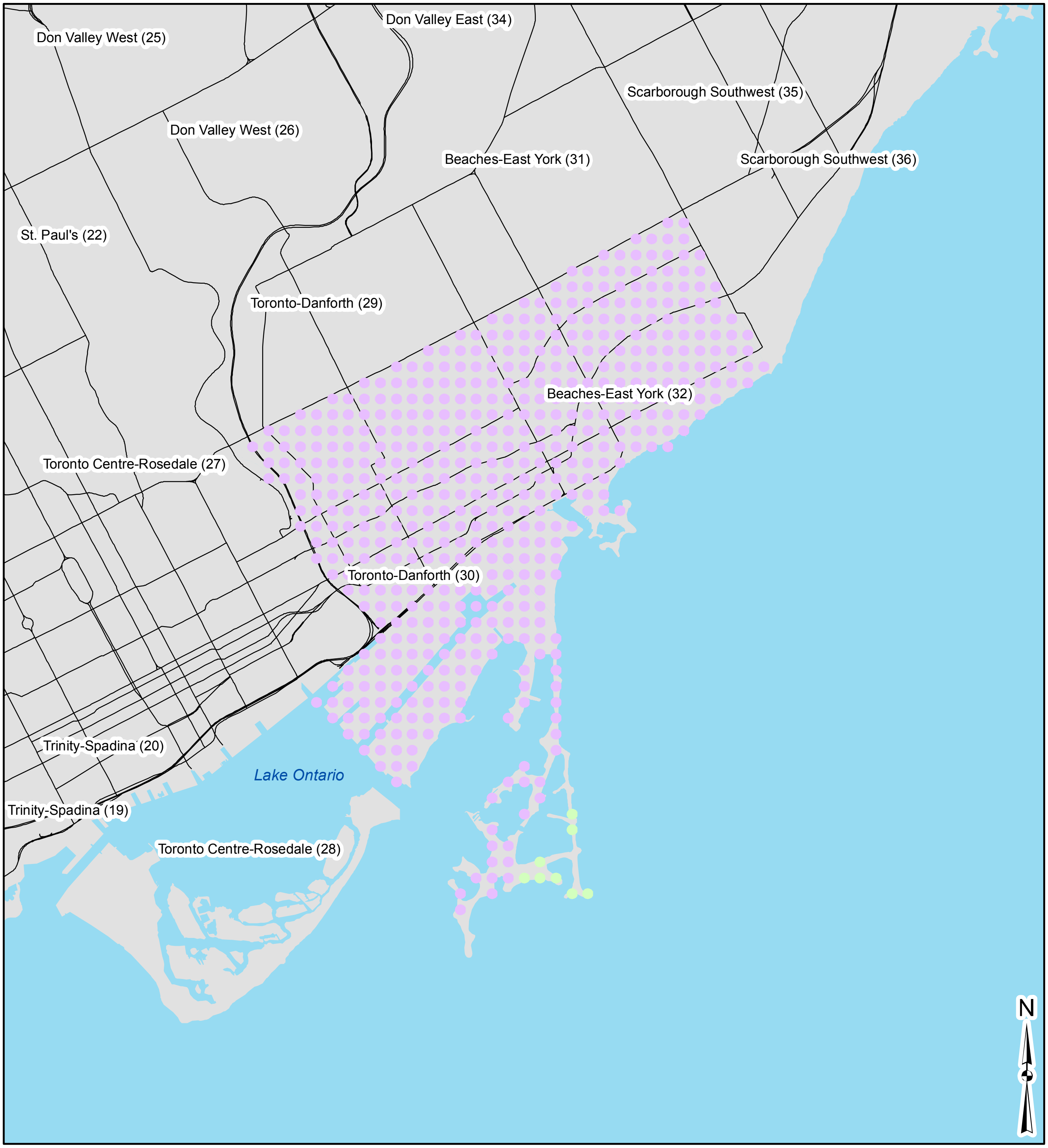
REFERENCE

Base Data - MNR NRVIS, obtained 2004, CANMAP v2008.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2010
Projection: Lambert Conformal Conic Datum: NAD 83 Coordinate System: US EPA LCC

Golder Associates
Mississauga, Ontario

PROJECT NO. 08-1112-0148			SCALE AS SHOWN	REV.
DESIGN	PRM	16 Nov. 2009	**FIGURE: 5-1**	
GIS	PP	25 Mar. 2011		
CHECK	AC	25 Mar. 2011		
REVIEW	AC	25 Mar. 2011		

G:\Projects\2008\08-1112-0148_TorontoAirShedModelling\GIS\MXDs\Final\March_24_11\5-1_Tier_I_AndTier_II_OverlappingGridsOnSouthRiverdaleBeaches.mxd



LEGEND

- Road
- Waterbody
- Toronto

All Beaches/Danforth Receptors

- Tier 2 Grid
- Tier 3 Grid

1 0.5 0 1 2

SCALE 1:70,000 KILOMETRES

REFERENCE

Base Data - MNR NRVIS, obtained 2004, CANMAP v2008.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2010
Projection: Lambert Conformal Conic Datum: NAD 83 Coordinate System: US EPA LCC

PROJECT

TORONTO AIRSHED MODELLING

TITLE

DISCRETE RECEPTORS OVER SOUTH RIVERDALE/BEACHES

Golder Associates
Mississauga, Ontario

PROJECT NO. 08-1112-0148			SCALE AS SHOWN	REV. 0.0
DESIGN	PRM	16 Nov. 2009	**FIGURE: 5-2**	
GIS	PP	25 Mar. 2011		
CHECK	BCo	25 Mar. 2011		
REVIEW	AC	25 Mar. 2011		

G:\Projects\2008\08-1112-0148_TorontoAirShedModelling\GIS\MXDs\Final\March_24_11\5-2_DiscreteReceptorsOverSouthRiverdaleBeaches.mxd

5.1.3 Terrain Effects

Puffs released from the various sources will tend to follow the topography of the earth's surface. To account for possible changes in plume trajectory over elevated terrain, the CALPUFF model's Partial Plume Path Adjustment Method (PPPAM) was used to modify the height of the puff to account for local effects. The PPPAM employs a plume path coefficient (PPC) to adjust the height of the plume/puff above the ground. Default PPC values of 0.5, 0.5, 0.5, 0.5, 0.35, and 0.35 for Pasquill-Gifford (PG) atmospheric stability classes A (unstable), B, C, D, E, and F (stable), respectively are recommended by the CALPUFF authors and were used in this study.

5.1.4 Dispersion Coefficients

A fundamental parameter controlling plume dispersion in a Gaussian model such as CALPUFF are the dispersion coefficients. These values, which must be specified for both the horizontal as well as the vertical directions in the model, can be computed using several different methods in CALPUFF. Internally calculated turbulence values based on local micrometeorological variables were used all for all three tiers. Thus the dispersion coefficients are calculated from surface micrometeorological variables (u*, w*, L, etc).

Two important computational parameters in CALPUFF are XMXLEN (maximum length of an emitted puff, in grid units) and XSAMLEN (maximum travel distance of a puff, in grid units, during one time step). The first parameter ensures that the length of an emitted puff does not become so large so that it cannot respond to changes in the wind field on the scale of the meteorological grid (i.e. 1 km resolution). The model will automatically increase the frequency of puff releases to ensure the length of a single puff is not larger than the grid size. The second parameter will decrease the internal time step to ensure the travel distance during one time step does not exceed the grid size.

The CALPUFF Options and Flags used for air quality modelling are presented in Table 5-1.

5.2 Model Confidence

In the US Guideline on Air Quality Models (U.S. EPA, 2005a), the need to address the uncertainties associated with dispersion modelling is acknowledged as an important issue that should be considered. The US Guideline divides the uncertainty associated with dispersion model predictions into two main types (U.S. EPA, 2005a), as follows.

- Reducible uncertainty, which results from uncertainties associated with the input values and with the limitations of the model physics and formulations. Reducible uncertainty can be minimized by improved (i.e., more accurate and representative) measurements and improved model physics.
- Inherent uncertainty is associated with the stochastic (turbulent) nature of the atmosphere and its representation (approximation) by numerical models. Models predict concentrations that represent an ensemble average of numerous repetitions for the same nominal event. An individual observed value can deviate significantly from the ensemble value. This uncertainty may be responsible for a ± 50% deviation from the measured value.

Table 5-1:CALPUFF Options and Flags

Option	Parameter	Tier I	Tier II	Tier III	Explanation
Vertical distribution used in the near field.	MGAUSS	1	1	1	Gaussian
Terrain adjustment method	MCTADJ	3	3	3	Partial plume path adjustment
Subgrid-Scale complex terrain flag	MCTSG	0	0	0	CTSG not modeled
Near-field puffs modelled as elongated?	MSLUG	0	0	0	No slug model.
Transitional Plume Rise modelled	MTRANS	1	1	1	Yes
Method used to simulate building downwash?	MBDW	0	0	0	No Downwash
Stack-tip downwash?	MTIP	1	1	1	Yes
Vertical wind shear modelled above stack top?	MSHEAR	0	0	0	Not modelled. If this option is chosen, a power law wind speed extrapolation is done above stack top.
Puff splitting allowed?	MSPLIT	1	1	1	Yes
Chemical Transformation Scheme...	MCHEM	0	0	0	RIVAD/ARM3 scheme
Aqueous phase transformation flag (only used if MCHEM =1 or 3)	MAQCHEM.	0	0	0	No
Wet removal modelled?	MWET	0	0	0	No
Dry deposition modelled?	MDRY	0	0	0	No
Methods used to compute dispersion coefficients	MDISP	2	2	2	Dispersion from internally calculated sigma v and sigma w
Sigma measurements used?	MTURBVW	3	3	3	No
Back-up method used to compute dispersion when measured turbulence data are missing	MDISP2	3	3	3	No
PG sigma y,z adjusted for roughness.	MROUGH	0	0	0	Not recommended for tall stacks or when surface roughness lengths > 1m. May be appropriate for near surface releases.
Partial plume penetration of elevated inversion?	MPARTL	1	1	1	Yes, partial plume penetration
Strength of temp inversion provided in PROFILE.DAT extended records?	MTINV	0	0	0	Typically computed from measured/default gradients. Depends on whether PROFILE.DAT contains extended records
Probability Distribution Function used for dispersion under convective conditions?	MPDF	0	0	0	PDF option is only available for turbulence-based dispersion (MDISP=1,2) Yes. if MDISP = 2 (simulates AERMOD-type dispersion, averaging the balance between up- and down-drafts in vertical column).
Sub-grid TIBL module used for shore line	MSGTIBL	0	0	0	Generally not used. May be used in special coast line circumstances
Boundary conditions (concentration) modeled?	MBCON	0	0	0	Boundary concentrations not modelled.
Configure for FOG Model output	MFOG	0	0	0	No

Models include inherent uncertainty since they are attempting to mimic nature. Both reducible and inherent uncertainties mean that dispersion modelling results may over- or under-estimate measured ground-level concentrations at any specific time or place. However, the US Guideline on Air Quality Models (U.S. EPA, 2005a) also states that:

> *"Models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of +/- 10 to 40 percent are found to be typical, i.e., certainly well within the often-quoted factor of two accuracy that has long been recognized for these models. However, estimates of concentrations that occur at a specific time and site are poorly correlated with actually observed concentrations and are much less reliable. "*

Thus, although model uncertainty is important to consider, when dispersion models such as CALPUFF are used to assess ground-level concentration and when a sufficiently large number of meteorological conditions are considered, the modelling results should ideally fall well within the often quoted "factor of two" accuracy for these modelled (U.S. EPA, 2005a).

Although the existence of model uncertainty is well-accepted, it does not mean that important environmental decisions cannot be made based on dispersion modelling results — it should simply be acknowledged and understood that given their inherent uncertainty, models are a best case approximation of what are otherwise very complex physical processes in the atmosphere, and should be used as one of many tools available.